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Screen Use at Bedtime and Sleep Duration and Quality Among Youths

Bradley Brosnan, PhD; Jillian J. Haszard, PhD; Kim A. Meredith-Jones, PhD; Shay-Ruby Wickham, MSc; Barbara C. Galland, PhD; Rachael W. Taylor, PhD

IMPORTANCE Although questionnaire-based cross-sectional research suggests that screen time before bed correlates with poor sleep, self-reported data seem unlikely to capture the complexity of modern screen use, requiring objective night-by-night measures to advance this field.

OBJECTIVE To examine whether evening screen time is associated with sleep duration and quality that night in youths.

DESIGN, SETTING, AND PARTICIPANTS This repeated-measures cohort study was performed from March to December 2021 in participant homes in Dunedin, New Zealand. Participants included healthy youths aged 11 to 14.9 years. Data were analyzed from October to November 2023.

EXPOSURE Objectively measured screen time, captured using wearable or stationary video cameras from 2 hours before bedtime until the first time the youth attempted sleep (shut-eye time) over 4 nonconsecutive nights. Video data were coded using a reliable protocol (κ = 0.92) to quantify device (8 options [eg, smartphone]) and activity (10 options [eg, social media]) type.

MAIN OUTCOMES AND MEASURES Sleep duration and quality were measured objectively via wrist-worn accelerometers. The association of screen use with sleep measures was analyzed on a night-by-night basis using mixed-effects regression models including participant as a random effect and adjusted for weekends.

RESULTS Of the 79 participants (47 [59.5%] male; mean [SD] age, 12.9 [1.1] years), all but 1 had screen time before bed. Screen use in the 2 hours before bed had no association with most measures of sleep health that night (eg, mean difference in total sleep time, 0 minutes [95% CI, −3 to 20 minutes] for every 10 minutes more total screen time). All types of screen time were associated with delayed sleep onset but particularly interactive screen use (mean difference, 10 minutes; 95% CI, 4 to 16 minutes for every additional 10 minutes of interactive screen time). Every 10 minutes of additional screen time in bed was associated with shorter total sleep time (mean difference, −3 minutes; 95% CI, −6 to −1 minute). The mean difference in total sleep time was −9 minutes (95% CI, −16 to −2 minutes) for every 10 minutes of interactive screen use and −4 minutes (95% CI, −7 to 0 minutes) for passive screen use. In particular, gaming (mean difference, −17 minutes; 95% CI, −28 to −7 minutes for every 10 minutes of gaming) and multitasking (mean difference, −35 minutes; 95% CI, −67 to −4 minutes on nights with vs without multitasking) were associated with less total sleep time.

CONCLUSIONS AND RELEVANCE In this repeated-measures cohort study, use of an objective method showed that screen time once in bed was associated with impairment of sleep, especially when screen time was interactive or involved multitasking. These findings suggest that current sleep hygiene recommendations to restrict all screen time before bed seem neither achievable nor appropriate.

Supplemental content

Author Affiliations: Department of Medicine, University of Otago, Dunedin, New Zealand (Brosnan, Meredith-Jones, Wickham, Taylor); Biostatistics Centre, University of Otago, Dunedin, New Zealand (Haszard); Department of Women's and Children's Health, University of Otago, Dunedin, New Zealand (Galland).

Corresponding Author: Rachael W. Taylor, PhD, Department of Medicine, University of Otago, PO Box 56, Dunedin 9016, New Zealand (rachael.taylor@otago.ac.nz).

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In the digital age, adolescents spend more time with screens than ever before, potentially at the cost of their sleep.[1-3] As such, the American Academy of Pediatrics[4] and government health bodies internationally[5,6] have recommended that adolescents stop using screens 1 to 2 hours before bedtime to ensure good sleep health. However, this advice contrasts with screen behaviors observed globally,[7] with most adolescents extending screen activity into the nighttime hours.[3,8,9] Moreover, the evidence on which these guidelines are based largely comes from cross-sectional studies with many inherent limitations.[2,10-12] Most used self- or parent-reported data on total screen use rather than assessing specific device or activity types that might have differing associations with sleep.[2,13] Most research examined screen use over the whole day rather than that more immediate to bedtime, which is probably more detrimental to sleep.[14-16] Many studies compared average screen time with average sleep and thus could not determine whether variation in screen time was associated with subsequent sleep that night.[17,18] A stronger study design would be a repeated-measures approach that examines how changing screen use from night to night is associated with subsequent sleep at the within-person level.

The limited existing research in this area has reported few associations between device use before bed and subsequent sleep,[19-21] although screen use was measured objectively in just 1 study (smartphones only).[19] Similarly, few studies have had objective measures of sleep end points. While researchers are beginning to use apps and other software to objectively measure screen time, these are often restricted to individual devices,[22] which precludes measurement of multitasking (using >1 device simultaneously), thought to be particularly relevant for sleep.[23,24] Wearable cameras that take regular photographs offer a suitable alternative[25,26] but have not yet been used in sleep studies. We recently developed a reliable coding protocol that uses video cameras to measure screen time in youths, which offered the advantage of continuous recording to capture nuances, such as rapid changes in screen types or activities.[27] The aim of this study was to examine whether objectively measured evening screen time was associated with sleep that night in youths.

Key Points

Question Is there an association between screen time before bed and sleep duration and quality in youths?

Findings In this repeated-measures cohort study of 79 participants aged 11 to 14 years, objectively measured screen time in the 2 hours before bed had no association with most measures of sleep health. Screen time once in bed, particularly interactive screen activities, such as gaming and multitasking, was associated with less sleep.

Meaning The findings showed that not all screen time before bed was associated with impaired sleep, suggesting that presleep recommendations require modification.

Methods

The Bedtime Electronic Devices study was a repeated-measures longitudinal cohort study (following the Strengthening the Reporting of Observational Studies in Epidemiology [STROBE] reporting guideline[28]) examining how evening screen use was associated with sleep that night. The study received ethical approval from the University of Otago Human Ethics Committee. Eligible participants (11-14.9 years of age, lived locally, and no physical or intellectual barriers to participation) were recruited in Dunedin, New Zealand, by advertisement from March to December 2021. Written informed consent was obtained from parents and youths before data collection commenced.

We determined that 85 participants were required to reliably estimate the association between evening screen behaviors and sleep duration and quality. We assumed a relatively high intraclass correlation of 0.7, no more than 4 variables in the model, and at least 3 nights of sleep and allowed for 30% missing data or dropouts.

Parents completed a brief demographic questionnaire, including their highest educational level, ethnicity of the participant, and household address to calculate area-level deprivation.[29] Ethnicities included Asian, Māori, New Zealand European, and Pacific. In New Zealand, ethnicity is self-identified (or parent identified), multiple ethnicities can be selected, and a prioritization system is applied (in order of Māori, Pacific, Asian, New Zealand European, and others). Ethnicity was analyzed as it is always included in studies in New Zealand to describe the population. Participants were asked a single question about whether they felt the cameras had changed their behavior. Duplicate measures of height (Holtain Ltd) and weight (Wedderburn WM206) were undertaken by trained staff using standard techniques. Body mass index *z* scores were calculated (World Health Organization growth reference data[30]).

Sleep was measured using waterproof Axivity accelerometers on the nondominant wrist 24 hours a day for 8 days. Accelerometers were initialized, and the data were downloaded with OmGui software, version 1.0.0.30 (Open Movement), saved in raw format as .cwa files, and then converted into Actigraph counts for data processing.[31] Sleep variables were obtained using an automated script developed in MATLAB (MathWorks) that uses a count-scaled algorithm to estimate sleep variables specific to each individual for each day[32] and has been validated for this age group.[33] Sleep onset was obtained from the accelerometry data as the start of the first 15 continuous minutes of sleep preceded by 5 minutes of awake, sleep offset as the last of 15 continuous minutes of sleep followed by 5 minutes of awake, total sleep time as the number of minutes from sleep onset to sleep offset minus the number of minutes of time awake after sleep onset, and time awake after sleep onset as the number of minutes from the sum of all movement epochs that occurred over 5 continuous minutes of awake between sleep onset to offset.

Evening screen time was obtained from compact (7.7 × 5.6 × 2.8 cm; weight, 128 g), high-resolution (1080p), wide-angle (170° field of vision) wearable and stationary cameras (PatrolEyes SC-DV7 Ultra video camera; PatrolEyes) on 4 nonconsecutive nights (to reduce participant burden and improve

adherence) over the course of 1 week (1 weekend night, 3 weeknights). The wearable camera was attached to a chest harness (camera facing outward) and recorded screen time from 2 hours before bedtime until bedtime. The stationary camera (tripod mounted in the bedroom) captured any screen use after the participant had gone to bed until awakening the next morning. The team guided each family through established ethical protocols for camera use,[34] and families could delete footage before storage on a secure, high-capacity university system. Video data were coded using an established reliable protocol[27] on Observer XT, version 16.0 by 4 trained coders from May to December 2022. The coding quantified when and for how long participants spent time on 8 different devices (smartphone, tablet, laptop computer, desktop computer, handheld gaming console, gaming console, television, and other) and 10 screen activities (watching, listening, reading, educational or creative, browsing the internet, communication, social media, video gaming, multitasking within a device, and multitasking across multiple devices). Screen activities were also collapsed into passive (watching, listening, reading, browsing, and other unknown passive) and interactive (gaming, communication including messaging, device-based multitasking, educational or creative tasks, and other unknown interactive) groups. Social media (scrolling feeds, viewing stories, and interacting with posts, not including messaging) was excluded from these broader categories, being a blend of both passive and interactive. Interrater reliability (mean weighted κ) was determined from each coder independently coding a random subset of 83 thirty-minute video files, with adequate interrater reliability indicated by percentage agreement of 90% or more and a mean weighted κ of at least 0.80.[35]

Bedtime was determined from the video data as when the participant got into bed and under the covers and shut-eye time as when the participants stopped interacting with any device or person and appeared to close their eyes to try and go to sleep. Shut-eye latency was calculated as the difference between bedtime and the first shut-eye time from the video data, and sleep latency was calculated as the difference between the flagged shut-eye time from the video camera data until sleep onset time from the accelerometer.

Statistical Analysis

Stata, version 17.0 (StataCorp LLC) was used for statistical analyses. Participants needed to have at least 3 nights of screen use and corresponding sleep data. Night-to-night variability in screen use was described by within-person means and SDs. The association between presleep screen behaviors and sleep quantity or quality was estimated using mixed-effects regression models with the sleep variable as the dependent variable and the presleep screen behavior as the exposure. The participant was included as a random effect, and all analyses were adjusted for whether the day was a weekend (ie, a Friday or Saturday night). A sensitivity analysis assessed weeknights only. Mean differences and 95% CIs in sleep outcomes were reported for each 10 minutes more of screen use (these units were used so that estimates are meaningful). Screen-use data were also collapsed into binary variables for each night (eg, the participant did or did not use screens in the 2 hours before bed), and differences between these nights were estimated.

Table 1. Demographic Characteristics of Participants

Variable	Participants, No. (%) (N = 79)
Age, mean (SD), y	12.9 (1.1)
Gender	
Female	32 (40.5)
Male	47 (59.5)
Ethnicity	
Asian	5 (6.3)
Māori	30 (38.0)
New Zealand European	41 (51.9)
Pacific	3 (3.8)
Parents' highest level of education	
High school	10 (12.7)
Polytech or similar tertiary qualification	29 (36.7)
University	40 (50.6)
Socioeconomic deprivation[a]	
High	16 (20.5)
Medium	32 (40.5)
Low	31 (39.2)
Weight status (n = 77)[b]	
Normal weight	47 (61.0)
Overweight or obesity	30 (39.0)
Shares a room with someone else	19 (24.1)

[a] According to the New Zealand Index of Deprivation 2018,[29] which reflects the extent of material and social deprivation. Deciles 1 to 3 indicate low socioeconomic deprivation; 4 to 7, medium; and 8 to 10, high.

[b] Defined according to World Health Organization growth reference data.[30]

Residuals of all models were plotted and visually assessed for homoskedasticity and normality. Two-sided $P < .05$ was considered significant.

Results

Of 85 enrolled participants, 79 provided sufficient data for inclusion (eFigure in Supplement 1); 75 (95.0%) provided 4 to 5 nights of data (eTable 1 in Supplement 1), and the mean (SD) duration of screen use was 4.9 (2.4) hours per participant. The completion rate was high, with just 2 participants withdrawing and an additional 4 not having sufficient data. Of the 79 participants, 32 (40.5%) were female and 47 (59.5%) were male, with a mean (SD) age of 12.9 (1.1) years. Participants were ethnically diverse: 5 (6.3%) were Asian; 30 (38.0%), Māori; 41 (51.9%), New Zealand European; and 3 (3.8%), Pacific. Parental educational levels were high (**Table 1**).

Table 2 shows how youths used their screens during evening hours using a reliable coding protocol (Cohen κ [SD] was 0.92 [0.1] for interrater reliability and 0.80 [0.1] for drift reliability). Mean (SD) screen time in the 2 hours before bedtime was 56 (25) minutes, although night-to-night variability was high at 27 (11) minutes. Youths spent more time engaged in passive than interactive screen activities or social media, and little difference was observed between weekday and weekend nights. In the mean (SD) of 29 (28) minutes it took

Table 2. Objective Measurements of Mean Screen Use and Sleep[a]

Variable	Mean (SD)				
	All nights (N = 79)	Within-person SD for all nights	Weekends (n = 77)[b]	Weekdays (n = 79)	Within-person SD for weekdays
Screen use in the 2 h before bedtime, min					
Total	56 (25)	27 (11)	60 (38)	54 (26)	24 (14)
Passive	37 (24)	26 (14)	43 (39)	35 (25)	23 (17)
Interactive	22 (23)	17 (13)	22 (33)	22 (22)	16 (13)
Social media	5 (8)	5 (8)	4 (11)	5 (9)	5 (9)
Screen use after bedtime but before shut-eye time, min					
Total	16 (26)	14 (22)	21 (39)	14 (24)	12 (22)
Passive	11 (20)	11 (18)	16 (34)	10 (18)	10 (17)
Interactive	3 (6)	4 (10)	3 (9)	3 (7)	4 (11)
Social media	4 (9)	5 (12)	5 (15)	3 (8)	3 (11)
Clock times					
Bedtime	21:32 (57)	38.0 (25)	21:59 (14)	21:21 (57)	23 (21)
Shut-eye time	22:01 (62)	49.8 (28)	22:29 (24)	21:49 (59)	26 (25)
Sleep onset	22:44 (51)	45.6 (29)	23:12 (14)	22:32 (49)	33 (27)
Sleep offset	6:54 (40)	49.4 (33)	7:22 (15)	6:41 (38)	37 (32)
Sleep measures					
Total sleep time, h	7.2 (0.9)	1.0 (0.5)	7.2 (1.3)	7.3 (1.0)	0.9 (0.6)
Time awake after sleep onset, min	55 (41)	44 (22)	61 (58)	54 (43)	40 (26)
Shut-eye latency, min	29 (28)	23 (26)	30 (45)	29 (26)	21 (28)
Sleep latency, min	43 (36)	29 (24)	42 (49)	43 (37)	26 (24)

[a] Screen time data were quantified through video recording, and sleep parameters were quantified using accelerometry. Measures are described in the Methods section.

[b] Within-person SD for weekend nights was not reported, anticipating minimal variability with typically a single weekend night per participant.

Table 3. Associations Between Screen Time in the 2 Hours Before Bedtime and Sleep Among 79 Participants Over 323 Nights

Variable	Mean difference, min (95% CI)[a]							
	Total sleep time	WASO	Bedtime	Shut-eye time	Sleep onset	Sleep offset	Shut-eye latency	Sleep latency
Total screen time								
For every 10 min more	0 (-3 to 20)	1 (-1 to 3)	-1 (-2 to 1)	0 (-2 to 2)	1 (-1 to 3)	1 (-1 to 3)	0 (-1 to 1)	0 (-1 to 2)
On nights with vs nights without	17 (-10 to 45)	-1 (-22 to 19)	-2 (-20 to 16)	-6 (-27 to 14)	31 (9 to 54)[b]	27 (5 to 49)[b]	-5 (-20 to 10)	10 (-6 to 26)
Passive screen time[c]								
For every 10 min more	-1 (-4 to 1)	2 (0 to 4)[b]	-1 (-3 to 1)	1 (-3 to 1)	0 (-2 to 2)	0 (-2 to 2)	0 (-1 to 2)	1 (-1 to 2)
On nights with vs nights without	17 (-9 to 42)	-3 (-22 to 16)	-4 (-21 to 13)	-2 (-22 to 17)	32 (11 to 53)[b]	27 (7 to 47)[b]	0 (-14 to 14)	12 (-4 to 27)
Interactive screen time[d]								
For every 10 min more	0 (-3 to 3)	-1 (-3 to 1)	1 (-3 to 1)	2 (-1 to 4)	3 (0 to 5)[b]	1 (-2 to 3)	2 (-0 to 3)	0 (-2 to 2)
On nights with vs nights without	6 (-13 to 24)	-2 (-15 to 12)	-6 (-18 to 6)	-2 (-16 to 11)	20 (5 to 35)[b]	17 (3 to 32)[b]	1 (-8 to 11)	11 (1 to 22)[b]
Social media[e]								
For every 10 min more	8 (0 to 16)[b]	-2 (-8 to 4)	-1 (-5 to 6)	-1 (-7 to 5)	-1 (-7 to 6)	6 (-0 to 12)	-2 (-7 to 2)	-3 (-8 to 2)
On nights with vs nights without	9 (-10 to 27)	-6 (-20 to 8)	-5 (-18 to 8)	-6 (-20 to 9)	5 (-11 to 20)	6 (-9 to 21)	-3 (-13 to 7)	-0 (-11 to 11)

Abbreviation: WASO, time awake after sleep onset.

[a] Estimated using mixed-effects regression models with the participant as a random effect.

[b] Results are statistically significant at $P < .05$.

[c] Noninteractive activities of watching, listening, reading, or browsing on devices.

[d] Engaging in gaming, communication including instant messaging, educational or creative tasks, or multitasking on a device.

[e] Scrolling feeds, viewing stories, and interacting with posts, not including messaging.

from the youths getting into bed until their first attempt at sleep (shut-eye latency), they spent a mean (SD) of 16 (26) minutes on screens, particularly engaging in passive screen time (Table 2).

Table 3 shows that screen time in the 2 hours before bed had no association with most measures of sleep health. On nights when screens were used, mean difference in sleep onset varied from 5 minutes (95% CI, -11 to 20 minutes) for social media to 32 minutes (95% CI, 11-53 minutes) for passive screen time, but these were offset by comparable mean differences in sleep offset (from 6 minutes [95% CI, -9 to 21 minutes] for social media to 27 minutes [95% CI, 7-47 minutes] for

Table 4. Associations Between Screen Time While in Bed But Before Shut-Eye Time and Sleep Among 79 Participants Over 323 Nights

Variable	Mean difference, min (95% CI)[a]							
	Total sleep time	WASO	Bedtime	Shut-eye time	Sleep onset	Sleep offset	Shut-eye latency	Sleep latency
Total screen time								
For every 10 min more	-3 (-6 to -1)[b]	-2 (-2 to 0.0)	-3 (-5 to -1)[b]	9 (7 to 10)[b]	7 (5 to 9)[b]	3 (1 to 5)[b]	11 (10 to 12)[b]	-2 (-3 to 0)[b]
On nights with vs nights without	-16 (-35 to 4)	-11 (-25 to 4)	-12 (-25 to 2)	27 (12 to 43)[b]	35 (20 to 51)[b]	8 (-7 to 23)	40 (31 to 49)[b]	-3 (-14 to 9)
Passive screen time[c]								
For every 10 min more	-4 (-7 to 0)[b]	-2 (-4 to 1)	-3 (-5 to -1)[b]	9 (7 to 11)[b]	8 (6 to 11)[b]	3 (1 to 6)[b]	12 (11 to 13)[b]	-1 (-3 to 1)
On nights with vs nights without	-14 (-34 to 6)	-13 (-27 to 2)	-21 (-35 to -7)[b]	20 (4 to 36)[b]	32 (16 to 48)[b]	6 (-10 to 22)	43 (34 to 52)[b]	1 (-11 to 13)
Interactive screen time[d]								
For every 10 min more	−9 (−16 to −2)[b]	-2 (-7 to 4)	-2 (-7 to 3)	13 (7 to 18)[b]	10 (4 to 16)[b]	2 (-4 to 8)	16 (12 to 19)[b]	-2 (-6 to 2)
On nights with vs nights without	−26 (−49 to −2)[b]	-9 (-26 to 8)	-1 (-17 to 15)	38 (20 to 56)[b]	35 (16 to 54)[b]	6 (-13 to 24)	41 (30 to 53)[b]	-8 (-22 to 6)
Social media[e]								
For every 10 min more	-1 (-7 to 5)	-3 (-7 to 2)	-4 (-8 to 0)[b]	9 (4 to 13)[b]	7 (2 to 12)[b]	3 (-2 to 8)	13 (10 to 16)[b]	-3 (-7 to 0)
On nights with vs nights without	-4 (-31 to 23)	-16 (-36 to 5)	-13 (-32 to 6)	45 (24 to 67)[b]	38 (15 to 60)[b]	23 (2 to 44)[b]	54 (40 to 67)[b]	-15 (-31 to 2)

Abbreviation: WASO, time awake after sleep onset.

[a] Estimated using mixed-effects regression models with the participant as a random effect.

[b] Results are statistically significant at $P < .05$.

[c] Noninteractive activities of watching, listening, reading, or browsing on devices.

[d] Engaging in gaming, communication including instant messaging, educational or creative tasks, or multitasking on a device.

[e] Scrolling feeds, viewing stories, and interacting with posts, not including messaging.

passive screen time), such that no difference in total sleep time was observed.

By contrast, using screens once in bed and prior to attempting sleep was associated with poor sleep health in several ways (**Table 4**). All types of screen behaviors were associated with delayed sleep onset but particularly interactive screen use, which was associated with delayed onset of 10 minutes (95% CI, 4-16 minutes) for every 10 minutes more screen time or 35 minutes (95% CI, 16-54 minutes) on nights with interactive screen time compared with nights without. Comparable figures for passive screen time were 8 minutes (95% CI, 6-11 minutes) and 32 minutes (95% CI, 16-48 minutes). Even social media, which was used for shorter amounts of time (Table 2), was associated with delayed sleep onset by significant amounts (mean difference, 38 minutes [95% CI, 15-60 minutes] on nights with compared with without social media). Unlike screen time before bed, there was no corresponding delay in sleep offset (except for social media use), such that reductions in total sleep time were observed (mean difference, −3 minutes [95% CI, −6 to −1 minute] for every 10 additional minutes of total screen use). Interactive screen time was associated with a mean difference in total sleep time of −9 minutes (95% CI, −16 to −2 minutes) for every 10 minutes more of screen time. Overall, total screen time had no association with bedtime or how much youths woke up after first going to sleep on nights with vs without screen time. However, all forms of screen use were associated with extended shut-eye latency (time spent in bed before attempting sleep), but none were associated with sleep latency (how long it took them to go to sleep once they started trying) (Table 4).

eTables 2 to 4 in Supplement 1 show the impact of gaming and multitasking (within and between devices) among participants who did these behaviors on at least 1 night (to retain the within-person comparisons). While gaming prior to bed was associated with delayed bedtime (mean difference, −13 minutes; 95% CI, −24 to −3 minutes), no significant association with total sleep time was observed. However, gaming once in bed was associated with reduced total sleep (mean difference, −17 minutes; 95% CI, −28 to −7 minutes), with a corresponding delay in sleep onset in the small group of participants who undertook this activity (n = 10). Using a single device to do more than 1 screen activity had no association with most sleep outcomes (eTable 3 in Supplement 1), although few participants (n = 6) did this once in bed. However, multitasking across multiple devices (eTable 4 in Supplement 1) was associated with reduced total sleep time (mean difference, −35; 95% CI, −67 to −4 minutes) on nights when this was undertaken compared with nights when it was not. In particular, this activity was associated with large delays in sleep onset (mean difference, 41 minutes; 95% CI, 6-76 minutes) by delaying attempts to sleep (mean difference, 63 minutes; 95% CI, 36-90 minutes).

The sensitivity analysis presented in eTables 5 and 6 in Supplement 1 showed that when restricting analyses to weeknights only, findings were broadly comparable to those for the full dataset, with some greater differences in in-bed use. Potential for reactivity was assessed by comparing differences in screen time between the initial and subsequent nights of camera use, with 61 participants (77.2%) reporting no change in behavior despite the video recordings.

Table 5. Potential Screen Use Cutoffs and Sleep Outcomes Among 79 Participants

Variable	Nights with screen use, No. (%) (N = 323)	Mean difference, min (95% CI)[a]		
		Sleep latency	Total sleep time	WASO
Screen use in the 30 min before shut-eye time	200 (61.9)	5.2 (−4.6 to 15.0)	−7.6 (−25.0 to 9.8)	3.2 (−9.9 to 16.4)
Screen use in the 1 h before shut-eye time	262 (81.1)	9.3 (−2.5 to 21.2)	3.1 (−18.0 to 24.1)	−1.4 (−17.4 to 14.6)
Screen use in the 2 h before shut-eye time	293 (90.7)	2.4 (−13.7 to 18.5)	13.4 (−15.1 to 41.9)	−5.1 (−26.7 to 16.5)

Abbreviation: WASO, time awake after sleep onset.

[a] For nights with screen use after the cutoff compared with nights without screen use after the cutoff.

Analyses also considered current screen-related sleep guidelines by examining whether time since screens were last used was associated with sleep. Whether 30, 60, or 120 minutes prior to attempting sleep was used as the guideline for stopping screen time, time since last screen use was not associated with any measure of sleep examined (**Table 5**).

Discussion

In this cohort study, we showed that total screen use in the 2 hours before bedtime was not associated with total sleep time despite being associated with delayed sleep onset, which was matched by a corresponding delay in sleep offset. By contrast, using screens during the interval between getting into bed (bedtime) and attempting to sleep (shut-eye time) was significantly associated with shorter sleep duration. Interactive screen use, such as gaming and multitasking, was particularly problematic, although even passive screen activities, such as watching movies, were associated with shortened sleep time, albeit to a lesser extent.

It is difficult to compare our findings with the literature, as objective measurement of screen time remains rare. Current systematic reviews of mostly cross-sectional research have consistently reported that screen use is associated with reduced sleep quantity and quality.[11,14,36] However, this research used aggregated data, which provide a less accurate depiction of the association between screen use and sleep.[17] More recent questionnaire-based studies have tried to characterize device type but have often been limited to a single device (usually smartphones).[14,37,38] Furthermore, although several observational studies used wearable image cameras to describe screen time,[25,26,39,40] they did not investigate associations with sleep outcomes. Only 2 previous studies appear to have used within-person analyses and objective measures (smartphone trackers) to examine how screens are associated with youth sleep.[19,21] They also reported no significant reduction in total sleep time associated with before-bedtime smartphone use in youths but did not examine devices other than Android smartphones or the shut-eye latency period.

Examining the interval from retiring to bed until attempting sleep (shut-eye latency) separately from bedtime is important, as bedtime is not synonymous with attempts to sleep straightaway in the modern world.[41] Our data showed that engaging in passive screen activities, such as watching videos or streaming shows in bed, was associated with earlier bedtimes by up to 21 minutes. It is feasible that these activities were used as a form of relaxation before sleep (the screen sleep-aid hypothesis)[21,42] but also are associated with reduced total time asleep, possibly because platforms such as video-streaming apps are designed to maintain engagement with content via recommendation algorithms and autoplay,[43,44] which can delay sleep onset.[45] The larger differences in measures of sleep health associated with screen use during the shut-eye latency period compared with the prebedtime period were even more marked considering the former was considerably shorter (mean, 16 minutes) than the latter (mean, 56 minutes) and highlight that screen use in bed may be associated with less sleep quantity.

Our findings suggest that the association of screen time with sleep is primarily through time displacement delaying sleep onset rather than any direct effects of blue light or interactive engagement,[11,46] as indicated by few associations with sleep latency and waking up after first going to sleep (measure of total wakefulness during the sleep period). Screen time was not significantly associated with disruptions in these facets of sleep quality, which suggests that it may be associated with sleep scheduling rather than with sleep quality per se. Youths appeared to adjust their wake times to ensure a consistent amount of total sleep despite later bedtimes associated with screen engagement. For every extra 10 minutes of screen time on nights with screens, the sleep-wake cycle was shifted forward by approximately 30 minutes. Such phase delays are associated with increased risk of developing a sleep disorder (eg, Delayed Sleep-Wake Phase Disorder) among youths,[47] and the findings of this study suggest that further examination of the effects of additional in-bed screen time is warranted.

Our findings challenge the conventional belief that screen use before bed is always detrimental to sleep, with interactive screen activities and multitasking while in bed being associated with greater delays in sleep onset and reduced sleep duration compared with screen use in the hours before bedtime. These insights call for a reevaluation of sleep hygiene guidelines that currently discourage all screen use in the hour before bedtime.[4-6] A more nuanced approach that recognizes the low likelihood of adolescents fully disconnecting before bed[8,48] could focus on minimizing harm. This could include reducing or limiting interactive screen use during the in-bed period to align with the reality that screen time is a mainstay in adolescents' bedtime routines. Such pragmatic guidance could offer actionable strategies for health practitioners, parents, and adolescents to enhance sleep hygiene.

Strengths and Limitations

Our study has several strengths. To our knowledge, this appears to be the first study (and one that has used a reliable coding protocol) to objectively quantify passive, interactive, and multitasking screen activities and their timing across all devices to assess their varied associations with sleep outcomes in youths. We had objective measures of sleep via accelerometry and objectively measured screen time from getting into bed until shut-eye (the shut-eye latency period) using infrared night vision video cameras, a bedtime period often missed or mischaracterized in sleep research.[49,50] This approach revealed a high amount of screen time after getting into bed, which challenges the use of bedtime as a proxy for the start of attempting sleep in sleep assessments.[49] The sample was diverse in terms of gender and ethnicity, although parents were highly educated, which might limit generalizability. We had a high completion rate, with just 2 participants withdrawing and an additional 4 not having sufficient data. Importantly, our repeated-measures design and within-person analysis accounted for night-to-night variability, providing considerable advantages over studies that rely on between-person and aggregated data, which can introduce substantial confounding.[17]

Our study also has some limitations, principally around the labor-intensive manual coding of video data (total of 1080 hours). However, our intent was not to provide a simple tool for measuring screen time but rather to collect accurate data on varied types of screen time so that we could more clearly establish associations, if any, with sleep. While machine learning offers possibilities for more easily analyzing such video footage, these approaches to measuring screen time are still in their infancy,[22] and the detailed annotations from our already coded dataset provided an excellent starting point. Second, it is possible that participants altered their behavior because they knew they were being observed. However, the participants repeatedly told us that they quickly forgot about the cameras, and tests for reactivity revealed no differences in screen time, suggesting minimal behavioral modification. Finally, the age range was relatively narrow, representing an age group before significant shifts in chronotype (preference for evening or morning hours) become more pronounced.[51] We also cannot rule out the possibility of residual confounding.

Conclusion

In this cohort study, by using the accuracy of objective measures of both screen time and sleep and the power of a repeated-measures design, we found that screen time in the 2 hours before bed had no associations with most measures of sleep health that night in youths. However, screen time once in bed, particularly interactive screen activities, was associated with impaired sleep by clinically relevant amounts. The findings suggest that sleep hygiene guidelines restricting the use of screen media prior to sleep require clarification.

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