



CLINICAL REVIEW

Screen time and sleep among school-aged children and adolescents: A systematic literature review



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SUMMARY

We systematically examined and updated the scientific literature on the association between screen time (e.g., television, computers, video games, and mobile devices) and sleep outcomes among school-aged children and adolescents. We reviewed 67 studies published from 1999 to early 2014. We found that screen time is adversely associated with sleep outcomes (primarily shortened duration and delayed timing) in 90% of studies. Some of the results varied by type of screen exposure, age of participant, gender, and day of the week. While the evidence regarding the association between screen time and sleep is consistent, we discuss limitations of the current studies: 1) causal association not confirmed; 2) measurement error (of both screen time exposure and sleep measures); 3) limited data on simultaneous use of multiple screens, characteristics and content of screens used. Youth should be advised to limit or reduce screen time exposure, especially before or during bedtime hours to minimize any harmful effects of screen time on sleep and well-being. Future research should better account for the methodological limitations of the extant studies, and seek to better understand the magnitude and mechanisms of the association. These steps will help the development and implementation of policies or interventions related to screen time among youth.

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Introduction

Insufficient sleep, delayed sleep-wake behavior, and sleep disturbances are common among youth and adolescents around the world [1]. For example, the 2011 Sleep in America Poll [2] reported that about 60% of adolescents in the United States (US) receive less than eight hours of sleep on school nights, which has increased from 45% in the 2006 Sleep in America Poll [3]. In addition, 77% of adolescents reported having sleep problems, with waking up feeling un-refreshed (59%) and difficulty falling asleep (42%) most commonly reported [2].

A review article [4] describes how delays in bedtime among youth as they get older can be attributed to biological, psychosocial, and environmental causes. One of these environmental sources is the use of screen-based activities that often delay bedtime or truncate total sleep time (TST). Nearly all US adolescents (97%) have at least one electronic item (e.g., television, computer, mobile phone, video game console) in their bedroom [3]. With the ubiquitous presence of media items in an adolescent's bedroom, screen time is hypothesized to be a cause of insufficient and low quality sleep [5], operating through several mechanisms [5,6]. The first is

time displacement – with more time spent in front of screens, youth have less time available to sleep. Second, psychological and physiological arousal due to the content of the media [7] and social interaction may also interfere with the ability to fall and stay asleep. And finally, there is the effect of light on both circadian rhythm and alertness. The effect on circadian rhythm is mediated through physiological suppression of the sleep-promoting hormone melatonin through the bright light from screens [8] and in the bedroom [9]. A recent study found that self-luminous tablets (Apple iPads set to full brightness) caused statistically significant melatonin suppression after two hours of use, but not from only one hour [10]. Additional research has shown that light has an acute alerting effect in which the dose, exposure duration, timing and wavelength of light evokes an alerting response among humans [11].

Electronic media pervade modern life. In the US, school-aged children and adolescents spend around 7 h per day in front of a screen [12,13]. The consequences of excessive screen time on general health, physical activity, cognitive and social development have been addressed by numerous scholars [14–17]. The effects of screen time on sleep patterns and sleep quality are also actively being studied by researchers around the world, but these findings have not been compiled in a systematic literature review in over four years [5]. In this review, we concisely update the only known prior systematic literature review that summarized the literature on the

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associations between screen time exposure and a range of sleep outcomes [5]. Further we highlight limitations of the current studies, leading us to conclude with recommendations for further research.

Methods

We performed a systematic literature search in Web of Science for original scientific research publications about screen time and sleep. We used the following keywords to conduct our search “screen time AND sleep,” “media AND sleep,” “computer AND sleep,” “phone AND sleep,” “television AND sleep,” and “video game AND sleep.” On February, 24, 2014, 557 abstracts were returned. All were reviewed as to whether they met the inclusion/exclusion criteria discussed below. Additional searches in PubMed, Google Scholar, and various journals identified articles not duplicated in the original search. We also examined the cited literature in the included articles, and contacted three sleep experts to identify any missing articles. Two of the three experts responded and helped us identify nine additional articles. Based on these sources and after exclusions described below, the total number of original research articles included in the study is 67 [18–84]. Fig. 1 provides a flow chart of the studies included.

Inclusion and exclusion criteria

We include all studies that investigate the association between any type of screen time and any of the following sleep outcomes: sleep timing, sleep duration, sleep quality, sleep onset latency (SOL), subjective assessment of daytime tiredness or daytime

sleepiness, or other reported outcomes including subjective assessment of insomnia symptoms. In order to be consistent with the prior literature review [5], we narrowed the articles down to include any study that contained participants that were primarily between five and 17 years old. We did not limit the population to any geographical area or gender. When data from the same cohort were presented in more than one study, we included only the most relevant article. We divided studies into type of media included (e.g., television, computer, mobile phone, video gaming device), allowing each study to be categorized in more than one media type, if appropriate.

This project updates a 2010 literature review [5] that used similar inclusion criteria. In the four years since publication of that paper, we found 31 additional articles meeting the inclusion criteria. All articles that fit the above criteria, including those in the 2010 review, are included in this review (See Table 1).

Results

Table 1 provides an overview of the first author, publication year, and basic characteristics of all 67 articles included. Studies represent populations from around the world – most studies include samples from only one country and four studies cover multiple European countries at once. Over 40% (27 studies) of the samples used European populations. Twenty-one percent (14 studies) used US samples, 10% (seven studies) used Japanese samples, and 7% (five studies) relied upon Australian samples. The remaining studies included participants from Brazil, Canada, China, Israel, New Zealand, Saudi Arabia, and Taiwan.

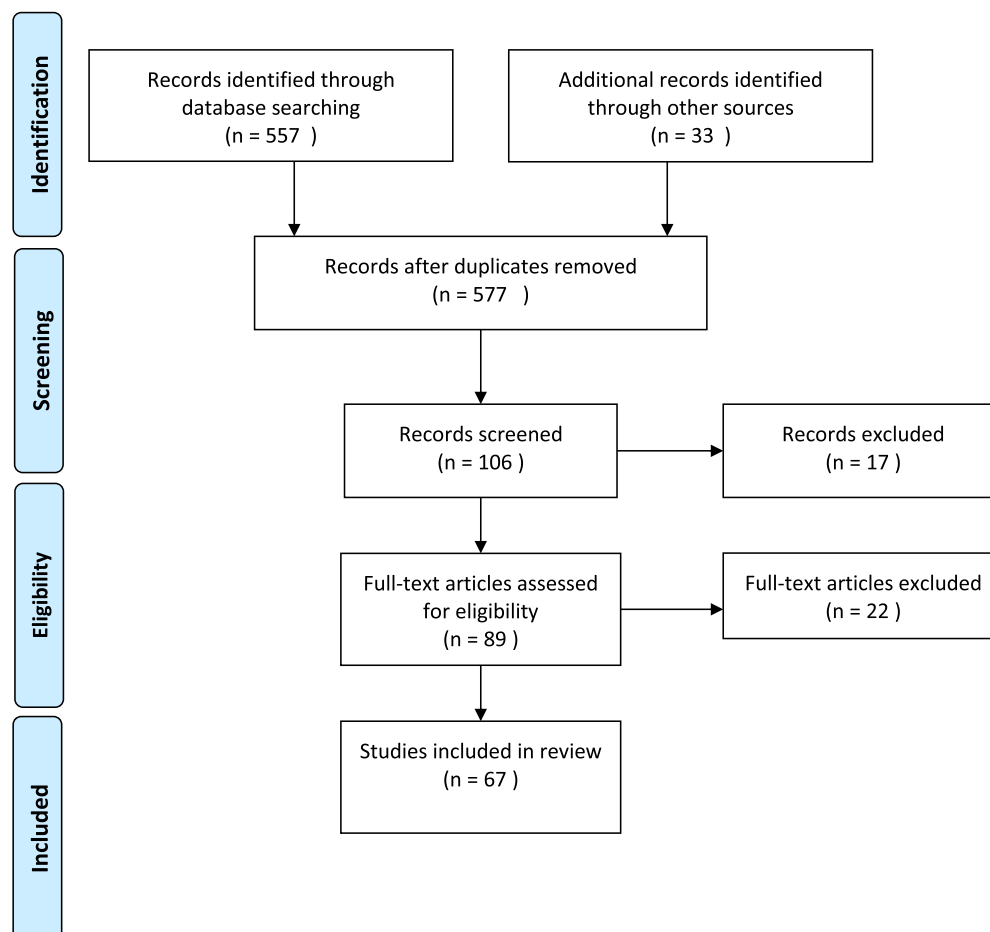


Fig. 1. Flow diagram.

Table 1
Summary of all studies that meet the inclusion criteria.

First author	Year	Region	Sample size	Age range (in years unless marked otherwise)	Type of study
Abe [18]	2010	Japan	1934	7th–9th grade	Cross-sectional
Adam [19]	2007	US	2454	5–19	Prospective (two random day)
Arora [20]	2013	UK	632	11–13	Cross-sectional
Arora [21]	2013	UK	738	11–18	Cross-sectional
BaHammam [22]	2006	Saudi Arabia	1012	5–13	Cross-sectional
Barlett [23]	2011	US	1317		Prospective (13 mo)
Calamaro [24]	2012	US	625	6–10	Cross-sectional
Calamaro [25]	2009	US	100	12–18	Cross-sectional
Cameron [26]	2012	Europe	7234	10–12	Cross-sectional
Cespedes [27]	2014	US	1864	6 mo (mean age at baseline followed annually); 3.2; 7.9	Prospective (7 y)
Chahal [28]	2012	Canada	3398	10–11	Cross-sectional
Chen [29]	2006	Taiwan	656	13–18	Cross-sectional
de Jong [30]	2013	Netherlands	4072	4–13	Cross-sectional
Do [31]	2013	South Korea	136,589	13–18	Cross-sectional
Drescher [32]	2011	US	319	10–17	Cross-sectional
Dworak [33]	2007	Germany	11 ^a	12–14	Cross-sectional
Eggermont [34]	2006	Belgium	2546	Mean ages 13.2 and 16.4 for 2 grade levels	Cross-sectional
Engelhardt [35]	2013	US	128 ^a	11–12	Cross-sectional
Foley [36]	2013	New Zealand	2017	5–18	Cross-sectional
Fuligni [37]	2005	US	750	14–15	Prospective (2 wk)
Gaina [38]	2006	Japan	9718	Mean age 12.8	Cross-sectional
Gaina [39]	2005	Japan	699	12–15	Cross-sectional
Garaulet [40]	2011	Europe	3311	12–18	Cross-sectional
Garmy [41]	2012	Sweden	3011	6–16	Cross-sectional
Harada [42]	2002	Japan		13–15; 18–25	Cross-sectional
Heins [43]	2007	Germany	1933	8–12	Cross-sectional
Hense [44]	2011	Europe	8543	2–9	Cross-sectional
Hitze [45]	2009	Germany	414	6–19	Cross-sectional
Ivarsson [47]	2013	Sweden	30	13–16	Cross-sectional
Ivarsson [46]	2009	Sweden	19 ^a	12–15	Trial
Johnson [48]	2004	US	759	14–22	Prospective
King [49]	2014	Australia	1287	12–18	Cross-sectional
King [50]	2013	Australia	17	15–17	Trial
Kubiszewski [51]	2013	France	332	Mean age 12.9	Prospective (8 d)
Lemola [52]	2011	Europe	190	13–17 (subset, max age is 30)	Cross-sectional
Li [53]	2010	China	20,778	5–12	Cross-sectional
Li [54]	2007	China	19,299	5–12	Cross-sectional
Magee [55]	2014	Australia	3427	4–8	Prospective (three waves, 5 y)
McKnight-Eily [56]	2011	US	12,154	14–18	Cross-sectional
Mesquita [57]	2007	Brazil	160	15–18	Cross-sectional
Mindell [58]	2009	US	1473	0–10	Cross-sectional
Mistry [59]	2007	US	3000+	0–5	Prospective (5.5 y)
Munezawa [60]	2011	Japan	95,680	13–18	Cross-sectional
Nathan [61]	2013	US	202	14–19	Cross-sectional
Nixon [62]	2008	New Zealand	591	7	Prospective (unclear how long)
Nuutinen [63]	2013	Finland	353	10–11	Prospective (18 mo)
Oka [64]	2008	Japan	509	6–12	Cross-sectional
Olds [65]	2012	Australia	2200	9–16	Cross-sectional
Ortega [66]	2010	Spain	2179	13–18.5	Cross-sectional
Owens [67]	1999	US	495	5–10	Cross-sectional
Paavonen [68]	2005	Finland	321	5–6	Cross-sectional
Padez [69]	2009	Portugal	4511	7–9	Cross-sectional
Punamaki [70]	2007	Finland	7292	12–18	Cross-sectional
Saarenpaa [71]	2001	Finland	582	9–17	Prospective (three waves, 3 y)
Seo [72]	2010	South Korea	3639	7–12	Cross-sectional
Shochat [73]	2010	Israel	470	Mean age 14	Cross-sectional
Soderqvist [74]	2008	Sweden	2000	15–19	Cross-sectional
Tazawa [75]	2001	Japan	1143	6–11	Cross-sectional
Thorleifsdottir [76]	2002	Iceland	668	1–20	Prospective (10 y)
Van den Bulck [77]	2007	Belgium	1656	13–16	Prospective (1 y)
Van den Bulck [78]	2004	Belgium	2546	13–16	Cross-sectional
Van den Bulck [79]	2003	Belgium	2546	13–16	Cross-sectional
Vazquez [80]	2008	Spain	103	9–10.5	Cross-sectional
Wallenius [81]	2009	Finland	4085	12–18	Cross-sectional
Weaver [82]	2010	Australia	13 ^a	14–18	Trial
Yen [83]	2008	Taiwan	8004	12–18	Cross-sectional
Zhou [84]	2012	China	1221	12–17	Cross-sectional

^a Males only.

Table 2
Summary of studies and their findings by sleep outcomes stratified by five definitions of screen time.

First author	STB	Sleep outcomes					
		TST	DBT	Quality	SOL	DT	Other
2a. Television screen time and sleep outcomes							
Abe [18]	No		+				*
Adam [19]	No	X	+				
Arora [20]	Yes	–					*
Arora [21]	Yes	–					
BaHammam [22]	Yes	–					
Calamaro [24]	No	0					
Calamaro [25]	Yes	0					
Cameron [26]	No	0					
Cespedes [27]	No	–					
Chahal [28]	Yes	–					
Chen [29]	No					0	
de Jong [30]	No	–					
Dworak [33]	No				0		
Eggermont [34]	Yes	–	X				+
Engelhardt [35]	No	0					
Fuligni [37]	No	0					
Gaina [38]	No				+		
Gaina [39]	No				0		
Garulet [40]	No	–					
Garmy [41]	No	–					
Heins [43]	No		+				
Johnson [48]	No						*
Li [53]	Both	–					
Li [54]	No	0	+		+	+	*
McKnight-Eily [56]	No	X					
Mindell [58]	No	–			0		*
Mistry [59]	No						
Nixon [62]	No	0					
Nuutinen [63]	No	X	X				
Oka [64]	Yes	0	X				
Ortega [66]	No	X					X
Owens [67]	Both	0			+	0	*
Paavonen [68]	No	–					
Padez [69]	No	–					
Saarenpaa [71]	No						*
Seo [72]	No	–					
Shochat [73]	Both	–	+		+		
Soderqvist [74]	No					0	
Tazawa [75]	No						*
Thorleifsdottir [76]	Both	X	+				
Van den Bulck [78]	Both	X	+				
Zhou [84]	Both						*
2b. Computer screen time and sleep outcomes							
Adam [19]	No	X	+				
Arora [20]	Yes	–					*
Arora [21]	Yes	–					
BaHammam [22]	Yes	–					
Calamaro [25]	Yes	–					
Chahal [28]	Yes	–					
Chen [29]	No					0	
de Jong [30]	No	–					
Do [31]	No	–					
Dworak [33]	No				+		
Eggermont [34]	Yes	–	X				+
Engelhardt [35]	No	–					
Fuligni [37]	No	–					
Gaina [39]	No				0		
Garmy [41]	No	–					
Heins [43]	No		+				*
King [49]	No	–	+		+		
Lemola [52]	Yes	–				+	
Li [54]	Both	–					*
Li [53]	No	–	X				
McKnight-Eily [56]	No	–					
Mesquita [57]	Yes	–			0	0	
Nuutinen [63]	No	–	+				
Oka [64]	Yes	X	+				
Punamaki [70]	No	–					*
Seo [72]	No	–					
Shochat [73]	Both	–	+		0		

Table 2 (continued)

First author	STB	Sleep outcomes					
		TST	DBT	Quality	SOL	DT	Other
Van den Bulck [78]	Both	X	+				
Wallenius [81]	No						+
Yen [83]	No	–					
Zhou [84]	Both						*
2c. Video game screen time and sleep outcomes							
Abe [18]	No		0				
Adam [19]	No	X	+				
Arora [20]	Yes	–				+	*
Arora [21]	Yes	–					
Chahal [28]	Yes	0					
Engelhardt [35]	No	–					
Gaina [38]	No					+	
Heins [43]	No		+				
Ivarsson [47]	Yes	0	0	–	0	0	
Ivarsson [46]	Yes	0	0	0	0	0	
King [49]	No	–	+				*
King [50]	Yes	–		0	+		
Lemola [52]	No	–				+	
Nuutinen [63]	No	–	+				
Oka [64]	No	–	+				
Punamaki [70]	No						*
Shochat [73]	Both	–	+			0	
Tazawa [75]	No						*
Van den Bulck [78]	Both	X	+				
Wallenius [81]	No						+
Weaver [82]	Yes					+	
2d. Mobile devices and sleep outcomes							
Arora [20]	Yes	–					
Arora [21]	Yes	–					*
Calamaro [24]	No	–					
Calamaro [25]	Yes	–					
Chahal [28]	Yes	0					
Gaina [39]	No					0	
Harada [42]	Both	–					*
Heins [43]	No		+				
King [49]	No	–	+			+	*
Kubiszewski [51]	Both		+				+
Munezawa [60]	Yes	–		–			+
Nathan [61]	Both						+
Oka [64]	Yes	X	+				*
Punamaki [70]	No						*
Soderqvist [74]	No						0
Van den Bulck [79]	Both						+
Van den Bulck [77]	Both						+
Yen [83]	No	0					0
2e. Unspecified screen time and sleep outcomes							
Barlett [23]	Both	–					
Calamaro [24]	No	–					
Drescher [32]	No	X					
Foley [36]	No					+	
Hense [44]	No	0					
Hitze [45]	No	–					
King [49]	No	–	+				*
Kubiszewski [51]	Both						*
Magee [55]	No	–					
Olds [65]	No	–	+				
Vazquez [80]	No	–					

Note: STB – Whether screen time is measured at bedtime ('Both' indicating nighttime as well as general measurement); TST – Duration of sleep; DBT – Delayed bedtime; SOL – Sleep onset latency; DT – subjective assessment of daytime tiredness or daytime sleepiness; (0) – No association; (+) – Significant positive association; (–) – Significant negative association; (X) – Significant interaction. Other: Includes other sleep outcomes such as nighttime awakenings, subjective assessment of insomnia symptoms, irregular sleep, as well as researcher-defined sleep outcomes. **p* < 0.05.

Table 2a–e divide the studies into screen type: 42 involved television media, 31 involved computer screens, 21 involved video game screens and 16 involved mobile device screens. There were 11 articles that categorized multiple types of screen into a single measure of screen time.

Television watching and sleep

Table 2a summarizes the studies involving television screens and television watching at bedtime; 32 out of 42 studies (76%) found an adverse association between television watching and adverse sleep outcomes, whereas 10 found no association.

Among the 32 articles that investigated the association between television watching and delayed bedtime or TST, 25 studies (78%) found that television watching was associated with significantly delayed bedtime or shortened TST. For studies that reported a significant negative association between television watching and sleep duration, higher levels of television screen watching was associated with either a larger effect size for shortened total sleep time or higher odds of short sleep duration.

Some of the studies had results with statistically significant associations between television and sleep only when stratified by certain variables. For example, television watching was associated with shorter sleep duration on weekdays compared to weekends [53,63,78]. Other studies found that older adolescents were more likely to have associations between television and later bedtimes compared to younger children [19,76]. Finally, male study participants were, in some studies, more likely than females to show an association between television watching and shorter sleep duration [56,66].

Of the studies that we coded as not reporting a significant association between television watching and TST, there are nuances worth discussing. Two studies [24,25] observed that television watching alone was not sufficient to significantly impact sleep (however, use of multiple screens did have a significant negative association with TST). One study [26] found that sleep duration did not mediate the association between the presence of a television in a bedroom and body weight. Another study [37] did not find an association between television watching and TST across individuals, but reported a positive daily-level association between these two measures within individual adolescents. The study author observed that adolescents watched more television on days where they studied less and were less stressed. These results were derived from a 14-d daily diary which is the longest daily diary prospective study that we catalogued (other studies that utilized a daily diary often used a 2-d daily diary or asked about sleep on a weekday and weekend (e.g., [72])).

Some studies found that television presence in the bedroom was associated with less sleep, even when reported use of television was not associated with less sleep [35,67]. The only study that relied upon objectively measured TST (using actigraphy) did not report a significant association between television watching and TST [62]. The lack of association in this study raises questions about the quality of self-reported and parental-reported sleep data.

Studies that estimated the magnitude of lost sleep time observed bedtime delays within the range of 5–10 min per hour of television watching [19,27,28]. These magnitudes can add up when one considers the total number of hours youth spend in front of a television [12,13]. Two separate studies, by the same lead author but on different samples, simply measured whether television watching occurred at bedtime (as a yes/no variable), and both found about a 20 min delay in sleep time [20,21].

The evidence for an association between television use and sleep onset latency (SOL) is equivocal: four of the seven studies that examined SOL found a significant association between television use and later sleep onset, while the other three studies reported no finding [33,39,58]. Several studies found an association between television watching and subjective assessment of daytime tiredness [34,54,66], while one study found no association [51]. Twelve studies included other measures of sleep outcomes and 75% of the studies found significant associations.

Computer use and sleep

Table 2b includes only the studies involving computer use. Twenty-nine out of 31 studies (94%) found an association between computer use and at least one of the sleep outcomes, while two found no association.

Our literature search yielded 24 scientific articles that specifically analyzed computer use and TST. All studies show shortened TST with computer use. In one study, the magnitude is 0.86 h (or 51 min) less TST for teens that report usually or always using the internet for social reasons at bedtime [20] than for teens who do not report using the internet at bedtime.

All of the nine studies that looked at delayed bedtime found that youth who use more computer screen time go to bed later. Five of the six studies (83%) that looked at sleep problems found that computer use predicted other sleep problems [20,33,51,83,84], whereas one study [52] did not find an association between computer use and other sleep problems. While no studies reported on the analysis of the association between computer use and general sleep quality specifically, three studies [34,52,81] (75% of 4) reported a significant association with subjective assessment of daytime tiredness or daytime sleepiness and only two out of five studies [33,49] reported a significant association with SOL. We also found that five out of the six studies that looked at “other” sleep outcomes found a significant association with computer use [20,43,54,70,84].

Comparing studies on computer use and sleep is difficult given the wide range of definitions and questions asked about computer time – for example, some asked about whether the computer was used for social networking, leisure, studying, or video gaming, while other studies grouped all computer use together. Nine of the studies specifically studied computer use at bed time [20–22,25,28,34,52,57,64], four of the studies asked about both daytime and bedtime use [53,73,78,84] and the remaining did not differentiate between timing of computer use.

Video gaming and sleep

Table 2c presents studies involving video game use. Among these, 18 out of 21 studies (86%) found an association between video games use and sleep patterns, while three found no association. All studies described in this section were included if study authors mentioned some form of screen-based game playing—which will henceforth be referred to as “video gaming.”

Among the 16 articles that examined video gaming and TST or delayed bedtime, 13 articles (81%) reported either a significant negative association with TST or a positive association with delayed bedtime. In several studies, significant results were moderated by age and day of the week. In one study, older study participants were more likely to have video game playing associated with later bedtimes [19]. In two studies, weekend video gaming was more likely to be associated with shorter sleep duration whereas this did not hold for weekday game playing [19,64]. Some studies estimated the magnitude of the sleep delay associated with bedtime video gaming as up to 28 min [20,21,28].

Of the three null findings: one study categorized video gaming as time spent at a game center/arcade [18], which is the only unconventional description of video gaming listed among these studies; and two studies examined low video game use as the unexposed group compared to high video game use [46,47], rather than comparing the high video game use to a no-use reference category.

For the outcomes of SOL and subjective assessment of daytime tiredness or daytime sleepiness, four out of seven studies (57%) reported a significant positive association between video gaming and higher SOL, while the two studies that looked at subjective assessment of daytime tiredness or daytime sleepiness found a significant

positive association with video gaming. Only three studies looked specifically at sleep quality: one found a significant negative association between video gaming and sleep quality [47], whereas two found no significant association [46,50]. Of the five studies that looked at other sleep outcomes, all of them found statistically significant associations with video gaming [19,20,49,51,75].

Mobile devices and sleep

Table 2d summarizes the studies involving mobile devices; among which 15 out of 18 studies (83%) found an association between mobile device use and at least one sleep outcome, while three studies found no association.

Of the 12 looking at TST or delayed bedtime, 10 (83%) found a statistically significant association between either shortened TST or delayed bedtime. Of the studies that estimated the amount to which sleep duration was shortened, one study of UK adolescents found that cell phone use at bedtime shortened sleep by 21 min [21] and another found that among pre-teens from the UK, usually using a mobile device at bedtime was associated with a shortened sleep duration of around 45 min [20]. Two studies failed to find the association between mobile phone use and sleep duration. The first collected data from Taiwanese adolescents and found that “problematic cell phone use” did not predict short sleep duration at the $p < 0.05$ level, but the odds ratio (OR = 1.295, 95% CI 0.99–1.694) shows that the magnitude was reasonably large and was very close to reaching that level of significance [83]. The second study [28] found no significant association between use of a phone to chat or text at nighttime with sleep duration, but they did find a significant negative association between having a cellular phone (or other handheld communication device) in the student’s bedroom and TST. Two other studies that measured presence of a cell phone but did not measure its use found a significant association between having a cell phone in the bedroom and adverse sleep outcomes [24,43]. These and other findings on the effects of ownership or presence of devices are not included in the tables because we wanted to focus on use of the devices.

Two studies estimated the association between mobile phone use and SOL with one finding a positive association [49] and one finding no association [39]. This second study analyzed both mobile phone use ownership and SOL in a sample of Japanese schoolchildren in 2004 [39]. Given that mobile technology in 2004 was significantly different from the capabilities of modern smartphone technologies, there may be major differences in the impacts of mobile technologies on sleep between then and now. We speculate that this change in the technology utilization patterns over time may account for the differential in findings between the two studies.

Only one study investigated mobile phone use and sleep quality, and it found a negative association [60]. All five studies that investigated mobile phone use and subjective assessment of daytime tiredness or daytime sleepiness found an adverse association [51,60,61,77,79]. There were eight studies that looked at mobile devices and other sleep outcomes, of which six found significant associations [21,42,49,51,60,70], whereas two studies found no associations [74,83].

Unspecified screen time and sleep

Table 2e lists the 11 articles that clustered multiple types of screens into a single measure of screen time, which we term unspecified screen time. 91% of these found an adverse association between unspecified screen time and at least one of the sleep outcomes. All studies described in this section were included if study authors used an aggregate category of screen time and did not stratify by type of screen. Thus, while this category describes use of multiple screens, usage may not necessarily be simultaneous.

Among the nine articles that examined aggregate screen time and TST, eight articles (89%) reported a significant negative association with TST. Reported effect sizes range up to 45 min if multiple screens are present in a child’s bedroom [24]. One study [32] reported differential results by age group, where younger children under 13 y of age were more likely to have aggregate screen time associated with shorter sleep duration than older children, a finding in contrast to the stronger effects found among older teens for television viewing [19,76]. The study that reported a null finding [44] cited a limitation in aggregating screen time into one category.

Of the two remaining studies, one study [51] investigated screen time of middle-school aged children and found that evening screen time of one hour or more was associated with a 3.4-fold increased risk ($p < 0.01$) of going to bed at 22:00 h or later. One other study [36] reported a significant association between aggregate screen use and later sleep onset.

Summary and limitations

Across all types of screens, we found that 90% of published studies show a significant adverse association with at least one of the measured sleep outcomes. Computer use (94% of studies), unspecified screen time (91% of studies), video games (86%), and mobile devices (83%) were most consistently observed to be associated with adverse sleep outcomes. The screen category that was least likely to have an adverse association with sleep outcomes was television use (76% of studies). This ranking is consistent with work hypothesizing that interactive screen time like computer use is more detrimental to sleep than passive screen time like television watching [82,85].

Despite these relatively strong and consistent results, we encountered numerous methodological challenges and limitations of all of the studies, as summarized below. A primary concern is that with the wide range of study populations, measurement challenges, and model specifications, there is a limited ability to harmonize the results and provide the magnitude and clinical significance of the association between screen time and sleep. Further, we have concerns about publication bias, in that scholars and journal editors often prioritize studies that show “significant” results rather than those presenting negative findings [86].

Causality difficult to ascertain

Given the use of observational data to study population behavioral patterns that occur among real-life children and adolescents, all but the three smallest of these studies [46,50,82] lack an experimental design in which one group is randomly assigned into a screen time exposure group while the other one has no screen time. As a result, while the rest of the studies provide a relatively good portrait of the screen time and sleep behaviors of youth, along with how these behaviors are associated statistically with each other in real populations, they do not provide enough data to confirm whether the association is causally linked.

There are several ways in which the observed associations may not indicate a causal impact of screen time on sleep outcomes. First, reverse causality might occur because youth who need less sleep or have trouble sleeping for other reasons choose to spend their time in front of more screens simply because they have more time to do so [34]. Further, there could be other confounding factors that are associated with both increased screen time and decreased sleep duration that suggest a spurious association. Examples of such potential confounding factors include having low physical activity and being overweight. However, there are ways to improve the likelihood of a causal link using observational data. The first is to have the measure of exposure (screen time) precede the

measurement of the outcome (sleep), such as using a daily diary over multiple days, as was done in only nine of the 67 studies [19,33,37,46,50,51,55,72,82]. This allows for screen time to be measured the day or night before sleep time and address some key issues of reverse causality. Another advisable approach to address causality is to adjust for as many potentially confounding variables as possible, provided the sample size allows for it. While most studies adjusted for basic covariates such as age and gender, several studies did an excellent job of adjusting for a wide range of characteristics including family structure [53], family income [53], sleep environment, physical activity, bedtime routine, and child health, among other variables [20,21]. Another approach would be to test for within-individual differences on nights when they do and do not have exposure to screen time, as was done in one study [37]. The gold standard would be to test the effects of an intervention or experiment that reduces screen time through random assignment as was done in the three trials included in our review [46,50,82].

Measurement error

The vast majority of the included studies (99%) rely upon either self-report or parental report for both the exposure and the outcome variables. Unfortunately, there has been very little research validating measures of self-reported and parent-reported screen time among youth. In addition, the sleep outcomes are also vulnerable to misreporting among teenagers, especially on more complicated concepts such as TST, night wakings, and SOL. For example, teenagers tend to overreport their total sleep time compared to actigraphic or daily diary measures of sleep [87]. One study [88] found that both adolescents and parents vastly underreported the presence of a sleep problem with accurate identification in only 33% and 17% of cases, respectively. Similarly, among school-aged children, a comparison of actigraphy data with parental report shows differing results, especially with regard to sleep quality measures [89]. In general, measurement error leads to attenuated associations [90]. Thus reducing measurement error in these studies will likely lead to a stronger and truer reflection of the association between screen time and sleep.

Limited assessment of simultaneous screen exposure and other characteristics and content of screens

While the vast majority of studies show an association between screen time and sleep outcomes, the measure of screen exposure varies by nature of the question. About 37% of the studies asked specifically about screen exposure in the hours before bedtime while the others asked for a more general use. Another limitation is that only one of the studies addressed whether multiple screens were being watched at once [25], and none investigated potentially important characteristics of the screens (i.e., size of screen, closeness to face, volume of device, etc.). Recent evidence [91] from an international survey of internet users reveals that nearly half of evening television watchers are also simultaneously engaged with other types of screens, such as a mobile device or computer. This trend of “screen-stacking” is expected to increase given the rapid growth of mobile technology. Content of the programming and interactivity of the user is also a topic that is understudied and requires further research. Understanding the characteristics of the screen utilization patterns that are most disruptive to sleep would be useful for developing policies and interventions that might minimize interference with wellbeing.

Technological changes happening rapidly

Finally given the rapidly changing screen-based technologies and utilization of devices, research on the effects of screen time on

sleep will likely be outpaced by the adoption of novel devices. This creates an even more urgent need to remain current on the latest technologies and their social, physical, and sleep consequences.

Conclusions

Despite the above limitations, given the large number of studies with consistent findings, we report that there is a significant association between screen time and reduced sleep duration and increased sleep problems, across a range of screen types and sleep outcomes in 90% of the studies. Future research should seek to better quantify and harmonize these findings so scholars have a better sense of the magnitude and clinical significance of the observed associations. While the research on understanding the causal link between screen time and sleep will need to be better addressed, it is important for parents, educators, policy makers, and scholars to work on designing, implementing, and evaluating messages and interventions that might reduce harmful forms and timing of screen exposure and analyzing the consequences for sleep and wellbeing for children and adolescents.

Practice points

- 1) Screen-based technologies are ubiquitous among modern youth and frequently used at bedtime; 90% of studies show an adverse association between screen time and sleep.
- 2) Youth should be advised to limit or reduce screen time exposure, especially before or during bedtime hours to minimize any harmful effects of screen time on sleep and well-being.
- 3) Current studies have various methodological limitations but the results are consistent across a wide range of studies from around the world.
- 4) Screen-based technologies and their utilization patterns are changing rapidly and require close attention to their lasting impacts on sleep and wellbeing.

Research agenda

- 1) This review documents the widely observed association between screen time and sleep; future emphasis should focus on the strength of this association and the clinical significance of the magnitude.
- 2) Research needs to better address the causal pathways between screen time and sleep.
- 3) Research should seek to replicate studies using more objective measures of both screen time and sleep; and when possible account for potentially important characteristics of screen time (i.e., timing, duration, screen size, volume, closeness to face, content) that can lead to behavioral changes.
- 4) The types and utilization patterns of screen-based technologies are rapidly changing, requiring ongoing monitoring and assessment of the potential impacts on youth behaviors.
- 5) Future research should develop and measure the impacts of public health messaging and interventions that seek to reduce youth screen time and their potential consequence on sleep, health, and wellbeing.

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