# Digital Screen Time and Pediatric Sleep: Evidence from a Preregistered Cohort Study

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**Objectives** To determine the extent to which time spent with digital devices predicts meaningful variability in pediatric sleep.

**Study design** 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 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 3-8 fewer minutes of nightly sleep and significantly lower levels of sleep consistency. Furthermore, those children who complied with 2010 and 2016 American Academy of Pediatrics guidance on screen time limits reported between 20 and 26 more minutes, respectively, of nightly sleep. However, links between digital screen time and pediatric sleep outcomes were modest, accounting for less than 1.9% of observed variability in sleep outcomes.

**Conclusions** Digital screen time, on its own, has little practical effect on pediatric sleep. Contextual factors surrounding screen time exert a more pronounced influence on pediatric sleep compared to screen time itself. These findings provide an empirically robust template for those investigating the digital displacement hypothesis as well as informing policy-making. *(J Pediatr 2019;205:218-23).*

Digital screens are now regularly used by children of all ages.[1,2] Because young people spend an increasing share of their time using tablets, smartphones, and playing electronic games,[3] caregivers[4] and health professionals have expressed concerns that these digital activities might have deleterious impacts on pediatric health.[5] A literature examining 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 relationships 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 no screen use in children under age 2 years and restriction to fewer than 2 hours each day among older children.[16] More recently, the AAP has advised caregivers to limit young children to an hour of "high-quality" screen time each day, and encouraged pediatricians to discuss screen-based media and counsel families to minimize screen exposure.[17]

The relationships between technology and sleep are increasingly discussed, as research indicates that between 50% and 90% of school-age 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 a.m. to 6:00 a.m., suggest that interventions based on the digital displacement hypothesis are largely ineffective. Two independent analyses of this nationwide natural experiment showed it saved children an average of only 2 minutes of sleep each night.[24,25]

The studies investigating technology and pediatric sleep do so through an exploratory lens, (ie, 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 important to know if the digital displacement hypothesis holds up to stringent hypothesis testing.[26] In line with a preregistered analysis plan, it was predicted a priori that digital screen time would be negatively correlated with sleep consistency. Secondly, 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 compared with those whose caregivers did not follow the AAP guidance.

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|---|---|
| AAP | American Academy of Pediatrics |
| NSCH | National Survey of Children's Health |

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## Methods

The data analyzed were derived from self-report surveys completed by caregivers living in the 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 representative 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 1351 (Minnesota). Caregivers spent an average of 35 minutes completing either the paper questionnaire (9719, 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 divided evenly between male (n = 25,733, 51.2%) and female (n = 24,479, 48.8%) children. Ethics 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/).

### Outcome Variables

**Sleep Consistency.** Caregivers were asked to estimate how regularly their child 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 5-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 10 children (31.5%, n = 15 674) always got to bed at the same time each night and another and 6 in 10 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 = 5023).

**Sleep Duration.** Caregivers were asked to estimate children's typical sleep duration over a 24-hour period by answering 1 of 2 questions depending on the age of their child. For those age 6 months to 5 years old, caregivers were asked: "During the past week, how many hours of sleep did [child name] get on an average day (count both night-time sleep and naps)?" and used a 1 = less than 7 hours to 7 = 12 or more hours response scale. Caregivers of children age 6 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 6 years slept for an average of 11 hours (SD = 1 hour 19 minutes) and older children slept for an average of 8 hours (SD = 1 hour 9 minutes).

### Explanatory Variable

**Digital Screen Time.** Caregivers also estimated their child's daily digital screen time with 2 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 approximately 3 hours (mean = 3 hours 4 minutes, SD = 2 hours 3 minutes) 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 2-5 years. Two in 5 children (44.4%, n = 4581) were under the older 2-hour AAP guidance and 1 in 10 children (11.9%, n = 1225) were under the revised 1-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 as detailed in the analysis plan. Adjusting for the confounding influence of these factors serves to separate the effects of technology from other factors on the basis of the existing literature.[7,30,31] Child-level variables included age and sex, white or nonwhite race/ethnicity, presence of major life stressors, social support, and general health. Family-level variables included family adjustment and whether or not caregivers had completed secondary school, 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 included neighborhood conditions, affordances for outdoor activities, cohesion, and social support.

## Results

A visual inspection of the sleep and digital screen time trends (**Figure 1**) indicted digital screen time increases monotonically from age 6 months (28 minutes) to 15 years (4 hours 17 minutes), whereas sleep duration decreases monotonically from 6 months (11 hours 20 minutes) to age 16 years (7 hours 7 minutes). Zero-order Pearson product-moment correlations (**Table I**) indicated that digital screen time was negatively associated with sleep consistency and duration ($rs = -.18$ to $-.35$). Additional 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 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/). Because of differences in item wording across the 2 age groups, separate

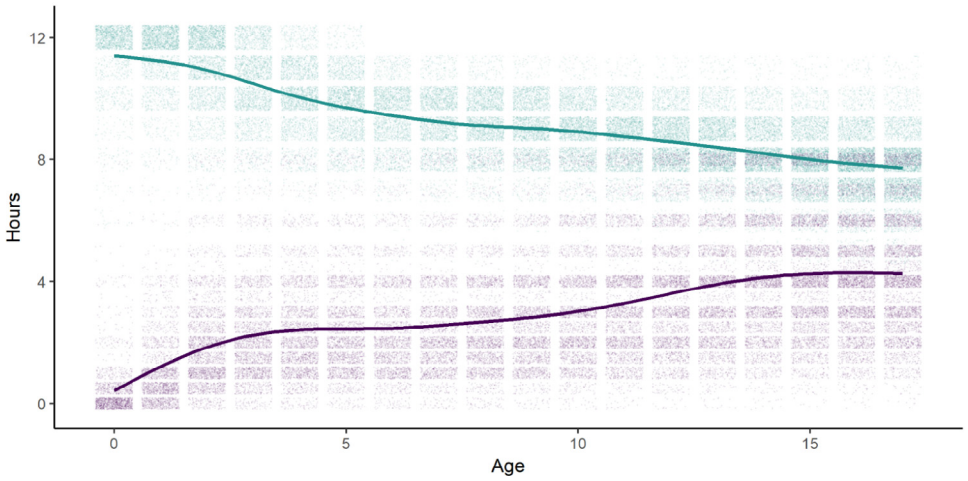


**Figure 1.** Hours of nightly sleep (top) and hours of digital screen time (bottom).

models were evaluated for those between the ages of 6 months and 5 years and those aged between 6 and 17 years. There were 3 deviations from the registered plan. First, 1 of the control variables, social support from people outside the home, was not available for analysis for children aged below age 6. Second, 2 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 with previous years, the scope of the NSCH was reduced for the 2016 wave. All 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 (**Table II**). 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 is negatively associated with sleep consistency (*b*s = −0.063 to −0.130). Importantly, although they were statistically significant in the direction predicted, the semipartial correlations (ie, $|\Delta r^2|$) accounted for only 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 (*b*s = −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 age 6 months-5 years), and 3 fewer minutes of sleep (for those ages 5 years and older).

### Hypothesis 3: Correlates of AAP Guidance

Four models tested the relation between AAP advice and sleep for children aged 2-5 years. The structure of these models

**Table I. Observed zero-order correlations between observed descriptive, explanatory, and outcome variables**

| 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† | — |

Coefficients above the diagonal are for children ages 6 months-5 years and coefficients below the diagonal are for children 6-17 years. Sex is coded 0 = male, 1 = female.
*$P < .05$.
†$P < .001$.
‡Coefficients for these variables are computed only for those between ages 2 and 5 years.

**Table II. Multiple regression models evaluating sleep hygiene as a function of digital screen time**

| Hypotheses | Explanatory variable | Outcome variable | Age cohort | *B* | SE | 95% CI | *B* | *P* | $\|\Delta r^2\|$ |
|---|---|---|---|---|---|---|---|---|---|
| Hypothesis 1 | | | | | | | | | |
| | Digital screen time | Sleep consistency | 6 mo-5 y | –0.063 | 0.004 | [–0.070, –0.055] | –0.147 | <.001 | 0.017 |
| | | | 6-17 y | –0.040 | 0.002 | [–0.044, –0.036] | –0.114 | <.001 | 0.011 |
| Hypothesis 2 | | | | | | | | | |
| | Digital screen time | Sleep duration | 6 mo-5 y | –0.130 | 0.007 | [–0.143, –0.117] | –0.158 | <.001 | 0.020 |
| | | | 6-17 y | –0.049 | 0.003 | [–0.055, –0.043] | –0.084 | <.001 | 0.006 |
| Hypothesis 3 | | | | | | | | | |
| | Under 2010 AAP limit | Sleep consistency | 2-5 y | 0.148 | 0.013 | [0.122, 0.174] | 0.110 | <.001 | 0.012 |
| | | Sleep duration | 2-5 y | 0.346 | 0.023 | [0.300, 0.392] | 0.137 | <.001 | 0.018 |
| | Under 2016 AAP limit | Sleep consistency | 2-5 y | 0.183 | 0.020 | [0.143, 0.223] | 0.088 | <.001 | 0.008 |
| | | Sleep duration | 2-5 y | 0.441 | 0.036 | [0.370, 0.511] | 0.113 | <.001 | 0.012 |

Models for ages 6 months to 5 years adjust for age, sex, child's age and sex, 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, neighborhood conditions, affordances for outdoor activities, neighborhood cohesion, and whether the family was able to get by financially, was able to afford food, or received government assistance. Models for those ages 6-17 years also adjusted for the availability of social support outside the home.

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 guidance (*b*s = 0.148-0.183). As predicted, average sleep duration also was longer for those children reported as under the 2010 and 2016 guidance (*b*s = 0.349-0.441). 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 with 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 relationships between children's sleep and digital technology use. The findings derived from this large and nationally representative investigation provide the first confirmatory (ie, 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 work for researchers to calibrate future work and a realistic foundation for practitioners when advising caregivers on the relative impact of screens vs other influences on pediatric sleep.

Although the effects were 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 3 and 8 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 800-2500 observations, depending on the age of the sample under analysis, so that hypothesis tests examining moderators (eg, blue light effects) are sensible, sensitive, and well-powered (ie, $\alpha = 0.05$; $1\text{-}\beta = 0.95$). 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 (8 hours 51 minutes) with one who devotes 8 hours a day to screens (8 hours 21 minutes) the differences, in terms of displacement, are inconsequential compared with contextual factors known to influence 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 (**Figure 2**; available at www.jpeds.com). Preliminary analyses indicated that all 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 nontrivial 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 semipartial correlation ($r = -.14$), an estimate adjusted for controls, was substantially smaller. In other words, 5 parts in 6 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 3 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 (eg, tablets) and evaluate whether the effects of usage are magnified at specific times (eg, 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 that the links reported herein are not merely artefacts of self-report.[35] Finally, the data analysis plan used statistical significance (ie, $\alpha = .05$) 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]

Whether engaged through tablets, smartphones, or electronic games, screens are now a fixture of modern childhood. Because of the pervasiveness of digital screens in daily activities, it is incumbent on researchers to clearly articulate 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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## Data Statement

Data sharing statement available at www.jpeds.com.

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## 50 Years Ago in *The Journal of Pediatrics*

### Hyperosmolality Complicating Diabetes Mellitus in Childhood

Rubin HM, Kramer R, Drash A. J Pediatr 1969;74:177-86.

Fifty years ago, hyperosmolar nonketotic diabetic coma, now commonly referred to as hyperglycemic hyperosmolar syndrome (HHS), was just starting to be recognized in children. This report details 6 children who presented with this unusual form of diabetic coma. None of the 6 was previously known to have diabetes. The lowest presenting blood glucose and serum osmolality of the group were 750 mg/dL and 321 mOsm/L. Case reports at the time demonstrated a mortality rate of ~50%, and only 2 of the 6 patients in this series survived, one of whom had significant morbidity.

In a wonderful paragraph, the authors show their humility and desire for improvement on these outcomes. "The proper therapy of hyperosmolar diabetic coma has not been devised. Our own lack of success in the management of this syndrome does not allow us to draw firm conclusions as to appropriate methods of management." Six principles are shared: (1) "prompt and repeated administration of adequate amounts of insulin. . .is essential"; (2) "avoidance of glucose in the initial parenteral fluid"; (3) "exchange transfusion may be considered in extreme cases of insulin resistance"; (4) "the type of parenteral fluid used and the rate of its administration are undoubtedly critical in the early management of HHS"; (5) "hyperosmolar states such as hypernatremia should be corrected slowly"; and (6) "severe acidemia should be corrected. . .sodium bicarbonate is theoretically preferable to sodium lactate".

Some of these principles hold true and others may cause today's practitioner to hyperventilate. Recent research[1] has led to a better understanding of HHS. Mortality has decreased, although further progress is needed. The guiding principles are that fluid resuscitation must be paramount and insulin should be held until the serum glucose is no longer decreasing from rehydration alone. Some debate remains on the point of insulin, but aggressive insulin therapy may cause more harm than benefit.

With the increase in pediatric type 2 diabetes, it appears that the incidence of HHS is increasing. Therefore, it is important for all pediatricians to be aware of this condition so that it can be recognized and treated quickly and safely.

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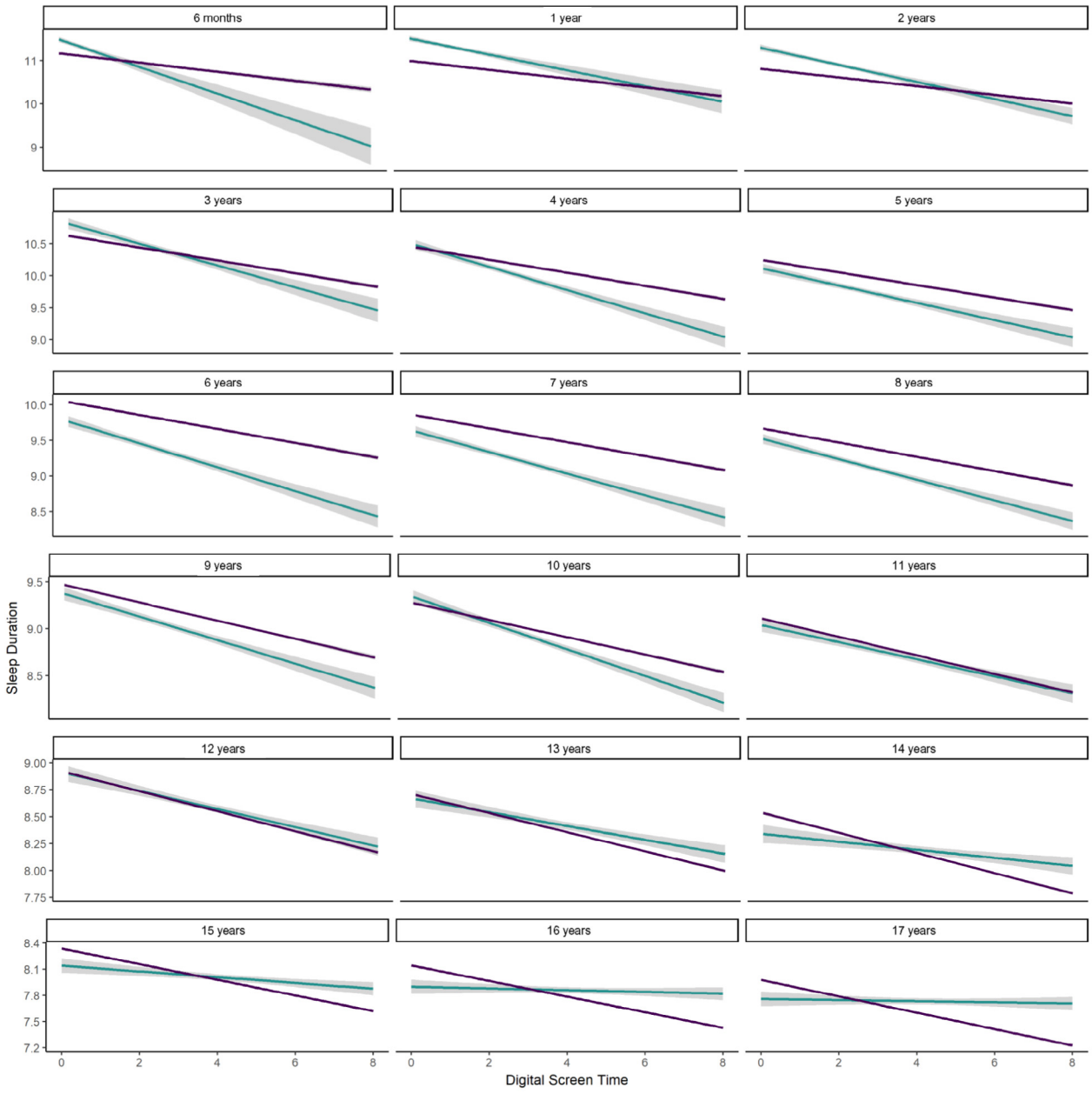


**Figure 2.** Separate plots for participants at each age between daily hours of digital screen time are along the x axis and hours of sleep along the y axis. Best fit lines and 95% CIs for uncorrected models are plotted in teal; models adjusted for controls are plotted in purple.