

Digital screen time and pediatric sleep: Evidence from a preregistered cohort study

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Abstract

Objectives

The rise of digital screens has driven concerns their use might have deleterious impacts on the quality and duration of pediatric sleep. Existing research identifies mixed results for technology displacing sleep yet no research to date has examined the effects through a confirmatory research lens. The objective of this study was to determine the extent to which time spent with digital devices predict meaningful variability in pediatric sleep.

Methods

Following a preregistered analysis plan, data from a sample of American children ($n = 50,212$) derived from the 2016 National Survey of Children's Health (NSCH) were analyzed. Models adjusted for child-, caregiver-, household-, and community-level covariates to estimate the potential effects of digital screen use.

Results

Each hour devoted to digital screens was associated with three to eight fewer minutes of nightly sleep and significantly lower levels of sleep consistency. Further, those below American Academy of Pediatrics guidance reported between 20 and 26 more minutes of nightly sleep.

Conclusions

Links between digital screen time and pediatric sleep outcomes were modest, accounting for less than 1.9% of observed variability in sleep outcomes. The findings provide an empirically robust template for those investigating the digital displacement hypothesis as well as informing policy-making.

Digital screen time and pediatric sleep: Evidence from a preregistered cohort study

Digital screens are now regularly used by children of all ages [1,2], and the fact that young people spend an increasing share of their time using tablets, smartphones, and playing electronic games [3] has given caregivers [4] and health professionals reason to express concerns that these digital activities might have deleterious impacts on pediatric health [5]. A literature testing the *digital displacement hypothesis*, a proposition that time spent with digital devices supplants important analogue developmental opportunities [6,7], attempts to address these concerns. Exploratory studies suggest there may indeed be relations between screen time and child and family factors [8], including age [9], body mass [10], and ethnicity [11], and there is mixed evidence suggesting that well-being [12], caregiver's education [13,14], and household income are consistently linked [15]. Informed by research on television [6], the American Academy of Pediatrics (AAP) has issued a number of policy statements regarding digital screen time, first advising children under two against any screen use and counselled restricting older children to fewer than two hours each day [16]. More recently, the AAP has advised caregivers limit young children to an hour of “high-quality” screen time each day, and encouraged pediatricians discuss screen-based media and counsel families to minimize screen exposure [17].

The relations between technology and sleep are increasingly discussed as research indicates that between 50% and 90% of school-aged children might not be getting enough quality sleep [18]. Digital screens are frequently used, ineffectively, as sleep aids possibly delaying sleep onset [19,20]. One systematic review showed screen use was unrelated to sleep in 15 cases, indirectly linked by way of intervening factors in 13 cases, and negatively correlated in 59 cases [19]. Results from longitudinal studies hint at a reciprocal relationship between screen use and sleep [21,22]; those unable to sleep gravitate to screens and then report lower sleep quality and duration [23]. Evaluations of *South Korea's Shutdown Law*, a statute that disables access to online games from 12:00 am to 6:00 am, suggest that

interventions based on the digital displacement hypothesis are largely ineffective. Two independent analyses of this nation-wide natural experiment showed it saved children an average of only two minutes of sleep each night [24,25].

Present Research

Importantly, all of the studies investigating technology and pediatric sleep do so through an exploratory lens, that is, the sampling and analysis plans are finalized after the data are collected [26]. Given the policy importance [27], caregivers' struggles with limits [28], and evidence that technological interventions are ineffective at bolstering sleep [25], it is critically important to know if the digital displacement hypothesis, in its simplest form, holds up to stringent hypothesis testing [26]. In line with a preregistered analysis plan, three a priori hypotheses were tested. First, it was predicted that digital screen time would be negatively correlated with sleep consistency. Second, it was hypothesized that digital screen time would be negatively correlated with sleep duration. Finally, it was expected that children whose caregivers follow the AAP guidance on digital screen time would sleep better as compared to those whose caregivers did not follow the AAP guidance.

Methods

Participants

The data analyzed were derived from self-report surveys completed by caregivers living in the United States (US) collected as part of the 2016 National Survey of Children's Health (NSCH). Conducted on behalf of the US Department of Health and Human Services, Health Resources and Services Administration's Maternal and Child Health Bureau, the NSCH uses an address-based sampling frame and was used both web-based and mailed paper data collection instruments fielded by the US Census Bureau [29]. Fieldwork was conducted between June 2016 and February 2017, and the data collected reflected a nationally represented sample of young people living in all 50 states and the District of

Columbia. State-level responses ranged from a low of 638 (Missouri) to a high of 1,351 (Minnesota). Caregivers spent an average of 35 minutes completing either a paper questionnaire (9,719, 19.4%) or the online instrument (40,493, 80.6%) to answer questions about themselves, households, and children ranging in age from 6 months to 17 years. The sample was evenly divided between male ($n = 25,733$, 51.2%) and female ($n = 24,479$, 48.8%) children. Ethical review was conducted by The US Department of Health and Human Services and all study data, code, and materials in this study are available for download using the Open Science Framework (https://osf.io/4czmd/?view_only=52c39589b21343a3b3832047b89b82d7).

Outcome Variables

Sleep consistency. Caregivers were asked to estimate regularly their slept by providing a response to a single question: “*How often does [your child] go to bed at about the same time on weeknights?*” using a five-point scale ranging from: 1 = “*Always,*” 2 = “*Usually,*” 3 = “*Sometimes,*” 4 = “*Rarely,*” to 5 = “*Never*”. Nearly all (99.0%, $n = 49,731$) caregivers responded with usable data. Three in ten children (31.5%, $n = 15,674$) always got to bed at the same time each night and six in ten usually did so (58.4%, $n = 29,034$). The remaining caregivers reported their children sometimes, rarely, or never went to sleep at a regular time (10.1%, $n = 5,023$).

Sleep duration. Caregivers were asked to estimate children’s typical sleep duration over a 24-hour period by answering one of two questions depending on the age of their child. For those aged six months to five years old caregivers were asked: “*DURING THE PAST WEEK, how many hours of sleep did [child name] get on an average day (count both nighttime sleep and naps)?*” and used a 1 = “*Less than 7 hours*” to 7 = “*12 or more hours*” response scale. Caregivers of children aged six years and older were asked: “*DURING THE PAST WEEK, how many hours of sleep did [child name] get on an average weeknight?*” using a 1 = “*Less than 6 hours*” to 7 = “*11 or more hours*” scale. Nearly all caregivers of

children below (99.1%, $n = 14,366$) and those at or above (97.7%, $n = 34,909$) 6 years of age responded. Those under the age of six slept for an average of 11 hrs ($SD = 1\text{ hr } 19\text{ min}$) and older children slept for an average of 8 hours ($SD = 1\text{ hr } 9\text{ min}$).

Explanatory Variable

Digital screen time. Caregivers also estimated their child's daily digital screen time with two questions: "*On an average weekday, about how much time does [your child] usually spend with computers, cell phones, handheld video games, and other electronic devices?*" and "*On an average weekday, about how much time does [child name] usually spend in front of a TV watching TV programs, videos, or playing video games?*" Nearly all (99.2%, $n = 49,816$) caregivers responded and responses were summed for individual screen time estimates. Children spent on average about three hours ($M = 3\text{ hr } 4\text{ min}$, $SD = 2\text{ hr } 3\text{ min}$) with digital screens each day and these scores were used to code participants in line with both 2010 and revised 2016 AAP guidance for those aged 2 to 5 years. Two in five children (44.4%, $n = 4,581$) were under the older two-hour AAP guidance and one in ten children (11.9%, $n = 1,225$) were under the revised one-hour AAP guidance.

Control Variables

Because previous research suggests that digital screen time and sleep may be correlated with child-, family-, and community-level variables, a series of control variables were included in hypothesis testing models detailed in the analysis plan. Adjusting for the confounding influence of these factors serves to disambiguate the effects of technology from other factors on the basis of the existing literature [7,30,31]. Child-level variables included age and gender, white or non-white race/ethnicity, presence of major life stressors, social support, and general health. Family-level variables included whether or not caregivers had completed secondary school, family adjustment, whether the family was able to get by financially, whether the family could afford food, and whether they received government assistance. Finally,

community-level variables including neighborhood conditions, affordances for outdoor activities, cohesion, and social support.

Results

Preliminary Analyses

A visual inspection of the sleep and digital screen time trends (see Figure 1) indicated digital screen time increases monotonically from six months (28 min) to fifteen years of age (4h 17min), whereas sleep duration decreases monotonically from six months (11hr 20min) to sixteen years of age (7hr 7min). Zero-order Pearson product-moment correlations (see Table 1) indicated that digital screen time was negatively associated with sleep consistency and duration ($r_s = -.18$ to $-.35$). Ancillary analyses indicated that the child-, caregiver-, and household-level control variables were significantly associated with daily digital screen time and sleep outcomes ($|r|s = .02$ to $.49$). This pattern of correlations underlined the empirical value of adjusting the for variability linked to the control variables in hypothesis testing.

Confirmatory Hypothesis Testing

Three hypotheses were tested in line with the preregistered analysis plan (https://osf.io/ju6bz/?view_only=dee7ee24e95b426fa1a877f0820a3855). Because of differences in item wording across the two age groups, separate models were evaluated for those between the ages of six months and five years and those aged between six and seventeen years. There were three deviations from the registered plan. First, one of the control variables, social support from people outside the home, was not available for analysis for children aged below six years of age. Second, two outcome variables included in the plan are not reported here because they are part of a project unrelated to sleep. Third, the observed sample size ($n = 50,212$) was smaller than was expected because, compared to previous years,

the scope of the NSCH was reduced for the 2016 wave. All of the variables relevant to pediatric sleep and technology use are included in this reporting of results.

Hypothesis 1: Digital Screens and Sleep Consistency

Two models tested the relations between digital screen time and sleep consistency (See Table 2). In both, sleep consistency was regressed onto the control variables in the first step of the model and onto daily digital screen time in the second step. Results confirmed the prediction that digital screen time would be negatively associated with sleep consistency ($bs = -0.063$ to -0.130). Importantly, although they were statistically significant in the direction predicted, the semi-partial correlations (i.e. $|\Delta r^2|$) accounted for small shares of unique variance for younger (1.7%) and older children (1.1%) alike.

Hypothesis 2: Digital Screens and Sleep Duration

Two models tested the relations between daily digital screen time and sleep duration. In both, the duration of children's sleep estimated by caregivers was regressed onto the control variables and then onto daily digital screen time. Results supported the hypothesis that digital screen time would be negatively associated with sleep duration ($bs = -0.040$ to -0.049). Just as was the case for evidence supporting the first hypothesis, these links were significant in the direction predicted and the unique variance associating digital screen time with sleep were modest in standardized terms for younger (1.9%) and older children (0.06%). To contextualize these effect sizes, and in line with the analysis plan, every hour of digital screen time was associated with 8 fewer minutes of sleep each day (for those aged six months to five years), and 3 fewer minutes of sleep (for those ages five years and older).

Hypothesis 3: Correlates of AAP Guidance

Four models tested the relation between AAP advice and sleep for children aged two to five years. The structure of these models mirrored those used to test the previous hypotheses and defined dummy coded variables reflecting being over (coded 0) or under (coded 1) the AAP's 2010 or 2016 limits as the

predictors. In line with predictions, sleep consistency was significantly higher for those under both the 2010 and 2016 guidances ($bs = 0.148$ to 0.183). Also, as predicted, average sleep duration was longer for those children reported as under the 2010 and 2016 guidance ($bs = 0.349$ to 0.441). Just as was the case for results for Hypotheses 1 and 2, the standardized effects were quite small in all cases accounting for less than 1.2% of variability. In real world terms, those under the 2010 limit slept for an average 20 additional minutes, and those under the 2016 limit slept for an average of 26 more minutes compared to children whose caregivers reported they exceeded these recommendations.

Discussion

The goal of the present study was to provide a critically-needed rigorous empirical test of the relations between children's sleep and digital technology use. The findings derived from this large and nationally representative investigation provide the first confirmatory (i.e theory-testing) evidence that digital screen time is negatively correlated with sleep consistency and sleep duration. These findings are important because nearly all that is known about the effects of digital screens on young people is inferred from exploratory studies of adolescents and college aged young adults. Importantly, the present findings provide both a plausible empirical prior for researchers to calibrate future work and a realistic foundation for practitioners when advising caregivers on the relative impact of screens versus other influences on pediatric sleep.

Although the effects were extremely modest, the consistent pattern of results provides a plausible and robust baseline for scientists studying the effects of technology on sleep. The basic displacement effect uncovered here, between three and eight fewer minutes of sleep for each hour of digital screen time, offers a guide for the minimum sample size needed to recruit for reliable investigations of sleep displacement effects. Based on the present findings, future studies should set a minimum sample size of 800 to 2,500 observations, depending on the age of the sample under analysis, so that hypothesis tests

examining moderators (e.g., blue light effects) are sensible, sensitive, and well-powered (i.e., $\alpha = 0.05$; $1-\beta = 0.95$). Only samples of this size or larger have a fair chance of justifiably rejecting the null hypothesis if the displacement effect is itself reliable. Exercising care on this point will allow researchers to compare the effects of different kinds of digital screen time across key social and developmental contexts.

It is important that scientists, policymakers, practitioners, and parents place these findings in real-world terms. If one compares the average nightly sleep of a tech abstaining teen (8hrs and 51min) to one who devotes eight hours a day to screens (8hrs and 21min) the differences, in terms of displacement, are inconsequential compared to contextual factors known to impact sleep and behavior such as an early starts to the school day [32]. This is not to say we should not study the effects of digital screens, but to highlight the fact that those working in this area must articulate what does and what does not constitute a practically meaningful effect on theoretical or medical grounds *before* conducting research studies [33].

Findings provided robust empirical support for the analytic decision to include child-, caregiver-, household-, and community-level variables as controls based on existing theory and literature (see Figure 2). Preliminary analyses indicated all of the control variables were significantly associated with the explanatory and outcome variables. These relations underscore the often cited but seldom demonstrated value of including reasonable control variables in line with the extant literature [30]. For example, the zero-order correlation linking screen use to sleep duration ($r = -.35$) would, on its own, be rightly regarded as non-trivial in medical and social research [34]. However, results from the confirmatory analyses based on the preregistered plan lead to a markedly different interpretation. In this case, the observed semi-partial correlation ($r = -.14$), an estimate adjusted for controls, was substantially smaller. In other words, five parts in six of the uncorrected correlation were linked to control variables.

Even if this extremely modest correlation is causal, the contextual factors surrounding screen time exert a more pronounced influence on pediatric sleep than many might assume.

The present study highlights three ways that future studies could deepen our empirical understanding of the digital displacement hypothesis. First, the data considered digital screen use in aggregate on a daily basis, and follow-up studies should examine such effects in specific technologies (e.g. tablets) and evaluate whether the effects of usage are magnified at specific times (e.g. bedtime). Second, the data were provided by caregiver respondents, and convergent evidence derived directly from technological devices and physiological sleep measures are needed to ensure the links reported herein are not merely artefacts of self-report [35]. Finally, the data analysis plan used statistical significance (i.e., $\alpha = .05$) as the benchmark for drawing inferences about the presence of effects. Given the large sample sizes found in the literature [7], even modest correlations will meet this threshold. Instead of using statistical significance as a guide, researchers investigating the digital displacement should articulate a Smallest Effect Size of Interest (SESOI), on theoretical and practical grounds before collecting data [33,34].

Conclusions

Whether engaged through tablets, smartphones, or electronic games, screens are now a fixture of modern childhood. Because the digital genie cannot be put back in the bottle, it is incumbent on researchers to rigorously identify the ways and extent to which exposure to screens influences young people. Doing so will allow the most pronounced challenges to be identified and promising benefits to be capitalized upon. The present research aimed at the former and found digital screen time, on its own, has little practical effect on pediatric sleep. The work provides a robust empirical baseline for those investigating this topic and identifies key social and contextual factors surrounding digital screens for researchers to integrate into their studies of the digital displacement hypothesis.

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Table 1

Table 1. Observed Zero-Order Correlations Between Observed Descriptive, Explanatory and Outcome Variables

	1.	2.	3.	4.	5.	6.	7.
1. Age	-	-0.01	0.401**	-0.105	-0.128**	-0.026**	-0.438**
2. Female	0.007	-	-0.013	0.030**	0.004	0.008	0.008
3. Digital Screen Time	0.331**	-0.059**	-	-0.723**	-0.446**	-0.177**	-0.348**
4. Under AAP 2010†	-	-	-	-	0.411**	0.150**	0.208**
5. Under AAP 2016†	-	-	-	-	-	0.111**	0.173**
6. Sleep Consistency	-0.186**	-0.015**	-0.211**	-	-	-	0.217**
7. Sleep Duration	-0.464**	-0.011*	-0.263**	-	-	0.277**	-

Note. Coefficients above the diagonal are for children aged 6mo. to 5yrs and coefficients below the diagonal are for children 6 years to 17 years. Gender is coded 0 = male, 1 = female. † Coefficients for these variables only computed for those aged between 2yrs and 5yrs.

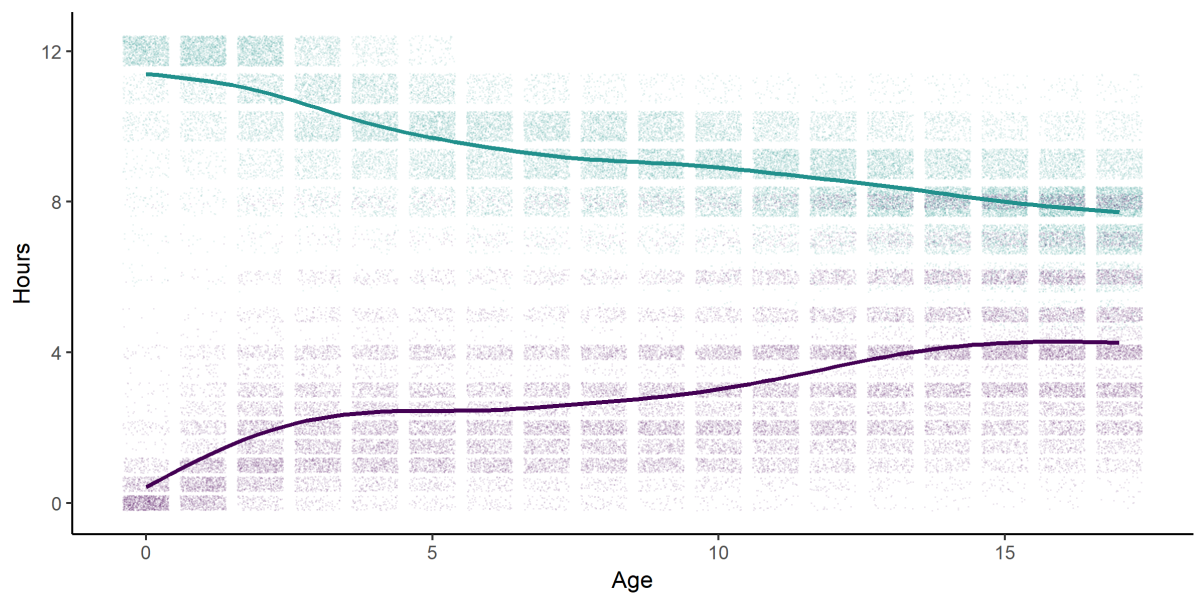
Table 2

Table 2. Multiple Regression Models Evaluating Sleep Hygiene as a Function of Digital Screen Time

Hypothesis	Explanatory Variable	Outcome Variable	Age Cohort	<i>B</i>	<i>SE</i>	95% CI	β	<i>p</i>	$ \Delta r^2 $
Hypothesis 1	Digital Screen Time	Sleep Consistency	6 mo. to 5yrs	-0.063	0.004	[-0.070, -0.055]	-0.147	< .001	0.017
			6yrs to 17yrs	-0.040	0.002	[-0.044, -0.036]	-0.114	< .001	0.011
Hypothesis 2	Digital Screen Time	Sleep Duration	6 mo. to 5yrs	-0.130	0.007	[-0.143, -0.117]	-0.158	< .001	0.020
			6yrs to 17yrs	-0.049	0.003	[-0.055, -0.043]	-0.084	< .001	0.006
Hypothesis 3	Under 2010 AAP Limit	Sleep Consistency	2yrs to 5yrs	0.148	0.013	[0.122, 0.174]	0.110	< .001	0.012
		Sleep Duration	2yrs to 5yrs	0.346	0.023	[0.300, 0.392]	0.137	< .001	0.018
	Under 2016 AAP Limit	Sleep Consistency	2yrs to 5yrs	0.183	0.020	[0.143, 0.223]	0.088	< .001	0.008
		Sleep Duration	2yrs to 5yrs	0.441	0.036	[0.370, 0.511]	0.113	< .001	0.012

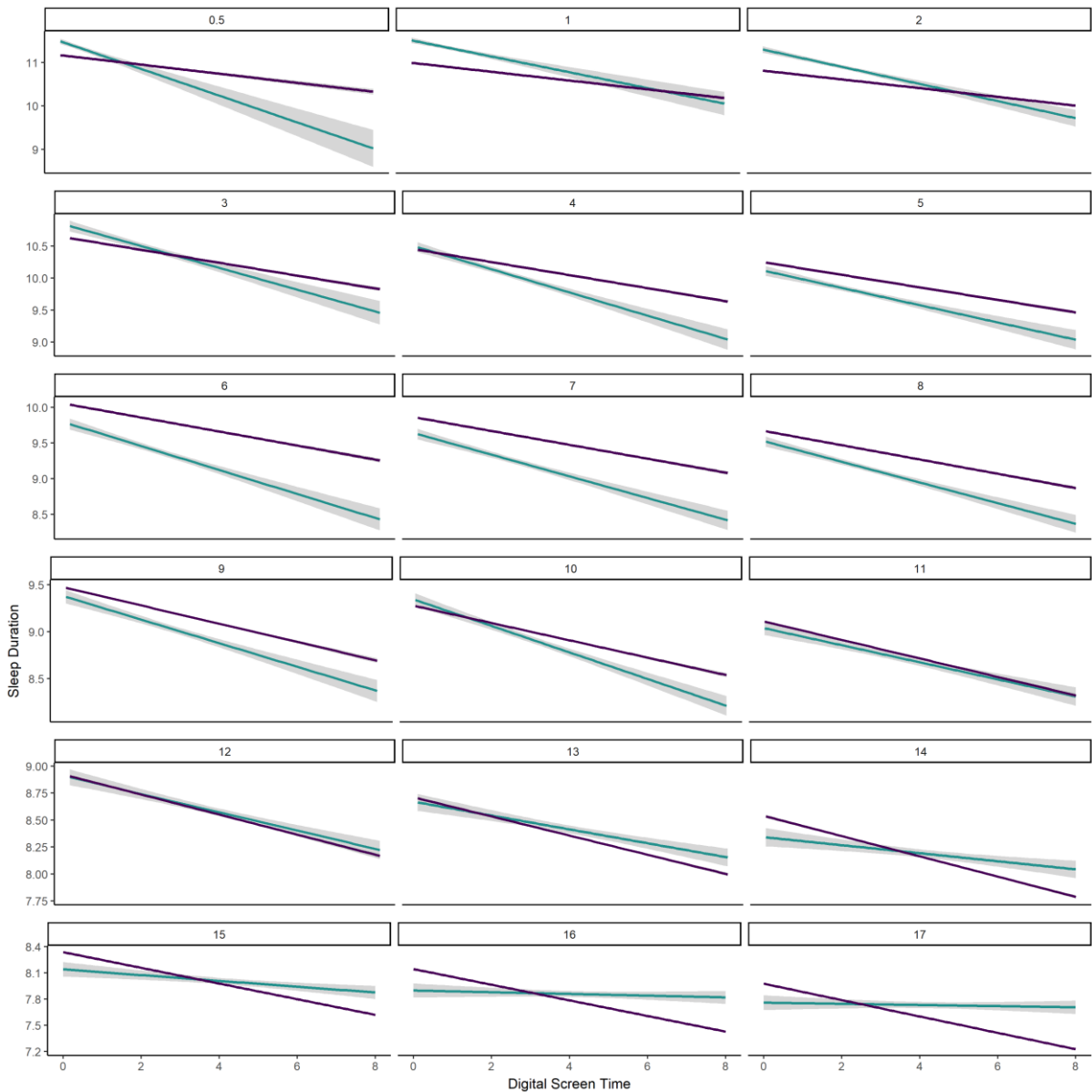
Note. Models with for 6 mo. to 5yr olds control for age, gender, child’s age and gender, white or non-white race/ethnicity, the presence of major life stressors, social support, general health, whether or not caregivers had completed secondary school, family adjustment, whether the family was able to get by financially, they were able to afford food, whether they receive government assistance, neighbourhood conditions, affordances for outdoor activities, and neighbourhood cohesion. Models for those aged 6yrs to 17yrs also controlled for the availability of social support outside the home.

Figure 1.



Note. Hours of nightly sleep are depicted in teal and hours of digital screen time are plotted in purple.

Figure 2.



Note. Sperate plots for participants at each age between daily hours of digital screen time are along the x axis and hours of sleep along the y axis. Best fit lines and 95% confidence intervals for uncorrected models are plotted in teal, models adjusted for controls are plotted in purple.