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Associations between Digital Screen Exposure and Sleep Disturbances Among School Aged Children: A Cross-Sectional Analytical Study

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ABSTRACT

Background: Sleep is a critical determinant of physical, cognitive, and emotional development in children. Rapid expansion of digital screen exposure has emerged as a major behavioral factor disrupting pediatric sleep, particularly in developing digital environments such as India. This study aimed to assess the prevalence of sleep disturbances associated with digital screen use and to identify independent behavioral and environmental predictors among school-aged children.
Methods: A cross-sectional analytical study was conducted from January to April 2024 among 600 children aged 6–12 years enrolled in five urban private schools in Srinagar, India. Sleep disturbances were assessed using the Pediatric Sleep Questionnaire, while digital exposure patterns were evaluated using a structured Screen Behavior Inventory. Multivariate logistic regression analysis was performed to identify independent predictors of sleep disturbance.
Results: The prevalence of clinically significant sleep disturbance was 42.3%. Mean daily screen-time was 3.1 ± 1.4 hours. Sleep disturbance showed a significant dose–response relationship with increasing screen exposure. Screen use within one hour of bedtime emerged as the strongest predictor, followed by daily screen-time exceeding three hours, smartphone gaming, bedroom device availability, and low parental monitoring. The final regression model demonstrated good predictive accuracy and explained a substantial proportion of variance in sleep outcomes.
Conclusion: Digital screen exposure is strongly and independently associated with sleep disturbances among school-aged children. Targeted interventions focusing on evening screen restriction, reduced screen duration, and improved parental monitoring may substantially improve pediatric sleep health

Keywords*: Digital screen exposure; Pediatric sleep disturbance; Screen-time; Evening screen use; Smartphone gaming; Parental monitoring; School-aged children; India*

INTRODUCTION

Sleep is a foundational neurobiological process that plays a pivotal role in children's cognitive development, emotional regulation, physical maturation, metabolic homeostasis, and overall well-being. During childhood, sleep undergoes complex, age-dependent transformations involving synaptic pruning, neuroplasticity, memory consolidation, hormonal secretion, and cortical maturation. Disruption of sleep during this critical developmental window has been robustly associated with impaired learning capacity, diminished executive functioning, behavioral dysregulation, attention-deficit symptoms, compromised immune function, obesity risk, and long-term cardiometabolic consequences [1–4]. Given the centrality of sleep to healthy neurodevelopment, identifying modifiable factors that compromise pediatric sleep is of paramount clinical and public health importance.

Over the last decade, digital screen exposure has emerged as one of the most significant behavioral disruptors of sleep in children [4,8,9,10]. The advent of affordable smartphones, tablets, laptops, portable gaming devices, and on-demand streaming services has markedly increased children's daily engagement with digital media. This shift has created a

"digital childhood," wherein screen-based entertainment and communication have been integrated into academic activities, recreation, and social interaction. As a consequence, modern children are exposed to more screen content, in more interactive formats, and at younger ages than any prior generation [4,9].

Prevalence and trajectory of screen use among children

International surveys indicate exponential growth in screen exposure. In the United States, children aged 8–12 years now spend an average of multiple hours per day consuming digital media, excluding school-related use [1,4,9]. European cohorts report similar trends, with more than two-thirds of children owning or regularly accessing smartphones by age 10 [4,8]. In East and Southeast Asia, one of the fastest-growing digital markets globally, early smartphone adoption and intensive gaming culture compound these statistics [7,13,14].

In India, digital penetration has expanded at an unprecedented rate due to rapid smartphone affordability, widespread internet connectivity, and increasing use of electronic educational platforms [15–19]. Recent Indian studies show that even children aged 5–7 years demonstrate daily screen use exceeding international recommendations, with usage peaking sharply in urban regions [15–19]. The COVID-19 pandemic further increased screen exposure due to remote learning and social isolation, reinforcing digital habits that have persisted beyond the pandemic period [15,16,18].

Sleep physiology and vulnerability to digital interference

Children's sleep is uniquely vulnerable to digital disruption for several neurophysiological reasons:

1. Melatonin suppression by blue light:
   LED-based screens emit high-intensity blue light at wavelengths known to suppress melatonin synthesis. Children exhibit higher lens transparency and increased photosensitivity compared with adults, resulting in greater melatonin suppression for the same intensity of blue light [5,6].
2. Circadian phase delays:
   Evening screen exposure within 1–2 hours of bedtime delays sleep onset by shifting the circadian phase and dim-light melatonin onset [5,6,9].
3. Neurocognitive hyperarousal:
   Fast-paced, interactive content—especially gaming—activates the sympathetic nervous system, increases cortisol, and promotes cognitive arousal [8,9,11].
4. Behavioral displacement:
   Screen use delays bedtime routines, reduces available sleep opportunity, and disrupts consistent sleep–wake schedules [1,3,4].
5. Nighttime awakenings:
   Device notifications, messaging alerts, and proximity of electronics in bedrooms contribute to sleep fragmentation [3,8,11].

Evidence linking screen exposure and pediatric sleep disturbances

A substantial body of international literature consistently confirms associations between elevated screen-time and poor sleep outcomes in children [1–4,7–12]. Observational studies across multiple countries have documented relationships between screen exposure and: Delayed sleep onset

Reduced total sleep duration Increased bedtime resistance Night time awakenings Daytime sleepiness Emotional dysregulation Behavioral concerns. Meta-analyses show that children with >2 hours/day of recreational screen use have significantly higher odds of late bedtimes and insufficient sleep [1,3,8].

However, most existing studies have been conducted in Western or East Asian populations [1,3,4,7,13,14]. Cultural, environmental, and developmental contexts vary widely across regions. Therefore, high-quality, region-specific data are crucial.

Gaps in Indian pediatric sleep research

Despite India's rapidly increasing digital exposure among children, comprehensive epidemiological data on pediatric screen-related sleep disturbances remain limited [15–19]. Most existing Indian studies are:

Small sample sizes
Single-center
Lacking robust statistical modeling
Not differentiating types of screen behaviors
Missing validated sleep assessment instruments
Inadequately assessing environmental predictors like bedroom device access

India's unique sociocultural landscape—multigenerational households, academic pressure, irregular sleep schedules, and variable parental monitoring—necessitates tailored research [15–19].

Behavioral and environmental contributors to sleep disturbance

Digital exposure contributes to sleep impairment through behavioral, physiological, and environmental mechanisms.

Daily screen-time duration
Evidence suggests a dose–response relationship between daily screen duration and sleep impairment [1,3,8,9,16].

Evening exposure (within 1 hour of bedtime)
Evening screen use is the most physiologically disruptive due to circadian sensitivity to blue light [5,6,9].

Device type and content
Interactive content produces greater cognitive arousal than passive television [8,9,11].

Bedroom device availability
Children with screens in bedrooms experience poorer sleep outcomes [3,8,9].

Parental monitoring
Permissive digital environments are associated with greater sleep disturbances [15–18].

Study significance
Given the scarcity of robust, large-scale studies from India, this research aims to provide:
Reliable prevalence estimates. Identification of independent behavioral and environmental riskfactors. A foundation for pediatric counseling strategies. Data to inform digital hygiene guidelines. Few previous Indian studies have integrated validated sleep measures and multivariate analytical models simultaneously [15–19].

Study objectives
1. To determine the prevalence of sleep disturbances associated with digital screen exposure among school-aged children.
2. To identify independent predictors, including screen duration, timing, gaming, bedroom device access, and parental monitoring.
3. To develop a multivariate predictive model for pediatric sleep impairment.

This investigation integrates digital behavior science, pediatric sleep physiology, and epidemiological modeling to provide a comprehensive understanding of the impact of digital exposure on child health in an Indian context.

MATERIALS AND METHODS

Study Design
This investigation employed a cross-sectional analytical design selected for its suitability in characterizing prevalence patterns and identifying behavioral and environmental correlates of pediatric sleep disturbances within a large, naturalistic population. While longitudinal designs offer temporal causality, cross-sectional frameworks are scientifically advantageous for initial epidemiological profiling, hypothesis generation, and multivariate risk assessment, especially when large samples and diverse variables are involved.
The study design adhered to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines to ensure high methodological and reporting standards.

Study Setting
The study was conducted between January and April 2024 in five English-medium private schools situated in Srinagar, Jammu & Kashmir, India. These schools were selected because:
1. They represent urban middle-income digital environments with widespread access to smartphones, Wi-Fi, and digital learning platforms.
2. They maintain structured academic schedules, enabling uniform assessment of sleep and screen behaviors.
3. Their pedagogical approach includes moderate digital integration, reflecting typical patterns in modern Indian schooling.

Each school hosted students from Grades 1 through 6, enabling recruitment across the desired age range (6–12 years).

Sampling Strategy
A cluster random sampling procedure was implemented:
1. Schools formed independent clusters.
2. Five schools were randomly selected using a random-number generator.
3. Within each school, one classroom per grade was randomly selected.
4. All students in the selected classrooms were invited to participate (universal sampling).

This strategy minimized intra-school variability and increased sample representativeness.

Sample Size Determination
Using an anticipated prevalence of 30% screen-associated sleep disturbance, 95% confidence interval, and 4% margin of error, the minimum sample size required was 480. To account for non-response, 600 children were included.

Eligibility Criteria

Inclusion criteria

Children aged 6–12 years
Enrollment in participating schools
Parental informed consent
Child assent

Exclusion criteria

Diagnosed neurological disorders (e.g., epilepsy, cerebral palsy)
Primary psychiatric disorders (e.g., ADHD, depression)
Known sleep disorders (e.g., obstructive sleep apnea, narcolepsy)
Medication affecting sleep architecture (e.g., melatonin, steroids)
Chronic illnesses affecting daily routine

Data Collection Instruments

Pediatric Sleep Questionnaire (PSQ)
The PSQ is a widely validated, parent-reported instrument used internationally for pediatric sleep research.
It assesses:
Sleep-disordered breathing
Insomnia symptoms
Daytime behavior
Parasomnias
Sleep fragmentation

Scoring:

Responses coded as Yes = 1, No = 0
Maximum score = 22
A score ≥8 indicates clinically meaningful sleep disturbance
Internal reliability during pilot testing: Cronbach's $\alpha = 0.84$, indicating high internal consistency.
Screen Behavior Inventory (SBI)
This structured tool was adapted from validated screen-use instruments used in prior Asian and Western pediatric studies.
It assesses:

1. Total daily screen-time (weekday/weekend)
2. Device type (smartphone, tablet, PC, TV)
3. Gaming frequency (minutes/day)
4. Evening exposure (<1 hour before bedtime)
5. Bedroom device availability (Yes/No)
6. Parental screen monitoring practices

Pilot testing showed Cronbach's $\alpha = 0.81$.

Data Management

- Data were double-entered into Excel for quality control.
- Discrepancies were resolved via source document verification.
- Statistical analyses were conducted using SPSS version 26.

STATISTICAL ANALYSIS

Analytical procedures were selected to match variable distributions and modeling objectives.

Descriptive Statistics

Continuous variables: mean ± SD
Categorical variables: frequencies and percentages

Group Comparisons

Chi-square test for categorical variables
One-way ANOVA for comparing mean PSQ scores across screen-time categories
Post-hoc Tukey tests for pairwise comparisons

Correlation

Spearman correlation assessed associations between continuous screen-time and PSQ total score

Regression Analysis
A multivariate logistic regression model identified independent predictors of sleep disturbance (dependent variable: PSQ ≥8).

Covariates included:
Age
Gender
Daily screen-time
Evening screen use (<1 hour before bedtime)
Gaming duration
Bedroom device availability
Parental monitoring score

Goodness-of-fit was evaluated using:
Hosmer-Lemeshow test
Nagelkerke R^2
Model classification accuracy

Significance threshold: $p < 0.05$.

RESULTS
Participant Characteristics
All 600 enrolled children completed the full questionnaire set.
Mean age: 9.1 ± 1.9 years
Boys: 308 (51.3%)
Girls: 292 (48.7%)
Mean BMI percentile: 57th ± 19

Family characteristics:
Nuclear families: 67%
Both parents employed: 51.8%
Shared bedroom with siblings: 44%
These contextual variables help interpret environmental influences on sleep.

Digital Exposure Patterns

Total daily screen-time
Mean = 3.1 ± 1.4 hours
Distribution:
<2 hours: 28.0%
2–3 hours: 25.3%
3 hours: 46.7%

Device type
Smartphone: 84.5%
Television: 78.3%
Tablet: 27.1%
Laptop/PC: 33.8%

Gaming behavior
Game usage >30 min/day: 39.7%
Preferred gaming: racing, shooter-type mobile games, multiplayer online games

Evening screen exposure
Screen use <1 hour before bedtime: 52.3%
Average time of last use: 9:34 PM ± 48 minutes

Bedroom device availability
Device kept in bedroom: 33.5%
TVs in bedroom: 22.8%
Smartphones under pillow/bedside: 11.4%

These metrics indicate substantial digital encroachment into evening routines and sleep environments.

Prevalence of Sleep Disturbance
Using PSQ ≥8:
254/600 = 42.3% prevalence of sleep disturbance
Subdomains most affected:
Sleep onset delay: 47%
Nighttime awakenings: 29%
Daytime irritability: 36%
Snoring/breathing symptoms: 11%

Association Between Screen-Time and Sleep Disturbance
Chi-square analysis
Sleep disturbance increased significantly with screen-time.

Screen-time	Sleep Disturbance (%)
<2 hours	16.7%
2–3 hours	33.6%
>3 hours	61.7%

$\chi^2 = 78.2$, $p < 0.001$.
This reflects a strong dose–response association.
4.5 ANOVA Results

Mean PSQ scores differed significantly:
<2 hours: 5.1 ± 2.3
2–3 hours: 7.4 ± 3.1
3 hours: 11.2 ± 3.8
ANOVA: $F = 69.4$, $p < 0.001$.
Post-hoc tests confirmed significant pairwise differences ($p < 0.01$ for all comparisons).
4.6 Correlation Between Screen-Time and Sleep Disturbance

Spearman correlation:
$r = 0.52$, $p < 0.001$
This indicates a moderate, statistically significant association between increased screen exposure and worsened sleep outcomes.

Multivariate Predictive Modeling

The logistic regression model achieved:
Nagelkerke $R^2 = 0.41$
Classification accuracy: 78.3%
Hosmer-Lemeshow p = 0.48 (good fit)

Predictor	Adjusted OR	95% CI	p-value
Screen-time >3 hours	3.46	2.41–4.96	<0.001
Screen within 1 hour of bedtime	4.12	2.98–5.68	<0.001
Smartphone gaming	2.21	1.54–3.17	<0.001
Bedroom device	1.93	1.25–2.98	0.004
Low parental monitoring	1.58	1.09–2.29	0.016
Age	1.09	0.72–1.64	0.68
Male gender	0.95	0.68–1.34	0.76

Interpretation
Even when controlling for age, gender, and parental factors:
Evening exposure was the strongest predictor
Screen-time above 3 hours nearly tripled risk
Gaming and bedroom devices were substantial contributors
These findings highlight the multifactorial nature of digital-induced sleep impairment.

DISCUSSION

The present study provides comprehensive evidence demonstrating that digital screen exposure is strongly associated with sleep disturbances among school-aged children in an urban Indian population. With a relatively large sample size (N = 600), validated measurement tools, and multivariate statistical modeling, the findings significantly advance current understanding of the complex interplay between technology use and pediatric sleep health in emerging digital environments.

The prevalence of sleep disturbance in the cohort(42.3%) aligns with international epidemiological trends and underscores the increasing scale of pediatric sleep problems in the digital age. Studies from the United States, China, Japan, and Australia similarly report prevalence figures between 30–50% in comparable age groups. This global consistency indicates that sleep impairment associated with digital media use is not limited to specific cultural or socioeconomic contexts; rather, it represents a widespread pediatric health challenge arising from contemporary technological environments.

Interpretation of major findings

Screen-time duration and dose–response relationships

The observed dose–response pattern—wherein children with >3 hours/day of recreational screen use exhibited a 3.46 fold greater risk of sleep disturbance—supports existing neurobehavioral and chronobiological evidence. Numerous studies suggest that prolonged exposure to digital screens disrupts sleep through:

Melatonin suppression
Circadian phase shifting
Increased cognitive and emotional arousal
Behavioral displacement of sleep routines

The monotonic rise in PSQ scores across screen-time categories further substantiates screen duration as a continuous predictor rather than a threshold-dependent variable. This finding is consistent with mechanistic research demonstrating that children exhibit greater photic sensitivity to blue-light exposure than adults, rendering them especially vulnerable to digital light exposure.

Evening screen exposure: the strongest predictor

Evening screen use within one hour of bedtime produced the largest adjusted odds ratio (OR 4.12, 95% CI 2.98–5.68), identifying it as the strongest independent behavioral predictor. This aligns with well-established circadian physiology:

Evening light exposure inhibits melatonin synthesis
Children's melatonin onset is more easily delayed
Evening use generates cognitive and sympathetic arousal
The circadian phase is highly sensitive during the pre-sleep window

This finding highlights a crucial counseling target for clinicians:
Timing may be more important than duration when advising families about digital exposure.

Smartphone gaming: interactive content as a unique risk

Interactive content, particularly smartphone games, significantly predicted sleep disturbance (OR 2.21). Gaming differs from passive viewing in that it induces:

Emotional stimulation
Sympathetic activation (increased heart rate, cortisol)
Prolonged engagement cycles
Difficulty disengaging cognitively

Several EEG studies demonstrate heightened cortical activation during and after gaming sessions, which may explain prolonged sleep latency. The popularity of reward-based and multiplayer games among children further exacerbates this effect.

Bedroom device availability and nighttime arousal

Bedroom device availability independently predicted sleep impairment (OR 1.93). This environmental factor promotes:

Nighttime checking behaviors
Sensitivity to notifications
Sleep fragmentation
Reduced parental monitoring

Environmental cues play a major role in pediatric sleep regulation. Removing devices from bedrooms is repeatedly shown to improve sleep onset and continuity.

Comparison with existing literature

A wealth of international evidence reinforces the findings of this study:

A meta-analysis of over 125,000 children from 20+ studies showed that bedtime media usage and high screen exposure are associated with significantly increased risk of insufficient sleep and adverse sleep outcomes in youth [20].
Canadian and North American cohorts found that evening screen use — particularly close to bedtime — is a strong predictor of delayed sleep onset and shorter sleep duration in children and adolescents [21].
Studies examining evening smartphone use report that screen exposure before bedtime delays melatonin release, contributes to later sleep timing, and is linked with increased daytime fatigue among youth [22].
Longitudinal and observational data from multiple populations indicate that persistent high screen use predicts worsening sleep patterns over time, including delayed sleep onset and reduced total sleep duration [21][23].
Our findings mirror these patterns, indicating that the mechanisms of digital sleep impairment are robust across diverse cultural and technological contexts.

Cultural factors unique to India
Despite similarities with international evidence, several Indian-specific contextual factors likely amplify digital sleep problems:

Academic pressures
Children in private Indian schools often face heavy homework loads, prompting evening academic screen use.

Multigenerational households
Shared bedrooms and irregular family routines may reduce structure and bedtime consistency.

Lower parental monitoring
Parents in dual-earning households may have reduced capacity to supervise evening digital exposure.

Smartphone-centric ecosystem
India's digital usage is overwhelmingly smartphone-driven, which is associated with greater neurological arousal and sleep disruption than television.
These contextual factors underscore the need for culturally sensitive digital hygiene interventions.

Mechanistic pathways explaining sleep disruption
The study's findings align with established biological pathways:

Melatonin suppression
Blue-light from screens reduces melatonin secretion by up to 30–50% in children.

Circadian phase shifts
Evening screen use delays the circadian clock by ≥40 minutes.

Cognitive hyperarousal
Digital engagement increases sympathetic output, prolonging sleep latency.

Behavioral displacement
Screen use replaces pre-sleep routines such as reading, bathing, and parent–child interaction.

Sleep fragmentation
Nighttime awakenings increase due to alerts, notifications, and urge to check devices.
Together, these pathways explain the strong statistical associations observed.

Strengths of the Study
This research has several notable strengths:
1. Large sample size (N=600) enhances statistical robustness.
2. Use of validated tools (PSQ, Screen Behavior Inventory).
3. High internal reliability ($\alpha = 0.81–0.84$).
4. Multivariate modeling identifies independent predictors.
5. Representative urban population reflective of modern Indian digital environments.
6. Behavioral + environmental variables analyzed simultaneously.
7. Dose–response evidence between screen exposure and sleep.

These strengths contribute to the study's value in informing pediatric clinical practice.

Limitations
Important limitations include:
1. Cross-sectional design prevents causal inference.

2. Self-reported data may involve recall biases.
3. No objective sleep measures (e.g., actigraphy, polysomnography).
4. Urban private school sample may not represent rural or low-income populations.
5. Device content categories were not stratified beyond gaming vs non-gaming.
6. No measurement of academic screen use vs recreational use.

Implications for pediatric clinical practice

Findings highlight multiple actionable clinical recommendations:
Pediatricians should screen for screen-time and evening exposure during routine visits.
Sleep counseling must include digital hygiene education.
Families should be advised to remove smartphones/TVs from children's bedrooms.
Evening screen curfews (1–2 hours before bedtime) should be recommended.
Gaming restrictions should be implemented, especially on school nights.
Visual schedules and structured bedtime routines should be encouraged.

Public health and policy implications

The study supports the need for:
National pediatric digital hygiene guidelines
School-based education programs
Public awareness campaigns
Government-supported digital literacy initiatives
Regulations for child-friendly device settings (night mode, blue-light filters)
Policies limiting in-school unnecessary screen exposure

Enhancing public understanding of screen–sleep connections is essential as India continues rapid digital expansion.

Future research directions

Longitudinal studies to examine causal pathways
Actigraphy or melatonin sampling to quantify physiological changes
Experimental interventions reducing evening screen exposure
Examination of specific content types: social media, gaming genres
Multicentric studies across rural, tribal, and low-income communities
Qualitative studies assessing family dynamics and digital norms

CONCLUSION

This large-scale analytical study demonstrates strong, independent associations between digital screen exposure and sleep disturbances among school-aged children in urban India. Evening screen exposure, prolonged daily screen-time, interactive gaming, and bedroom device availability emerged as significant risk factors. These findings have critical implications for pediatric practice, parental guidance, and education policies. Addressing digital behaviors offers a tangible, modifiable pathway to improving childhood sleep health and broader developmental outcomes.

CLINICAL RECOMMENDATIONS

- Limit recreational screen use to <2 hours/day.
- Avoid all screen exposure 1–2 hours before bedtime.
- Remove devices from children's bedrooms.
- Encourage consistent sleep–wake routines.
- Promote alternative evening activities (reading, quiet play).
- Screen for sleep problems in children with excessive digital use.

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