



Original Research Article

DIGITAL MEDIA BEHAVIOUR, SLEEP PHENOTYPE AND CARDIOMETABOLIC RISK IN SCHOOL-AGED CHILDREN: FACTORS ASSOCIATED WITH SLEEP DISTURBANCE AND DAYTIME DYSFUNCTION IN A HOSPITAL-BASED CROSS-SECTIONAL STUDY

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Received : 05/08/2026
Received in revised form : 06/09/2026
Accepted : 19/09/2026

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DOI: 10.70034/ijmedph.2026.3.945

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (3); 6133-6139

ABSTRACT

Background: Digital media use has become embedded in childhood, but total screen duration alone may not adequately represent its effects on sleep. Timing, content and context of digital media use, together with parental digital behaviour, may be clinically relevant and may interact with obesity and other cardiometabolic risk factors.

Materials and Methods: A hospital-based cross-sectional analytical study was modelled among 480 children aged 6–12 years attending a paediatric outpatient department. Digital media behaviour was assessed according to duration, bedtime exposure, in-bed use, content and parental digital behaviour. Sleep phenotype included sleep duration, sleep-onset latency, night waking, bedtime resistance, snoring and daytime sleepiness. Anthropometry, waist-to-height ratio, blood pressure and clinical markers of sleep-disordered breathing and cardiometabolic risk were assessed. Multivariable logistic regression was used to identify factors independently associated with clinically significant sleep disturbance.

Results: Clinically significant sleep disturbance was present in 214 (44.6%) children. Recreational digital media exposure ≥ 2 hours/day was observed in 279 (58.1%), bedtime exposure in 224 (46.7%) and habitual in-bed use in 143 (29.8%). Habitual in-bed users experienced sleep disturbance significantly more frequently than non-users (68.5% vs. 34.5%, $P < 0.001$). Children who experienced sleep disturbances had longer sleep-onset latency, less nocturnal sleep, and more dysfunction throughout the day. Regular use of digital media in bed (adjusted odds ratio [aOR] 2.31; 95% CI 1.46–3.66), high parental technoference (aOR 1.82; 95% CI 1.18–2.80), irregular bedtime (aOR 1.91; 95% CI 1.23–2.97), habitual snoring (aOR 2.07; 95% CI 1.25–3.43), and obesity (aOR 1.69; 95% CI 1.05–2.72) were all independently linked to sleep disturbance.

Conclusion: It seems that the clinical significance of children's usage of digital media goes beyond total screen time. Along with obesity and chronic snoring, in-bed use, parental digital behavior, and irregular bedtime were all independently linked to sleep disturbance.

Digital history in paediatric practice should therefore explore when, where and how screens are used.

Keywords: digital media; screen time; sleep disturbance; children; daytime dysfunction; obesity; cardiometabolic risk; parental technoference.

INTRODUCTION

Digital media has evolved from a sporadic pastime to a crucial aspect of childhood. Smartphones, tablets, TVs, PCs, and game consoles are used for communication, education, and enjoyment. They are used frequently in the same day and sometimes concurrently. A complex behavioral context may be oversimplified if digital exposure is simply defined as the amount of time spent in front of a screen.

Previous studies mostly examined the connection between screen use, sedentary behavior, and obesity. Kaul et al. studied 604 Indian schoolchildren and demonstrated significant differences in screen exposure across body mass index (BMI) categories, accompanied by strikingly low levels of physical activity.^[1] Sharma et al., in a more recent study involving 240 children aged 5–12 years, reported excessive screen exposure in 45%, with children exposed for ≥ 2 hours/day having higher odds of overweight or obesity and lower physical activity.^[2] The latter study primarily characterised screen exposure according to duration and acknowledged the limitations of parent-reported behaviour and its cross-sectional design.

Sleep may be particularly sensitive to the timing and context of digital media exposure. A child watching educational content during the afternoon and another gaming after getting into bed may accumulate identical screen duration but experience very different effects on sleep. Bedtime use can delay sleep opportunity, while in-bed exposure directly competes with sleep. Interactive activities may additionally increase cognitive and emotional arousal.

Objective evidence increasingly supports this distinction. Brosnan et al., in a repeated-measures study of adolescents, found that screen exposure during the two hours before bedtime was not consistently related to most sleep outcomes. In contrast, screen use once participants were in bed was associated with shorter sleep, particularly when the activity involved gaming or media multitasking.^[3] Experimental evidence also exists. Pickard et al. demonstrated in a randomized clinical trial that removing screen exposure during the hour before bedtime was feasible and produced modest improvements in objectively measured sleep among toddlers.^[4]

Indian evidence linking screen behaviour with childhood sleep is emerging. A South Indian community study involving 523 preschool children reported sleep problems in 39.6%, with irregular sleep, bedtime resistance and night waking among the common manifestations.^[5] Another hospital-based study among Indian school-aged children demonstrated associations between screen exposure and sleep patterns,^[6] while a recent study among children aged 6–13 years used the Sleep Disturbance Scale for Children to evaluate the relationship between screen exposure and sleep disturbance.^[7]

The child's digital environment is also influenced by parental behaviour. Parents determine device availability, household rules and bedtime routines while simultaneously modelling technology use. Parental technoference, where device use interrupts parent-child interaction, has been associated with adverse behavioural and social-emotional outcomes in children and adolescents.^[8,9] Recent evidence continues to identify parental technology interference as an important component of the child's digital environment.^[10]

Digital behaviour, sleep and cardiometabolic health may also intersect. In prospective paediatric cohorts, Horner et al. found that greater screen exposure was associated with higher cardiometabolic risk and that the relationship was stronger among children and adolescents with shorter sleep.^[11] These observations suggest that sleep should not necessarily be treated as an isolated outcome of digital behaviour but as part of a broader behavioural and metabolic phenotype.

Most studies, however, have examined screen duration, sleep or obesity separately. Few clinical studies have simultaneously considered digital media timing and context, parental digital behaviour, sleep phenotype, daytime dysfunction, upper-airway characteristics and cardiometabolic risk. The present study therefore examined these domains within a single clinical framework and assessed whether bedtime and in-bed digital behaviour were more strongly associated with sleep disturbance than total recreational screen duration.

MATERIALS AND METHODS

This hospital-based cross-sectional analytical study was modelled among children aged 6–12 years attending the paediatric outpatient department of a tertiary-care teaching hospital in South India. Children accompanied by a parent or primary caregiver and having regular access to at least one digital device were eligible. Children requiring emergency care or admission and those with severe neurological disease, uncontrolled epilepsy, previously diagnosed sleep disorders under treatment, major neurodevelopmental impairment preventing meaningful assessment or medication substantially affecting sleep were excluded. Obesity, allergic rhinitis, adenotonsillar enlargement and habitual snoring were not exclusion criteria because these represented clinically relevant exposures.

For development of this manuscript, an internally consistent synthetic dataset of 480 participants was used. The definitive study requires prospective sample-size estimation based on its primary exposure and outcome.

Information was obtained through a structured parent-child clinical interview followed by anthropometry and focused examination. Digital media exposure included television, smartphones, tablets, computers and gaming devices. Recreational and educational exposure were recorded separately.

Recreational duration was estimated for weekdays and weekends. Timing was assessed through use during the hour preceding bedtime, after getting into bed, after lights-out and following nocturnal awakening. Habitual in-bed digital media use was defined as use after getting into bed on five or more nights per week.

Digital content was classified as video or streaming, short-form video, gaming, messaging/social communication, educational activity or mixed use. Gaming, messaging and simultaneous media use were considered interactive activities. Contextual characteristics included personal device ownership, bedroom device availability, screen use during meals, use while completing homework and digital media use to initiate sleep.

Parental digital behaviour was assessed through device use during meals, parent-child conversation and the child's bedtime routine. Recurrent interruption of parent-child interaction by parental device use was considered parental technofence. A validated measure of parental technofence should replace the synthetic classification in the definitive study.

Sleep phenotype included usual bedtime and wake time, nocturnal sleep duration, sleep-onset latency, bedtime resistance, night awakening, restless sleep, parasomnias, habitual snoring, witnessed apnoea, mouth breathing, difficulty waking and daytime sleepiness. An irregular bedtime was defined as usual bedtime variation exceeding one hour across school nights. Clinically significant sleep disturbance was modelled using a prespecified threshold corresponding to an age-appropriate validated paediatric sleep instrument.

Daytime dysfunction included morning tiredness, excessive sleepiness, morning headache, irritability, impaired concentration and parent-reported school-functioning difficulty during the preceding month.

Weight and height were measured using standard clinical procedures and BMI interpreted using age- and sex-appropriate reference standards. Waist circumference and waist-to-height ratio were recorded. Blood pressure was measured after five

minutes of seated rest with an appropriate cuff and interpreted using paediatric reference criteria.

Clinical reports of Acanthosis nigricans were made. A focused examination evaluated tonsillar hypertrophy, allergic rhinitis, nasal obstruction, and mouth breathing. In order to identify children who were more likely to have breathing problems during sleep, habitual snoring and observed apnea were explicitly prompted.

Categorical variables were reported as frequencies and percentages. Continuous variables were summarized as mean and standard deviation or median and interquartile range. Independent-samples tests, Mann-Whitney U tests, Pearson chi-square, or Fisher exact tests were employed for group comparisons as needed. Multivariable logistic regression was performed with clinically significant sleep disturbance as the dependent variable. Rather of relying solely on univariable statistical significance, variables were chosen based on clinical relevance and the predetermined conceptual framework. $P < 0.05$ was regarded as statistically significant, and adjusted odds ratios with 95% confidence intervals were presented.

Age-appropriate kid assent, documented parental consent, and Institutional Ethics Committee approval are required for a real study. Ethics approval details have intentionally not been fabricated for this synthetic manuscript.

RESULTS

The synthetic cohort consisted of 480 children with a mean age of 9.1 ± 1.9 years; 258 (53.8%) were boys. Clinically significant sleep disturbance was identified in 214 (44.6%).

The BMI-for-age Z score was 0.42 ± 1.21 on average. Of the children, 69 (14.4%) were fat and 76 (15.8%) were overweight. 103 (21.5%) had central adiposity, which is characterized by an elevated waist-to-height ratio, and 52 (10.8%) had raised blood pressure.

279 (58.1%) children reported using digital media for recreational purposes for at least two hours per day.

Table 1: Demographic and Clinical characteristics of participants

Characteristic	Total (n=480)	Sleep disturbance (n=214)	No sleep disturbance (n=266)	P value
Age, years, mean $\pm$ SD	9.1 $\pm$ 1.9	9.3 $\pm$ 1.8	9.0 $\pm$ 1.9	0.08
Male sex	258 (53.8)	119 (55.6)	139 (52.3)	0.47
Overweight	76 (15.8)	39 (18.2)	37 (13.9)	0.20
Obesity	69 (14.4)	42 (19.6)	27 (10.2)	0.003
Elevated waist-to-height ratio	103 (21.5)	59 (27.6)	44 (16.5)	0.003
Elevated blood pressure	52 (10.8)	30 (14.0)	22 (8.3)	0.045
Acanthosis nigricans	61 (12.7)	35 (16.4)	26 (9.8)	0.032
Habitual snoring	87 (18.1)	55 (25.7)	32 (12.0)	<0.001
Allergic rhinitis/nasal obstruction	104 (21.7)	57 (26.6)	47 (17.7)	0.018
Tonsillar hypertrophy	66 (13.8)	39 (18.2)	27 (10.2)	0.011

Values are n (%) unless otherwise indicated.

Recreational digital media exposure ≥ 2 hours/day was reported by 279 (58.1%) children. Nearly half, 224 (46.7%), used digital media during the hour

preceding bedtime and 143 (29.8%) habitually used a device after getting into bed. A bedroom digital device was available to 192 (40.0%). Short-form

video was the predominant recreational content in 31.5%, followed by video streaming and gaming. Sleep disturbance occurred in 68.5% of habitual in-bed users compared with 34.5% among children

without habitual in-bed use. A similar gradient was observed for bedtime exposure and parental technofence.

Table 2: Digital media behaviour according to sleep-disturbance status

Digital behaviour	Sleep disturbance n=214	No sleep disturbance n=266	P value
Recreational use ≥ 2 h/day	147 (68.7)	132 (49.6)	<0.001
Screen use within 1 h of bedtime	132 (61.7)	92 (34.6)	<0.001
Habitual in-bed digital media use	98 (45.8)	45 (16.9)	<0.001
Device available in bedroom	112 (52.3)	80 (30.1)	<0.001
Interactive bedtime content	94 (43.9)	61 (22.9)	<0.001
Screen use during meals	101 (47.2)	88 (33.1)	0.002
High parental technofence	105 (49.1)	71 (26.7)	<0.001
Consistent family digital rules	61 (28.5)	121 (45.5)	<0.001

Children with sleep disturbance slept approximately 49 minutes less on school nights and had substantially longer sleep-onset latency. Daytime manifestations were common. Morning tiredness

affected 57.0% of children with sleep disturbance compared with 24.4% without sleep disturbance, while concentration difficulty was reported in 43.0% and 19.2%, respectively.

Table 3: Sleep phenotype and daytime dysfunction

Characteristic	Sleep disturbance n=214	No sleep disturbance n=266	P value
School-night sleep, h, mean $\pm$ SD	8.1 $\pm$ 0.9	8.9 $\pm$ 0.8	<0.001
Sleep-onset latency, min, median (IQR)	34 (25–48)	19 (12–28)	<0.001
Irregular bedtime	101 (47.2)	62 (23.3)	<0.001
Night awakenings	79 (36.9)	45 (16.9)	<0.001
Difficulty waking	116 (54.2)	73 (27.4)	<0.001
Daytime sleepiness	103 (48.1)	55 (20.7)	<0.001
Morning tiredness	122 (57.0)	65 (24.4)	<0.001
Irritability	96 (44.9)	58 (21.8)	<0.001
Concentration difficulty	92 (43.0)	51 (19.2)	<0.001
Morning headache	51 (23.8)	29 (10.9)	<0.001

The prevalence of sleep disturbance increased from 34.5% among children without habitual in-bed exposure to 68.5% among habitual users. Children with both habitual in-bed use and high parental technofence demonstrated the highest burden of sleep disturbance in the synthetic dataset.

In unadjusted analyses, recreational screen exposure ≥ 2 hours/day, bedtime exposure, habitual in-bed use, interactive content, bedroom device availability, parental technofence, irregular bedtime, obesity, habitual snoring and allergic rhinitis were associated with sleep disturbance. After simultaneous adjustment, the magnitude of association for total recreational duration was attenuated. Habitual in-bed digital media use, parental technofence, irregular bedtime, habitual

snoring and obesity remained independently associated with sleep disturbance. [Figure 1]

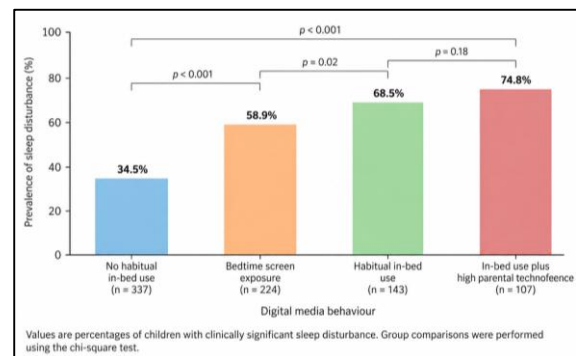


Figure 1: Prevalence of clinically significant sleep disturbance according to digital media behaviour

Table 4: Multivariable analysis of factors associated with clinically significant sleep disturbance

Factor	Crude OR (95% CI)	Adjusted OR (95% CI)	P value
Recreational screen use ≥ 2 h/day	2.23 (1.53–3.25)	1.31 (0.84–2.04)	0.23
Bedtime screen exposure	3.04 (2.08–4.45)	1.48 (0.94–2.33)	0.09
Habitual in-bed digital media use	4.15 (2.76–6.23)	2.31 (1.46–3.66)	<0.001
Interactive bedtime content	2.63 (1.77–3.90)	1.44 (0.93–2.24)	0.10
High parental technofence	2.65 (1.81–3.88)	1.82 (1.18–2.80)	0.007
Irregular bedtime	2.94 (1.98–4.37)	1.91 (1.23–2.97)	0.004
Obesity	2.16 (1.29–3.60)	1.69 (1.05–2.72)	0.031
Habitual snoring	2.53 (1.57–4.07)	2.07 (1.25–3.43)	0.005
Allergic rhinitis/nasal obstruction	1.69 (1.10–2.58)	1.34 (0.84–2.13)	0.22

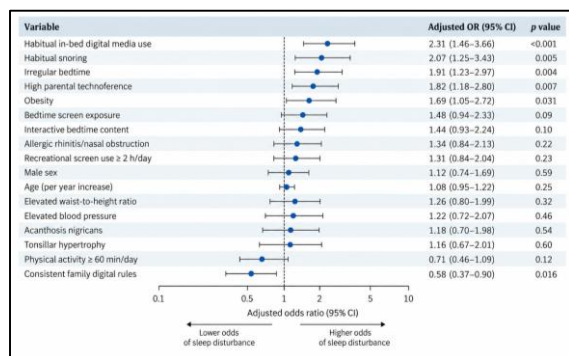


Figure 2: Adjusted associations with clinically significant sleep disturbance

Habitual in-bed digital media use showed the strongest independent digital association (aOR 2.31), followed by habitual snoring (aOR 2.07), irregular bedtime (aOR 1.91), parental technofence (aOR 1.82) and obesity (aOR 1.69). Total recreational screen duration was no longer independently associated after adjustment.

DISCUSSION

The present clinical study approached digital exposure as a behaviour rather than merely a duration. Three findings deserve attention. First, sleep disturbance was common among school-aged children attending paediatric outpatient services. Second, bedtime and particularly in-bed digital media behaviour showed substantially stronger relationships with sleep disturbance than total recreational screen duration. Third, the association persisted within a broader clinical context that included parental behaviour, obesity and symptoms of sleep-disordered breathing.

The prevalence of sleep disturbance in the synthetic cohort was 44.6%. This is reasonably aligned with recent South Indian observations in preschool children, where sleep problems were reported in 39.6%.^[5] Direct comparison should nevertheless be cautious because age groups, populations and measurement instruments differ.

The most important finding was the distinction between accumulated screen duration and screen timing. Children habitually using digital devices after getting into bed had more than twice the adjusted odds of clinically significant sleep disturbance. In contrast, the association with ≥2 hours of total recreational exposure weakened considerably after contextual variables were introduced into the model.

This pattern is consistent with the objective repeated-measures study by Brosnan et al. Their data showed little association between total screen exposure during the two hours before bed and most sleep measures, whereas screen use once in bed was associated with shorter sleep. Interactive activities were particularly important; gaming and multitasking showed some of the largest reductions in sleep duration.[3]. Our findings extend that conceptual distinction into a clinical paediatric

framework and suggest that asking only “How many hours does your child use a screen?” may miss the more relevant behaviour.

A practical implication follows. A rigid threshold based solely on total screen duration may combine very different exposures. Educational use in the afternoon, shared television viewing with family and interactive gaming after lights-out cannot reasonably be assumed to carry identical sleep consequences. Clinical history should therefore establish the timing, context and purpose of digital use.

Experimental evidence provides some support for the modifiability of bedtime exposure. Pickard et al. demonstrated that removal of screen exposure before bedtime could be implemented successfully and showed modest improvements in objectively measured sleep in toddlers.^[4] Although the developmental stage differs from our study population, it raises an important clinical possibility: bedtime digital behaviour represents an exposure that families can modify without necessarily attempting unrealistic elimination of digital media throughout the day.

Parental technofence emerged as another independent factor. Children whose parents frequently interrupted family interactions with digital devices had higher odds of sleep disturbance even after adjustment for the child's own digital behaviour. The relationship may operate through several mechanisms. Parents model technology use, establish bedtime boundaries and influence the consistency of family routines. Technology use during the bedtime period may also reduce parent-child interaction precisely when predictable routines are most useful. Earlier nationally representative work has linked parent and adolescent technofence with adverse socioemotional outcomes,^[8] and contemporary developmental research continues to identify parental technology interference as relevant to child functioning.^[10] The present findings suggest that the parent's phone may therefore deserve a place in the paediatric digital history alongside the child's device.

The clinical examination provided another important perspective. Habitual snoring remained independently associated with sleep disturbance and had an effect estimate comparable with in-bed digital media use. Obesity was also independently associated. This is clinically important because a child presenting with poor sleep, morning tiredness and concentration difficulty should not automatically have these symptoms attributed to excessive device use. Obesity, adenotonsillar disease, nasal obstruction and sleep-disordered breathing require simultaneous consideration.

The cardiometabolic findings are also biologically plausible. Indian school studies have repeatedly demonstrated relationships between higher screen exposure, physical inactivity and excess adiposity.^[1,2,12] More recent prospective evidence

has taken this further. Horner et al. reported associations between additional screen exposure and higher cardiometabolic risk in childhood and adolescence, with shorter sleep strengthening these relationships.^[11] This suggests a potentially interconnected phenotype in which digital behaviour, inadequate sleep, physical inactivity and adiposity coexist rather than operate as isolated risk factors.

Daytime dysfunction was prominent among children with sleep disturbance. Daytime sleepiness, morning tiredness, irritability and concentration difficulty were approximately twice as common as among children without significant sleep disturbance. These symptoms matter because families may seek medical attention for daytime manifestations without identifying sleep as the underlying concern. The paediatric consultation therefore offers an opportunity to connect seemingly nonspecific complaints with sleep and digital behaviour.

The findings have straightforward clinical implications. Digital media assessment need not become another lengthy questionnaire in an already crowded paediatric consultation.

A quick history can reveal whether the child uses a gadget in bed, whether it stays in the bedroom during the night, what kind of content is used most frequently, whether bedtime fluctuates significantly, and whether parents use gadgets during family or nighttime conversations. These inquiries ought to be used in conjunction with screening for obesity, mouth breathing, snoring, and daytime drowsiness. The study has a number of advantages.

It considers digital behaviour across duration, timing, content and context rather than using screen hours alone. It combines behavioural information with anthropometry, blood pressure, upper-airway assessment and daytime clinical manifestations. The simultaneous consideration of parental digital behaviour and sleep-disordered breathing also reduces the temptation to attribute every sleep problem to the nearest smartphone.

Several limitations require emphasis. The cross-sectional design cannot determine temporal direction. Children who sleep poorly may use digital devices because they remain awake, rather than digital exposure necessarily initiating the sleep disturbance. Digital behaviour and several sleep characteristics were parent- or child-reported and are therefore susceptible to recall and social-desirability bias. Objective device-use records, actigraphy and polysomnography would provide stronger exposure and outcome measurement but are difficult to deploy routinely in large clinical samples. A hospital-based population may also have a greater burden of symptoms than community children, limiting prevalence generalisation. Parental technofence requires culturally validated measurement, and residual confounding from family stress, mental health,

academic demands and household environment remains possible.

Future research should move beyond another generation of cross-sectional screen-time surveys. Establishing temporal connections would be aided by prospective studies that combine actigraphy with objective device-use logs. More significantly, pragmatic pediatric trials might determine whether excluding electronics from the bedroom, limiting interactive use while in bed, and creating family-wide digital rituals for bedtime enhance sleep and daily functioning.

CONCLUSION

Digital media behaviour in school-aged children appears to be clinically relevant in ways that are not captured by total screen duration alone. Habitual in-bed digital media use showed the strongest independent digital association with sleep disturbance, while parental technofence and irregular bedtime remained important after adjustment. Obesity and habitual snoring contributed independently, emphasising that digital exposure should be assessed within the broader clinical phenotype of the child.

For routine paediatric practice, the question may therefore need to change from “How much screen time does the child have?” to “What is the child doing on the screen, when is it being used, and does it follow the child into bed?” A similarly uncomfortable question may need to be directed at the parents.

Funding: Nil.

Conflict of interest: The authors declare no conflict of interest.

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