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Effects of the COVID-19 Pandemic on Screen Time and Sleep in Early Adolescents

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Data used in the preparation of this article were obtained from the Adolescent Brain Cognitive Development (ABCD®) Study (https://abcdstudy.org), held in the NIMH Data Archive (NDA). This is a multisite, longitudinal study designed to recruit more than 10,000 children aged 9–10 years and follow them over 10 years into early adulthood. The ABCD Study is supported by the National Institutes of Health and additional federal partners under award numbers U01DA041048, U01DA050989, U01DA051016, U01DA041022, U01DA051018, U01DA051037, U01DA050987, U01DA041174, U01DA041106, U01DA041117, U01DA041028, U01DA041134, U01DA050988, U01DA051039, U01DA041156, U01DA041025, U01DA041120, U01DA051038, U01DA041148, U01DA041093, U01DA041089, U24DA041123, and U24DA041147. A full list of supporters is available at https://abcdstudy.org/federal-partners.html. Additional support for this work was made possible from supplements to U24DA041123 and U24DA041147, the National Science Foundation (NSF 2028680), and Children and Screens: Institute of Digital Media and Child Development Inc. A listing of participating sites and a complete listing of the study investigators can be found at https://abcdstudy.org/Consortium_Members.pdf. ABCD consortium investigators designed and implemented the study and/or provided data but did not necessarily participate in the analysis or writing of this report. Dr. Gayathri Dowling was substantially involved in all the cited grants. This manuscript reflects the views of the authors and may not reflect the opinions or views of the ABCD consortium investigators, NIH, the U.S. Department of Health and Human Services, or any of its affiliated institutions or agencies. The ABCD data repository grows and changes over time. The ABCD data used in this report came from the ABCD 3.0 data release (DOI: https://nda.nih.gov/study.html?id=901) and the ABCD COVID-19 Survey First and Second Data Release (DOI: https://nda.nih.gov/study.html?id=1041, https://nda.nih.gov/study.html?id=1225).

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Objective: During the COVID-19 pandemic, adolescents and families have turned to online activities and social platforms more than ever to maintain well-being, connect remotely with friends and family, and online schooling. However, excessive screen use can have negative effects on health (e.g., sleep). This study examined changes in sleep habits and recreational screen time (social media, video gaming), and their relationship, before and across the first year of the pandemic in adolescents in the Adolescent Brain Cognitive Development (ABCD) Study. ***Method:*** Mixed-effect models were used to examine associations between self-reported sleep and screen time using longitudinal data of 5,027 adolescents in the ABCD Study, assessed before the pandemic (10–13 years) and across six time points between May 2020 and March 2021 (pandemic). ***Results:*** Time in bed varied, being higher during May–August 2020 relative to pre-pandemic, partially related to the school summer break, before declining in October 2020 to levels lower than pre-pandemic. Screen time steeply increased and remained high across all pandemic time points relative to pre-pandemic. Higher social media use and video gaming were associated with shorter time in bed, later bedtimes, and longer sleep onset latency. ***Conclusions:*** Sleep behavior and screen time changed during the pandemic in early adolescents. More screen time was associated with poorer sleep behavior, before and during the pandemic. While recreational screen usage is an integral component of adolescent's activities, especially during the pandemic, excessive use can have negative effects on essential health behaviors, highlighting the need to promote balanced screen usage.

Keywords: sleep, screen time, adolescence, pandemic, COVID-19

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The World Health Organization (WHO) declared the coronavirus disease 2019 (COVID-19) a pandemic on March 11, 2020. Adolescents needed to adapt their relationships, along with their school life and extracurricular activities, to social distancing protocols, against a backdrop of normal developmental changes and pandemic-related distress to themselves and family. The Bright Futures guidelines from the American Academy of Pediatrics identify adolescence as 11–21 years of age, divided into early (ages 11–14 years), middle (ages 15–17 years), and late (ages 18–21 years) adolescence (Hagan et al., 2008). Early adolescence is a critical period for cognitive, physical, social, and emotional development (Shlafer et al., 2014), including changes in sleep behavior (Galván, 2020), which may foster particular vulnerability to stress associated with the pandemic. Local and governmental restrictions to minimize social interactions and slow down the transmission of the coronavirus, drastically disrupted adolescents' daily routine, limited youth's contact with friends (Magson et al., 2021), and affected healthy lifestyle behaviors, including sleep (Stone et al., 2021). On the other hand, attending school from home may have allowed more flexible school schedules, leading to less restriction on time available to sleep. Indeed, studies have shown that adolescents had more sleep during the first few months of the pandemic (Moore et al., 2020) in association with more relaxed school schedules (Bruni et al., 2021; Roitblat et al., 2020). However, studies have mostly been cross-sectional, focused on older adolescents and the early stages of the pandemic (Roitblat et al., 2020).

Sufficient sleep is critical for adolescent mental (Van Dyk et al., 2019) and physical health (Blank et al., 2015). Previous studies showed a marked decline in school day time spent in bed across early adolescence, from 10 to 13 years old, due to progressively later bedtimes (Laberge et al., 2001), while the need for sleep does not appear to decrease across puberty (Crowley et al., 2018). A meta-analysis of actigraphy measures in adolescents showed that 12- to 14-year-olds had shorter sleep duration (weekday: 7.80 hr; weekend: 8.48 hr) than 9- to 11-year-olds (weekday: 8.69 hr; weekend: 8.83 hr; Galland et al., 2018). The steepest decline in sleep duration occurred across ages 12–16 (~17.5 min/year; Galland et al., 2018). Given the normative developmental changes, detrimental changes in sleep behavior during the pandemic (Lu et al., 2020), therefore, could have long-term consequences for adolescents as they age.

A behavior that has become ubiquitous in adolescents, and which has dramatically changed during the pandemic, is recreational screen usage, defined as activities done in front of, and/or with the assistance of a digital device with a screen, including gaming, texting, social media use, and watching/streaming TV/videos (Schmidt et al., 2020). Pre/early adolescents (8- to 12-year-olds) spend 4:44 hr with different screen-related activities, whereas 13- to 18-year-olds teens have 7:22 hr screen time per day (Rideout & Robb, 2019). Nagata et al. (2021) showed that ABCD Study participants (10–14 years old) reported 7.70 hr of total daily nonschool screen time during the pandemic, which was higher than pre-pandemic estimates. Spending time on social media during the pandemic allowed adolescents to stay connected with friends (Orben et al., 2020). Similarly, playing video games fosters social engagement (multiplayer), and may serve as a form of coping with stress or a way to escape and relieve negative moods (Männikkö et al., 2020), especially during the pandemic (Nagata et al., 2020). In fact, both the active presence on social media platforms and playing video games were recommended as part of the #HealthyAtHome campaign as buffering factors against COVID-19 pandemic distress. However, higher amounts of screen usage can be detrimental for mental health (Rosen et al., 2021) and sleep (Levenson et al., 2016).

Several studies have shown in adolescents that higher amounts of screen time are associated with poorer sleep quality (Parent et al., 2016), shorter sleep duration, and insomnia symptoms (Bartel et al., 2017). Too much screen time intrudes on time available for sleep in addition to other detriments (Cain & Gradisar, 2010), such as light from the screen interfering with sleep onset (Chang et al., 2015). Although there is considerable concern over the negative effects of the pandemic on both sleep and screen time use, few studies have examined longitudinal changes in these two behaviors in adolescents or considered their relationship in the context of the pandemic.

The aims of the present study were to (a) understand the effect of the COVID-19 pandemic on early adolescents' sleep and screen time and (b) evaluate the associations between screen time and sleep in the context of the pandemic. We took advantage of the ongoing, longitudinal Adolescent Brain Cognitive Development Study (ABCD Study) that assessed sleep and several domains of screen media use with surveys both before the pandemic (Year 2 follow-up) and at six time points during the pandemic, covering the period of May 2020 to March 2021.

Method

Participants and Procedure

We analyzed data from the ABCD Study, a demographically diverse study of development across adolescence including 11,875 children at 21 sites in the United States. The study sample, recruitment, procedures, and measures are described elsewhere (Garavan et al., 2018). Centralized institutional review board (IRB) approval was obtained from the University of California, San Diego (protocol number: 160091AW). Study sites obtained approval from local IRBs. Parent/guardian and the child provided written informed consent and assent, respectively.

Starting in May 2020, participants in the ongoing ABCD Study were invited to participate in a substudy comprising online surveys, which were distributed electronically at six time points across 2020–2021, to assess the effect of the pandemic on youth and families. Starting dates for distribution of the COVID surveys were: May 16, 2020 (Survey 1), June 24, 2020 (Survey 2), August 4, 2020 (Survey 3), October 8, 2020 (Survey 4), December 13, 2020 (Survey 5), and March 12, 2021 (Survey 6). Data included here are from 5,027 adolescents (2,424 girls and 2,603 boys), who completed the 2-year annual follow-up visit (pre-pandemic period; age range: 10–13 years, $M = 11.94$ years; 3.0 release: 2018–2020) and at least one COVID-19 Rapid Response Research Survey (COVID-19 assessments; age range: 11–14 years; ABCD COVID-19 Survey releases: DOI: https://nda.nih.gov/study.html?id=1041 and https://nda.nih.gov/study.html?id=1225). A more detailed description of the sample selection pipeline is presented in Figure S1 in the online supplemental materials.

Participants included in this analysis were less likely to be Black (15% vs. 9%), less likely to be Latino/Latina/Latinx (20% vs. 17%), and tended to have higher parental education level than the original ABCD sample. Table 1 summarizes the demographic characteristics of the sample.

Table 1

Demographics of the Sample Included Here and the Original Adolescent Brain Cognitive Development (ABCD) Study Cohort

Variable	Release 3.0 baseline data $N = 11,878$ (%)	Current sample $N = 5,027$ (%)
Sex		
Female	47.8	48.2
Male	52.1	51.8
Race[a]		
White	69.4	77.5
Black	15.9	9.6
Asian	4.1	4.6
Multiracial/multiethnic	1.5	1.1
Other	7.1	5.8
Unknown/not reported	1.7	1.1
Ethnicity		
Hispanic/Latino	20.3	17.8
Non-Hispanic	78.4	81.0
Unknown/not reported	1.2	1.1
Parental education		
<High school diploma	11.7	6.7
High school diploma/GED	2.7	1.3
Some college	25.9	22.7
Bachelor's degree	25.3	29.0
Postgraduate degree	34.0	40.1
Unknown/not reported	0.1	0

[a]Categories for race for the ABCD cohort were defined as in Goldstone et al. (2020).

Measures

Outcome Measures: Sleep Timing and Quality

We used items belonging to a subscale of the Munich Chronotype Questionnaire (MCTQ—youth version; Roenneberg et al., 2003) that were included in the original ABCD Study (Year 2) and compared them with items of the same subscale obtained during the pandemic (COVID-19 surveys). While questions were similar, there were some differences in response options and participants reported their sleep in the past week, with no differentiation between weekday and weekend/free days in the COVID-19 surveys. In contrast, for Year 2, participants reported their typical sleep, considering school and free days separately. We therefore harmonized the measures across time points before analysis (see the online supplemental materials for more details).

Time in bed (TIB), measured in hours, was calculated from the reported wake-up time ("I wake up at…") and bedtime ("I go to bed at…"). The individual item "I go to bed at…" was used as the measure for typical bedtime. Possible responses varied between 7 p.m. and 6 a.m. Sleep onset latency was represented by the item "I need __ minutes to fall asleep" (with responses from 0 min up to 4 hr) on a pseudo-continuous scale. In addition, we used the number of awakenings: "After falling asleep, I wake up __ times during the night" (ranging from 0 to 10).

Predictors

Demographic Variables

Age in months at the Year 2 follow-up of the ABCD Study was used. Other demographic information was taken from the ABCD Study baseline visit: sex at birth (male or female), race (White, Black, Asian, Multiple, Other, Not Reported), ethnicity (Hispanic/Latino, Non-Hispanic, Not Reported). Parental education (less than high school diploma, high school diploma/GED, some college, bachelor's degree, postgraduate degree) was used as an indicator of family socioeconomic status (Duncan et al., 2002).

Pre-Pandemic Period and School Breaks During the Pandemic

The Year 2 assessment of the ABCD Study was indicated as the *Pre-pandemic period.* Since the COVID-19 survey data covered more than a year of the pandemic, we included information about school derived from the COVID-19 surveys. Participants were asked what time they started their schoolwork in the past week. Where participants indicated "Not applicable," we coded that data as "no-school," likely reflecting school breaks (e.g., summer).

Screen Time Measures

Pre-pandemic screen time was determined for the Year 2 follow-up visit using the Youth Screen Time Survey. Participants answered questions about typical hours per day (not including school-related activities, separately for school days and weekend days) spent on six screen activities (internet browsing, texting, video chatting, social media use, playing single player, and playing multiplayer, video games). Variables were measured on a pseudo-continuous scale ranging from 0 min to 9 hr or more. We calculated the weighted average of weekdays and schooldays. The same questions about screen usage were asked in the COVID-19 surveys; however, usage was asked for the past week, with no differentiation between weekdays and weekends.

Statistical Analysis

To avoid multicollinearity of the predictors, we reduced the six screen time variables to the items that had the lowest correlation (Spearman's $\rho = 0.13$): *time spent with social media use* and *single player video game time*, as representatives for screen time (see Table S1 in the online supplemental materials).

The main analyses focused on examining changes in sleep measures (TIB, bed time, sleep onset latency in minutes) as well as the relationship between sleep and screen time before and during the pandemic, using linear mixed-effect models (LMMs, R package "lme4"; Bates et al., 2015). Changes in the number of awakenings (discrete, nonnegative count data) were analyzed using the generalized mixed-effect model (GLMM, R package "lme4"; Bates et al., 2015) with Poisson distribution. All the models included *assessment* date (factor with seven levels: pre-pandemic, COVID-19 surveys from 1 to 6), pre-pandemic *age* (in months, at Year 2 assessment), *school* (no school/school), *time spent on social media platforms* (in minutes), *time spent on single player video games* (in minutes), *sex* (male/female), adjusting for race (factor with six levels), ethnicity (factor with three levels), and highest level of parental education. Interaction terms of age-by-assessment and sex-by-assessment were included to determine divergence in sleep according to age and sex. Furthermore, interaction terms of sex-by-screen time (social media and video game time) and assessment-by-screen time, were added to the model (two-way interactions) to evaluate differences in sleep–screen time relationships according to sex and assessment. Participant ID and ABCD collection site were included as random terms. We winsorized (Garson, 2012) all sleep variables at the 1 and 99 percentile level to mitigate the impact of outliers. The continuous predictors were standardized. We also analyzed changes in the screen time variables (*time spent on social media platforms*, *time spent on single player video games*) from before and during the pandemic, using random intercept LMMs (R package "lme4"; Bates et al., 2015) with sex, school assessment, and pre-pandemic age as predictors, adjusting for race, ethnicity and parental education. The model included the collection site and the participant ID as random terms.

We provide χ^2 and p values of likelihood ratio tests. To interpret the interaction effects, we performed simple slope analysis (R package "interactions"; Long, 2019). The complete likelihood ratio test results of the LMM and GLMM models are provided in Tables S2–S7 in the online supplemental materials.

To distinguish the pandemic effect from the developmental changes, we conducted an additional cross-sectional analysis focusing on a subsample of the participants as described in the online supplemental materials (p. 2).

Results

Time Spent in Bed

At the pre-pandemic assessment, 83.3% of the adolescents had a TIB between 9 and 11 hr (13.4%: <9 hr, 3.2%: >11 hr). During the COVID-19 pandemic, this proportion decreased to 70.6% of the sample (average across all six COVID-19 assessments), with ~20% having <9 hr sleep, while ~10% of children slept >11 hr. Model outputs are shown in Table S2 in the online supplemental materials. Time spent in bed varied from before and across pandemic assessments; *assessment* main effect, $\chi^2(6) = 1{,}987.61$, $p < .01$. In general, TIB increased at the first COVID-19 assessment (May 2020) and stayed high through August 2020, relative to the pre-pandemic assessment before decreasing in the second half of the pandemic assessments, starting with October 2020, to a level that was significantly lower compared with the pre-pandemic assessment, $t(5{,}609.19) = 12.88$, $p < .01$, CI [0.33, 0.44]. The variability in TIB across COVID-19 surveys was, in part, related to the effect of school. During the period of June–August 2020 many participants were not enrolled in any school activity (Figure S2 in the online supplemental materials). Consequently, we found a main effect of *school*, $\chi^2(1) = 106.86$, $p < .01$, and a significant interaction effect of the *assessment* × *school*, $\chi^2(5) = 21.95$, $p < .01$, with participants having longer TIB during assessments when there were no school activities (Figure 1A; Figure S3A in the online supplemental materials).

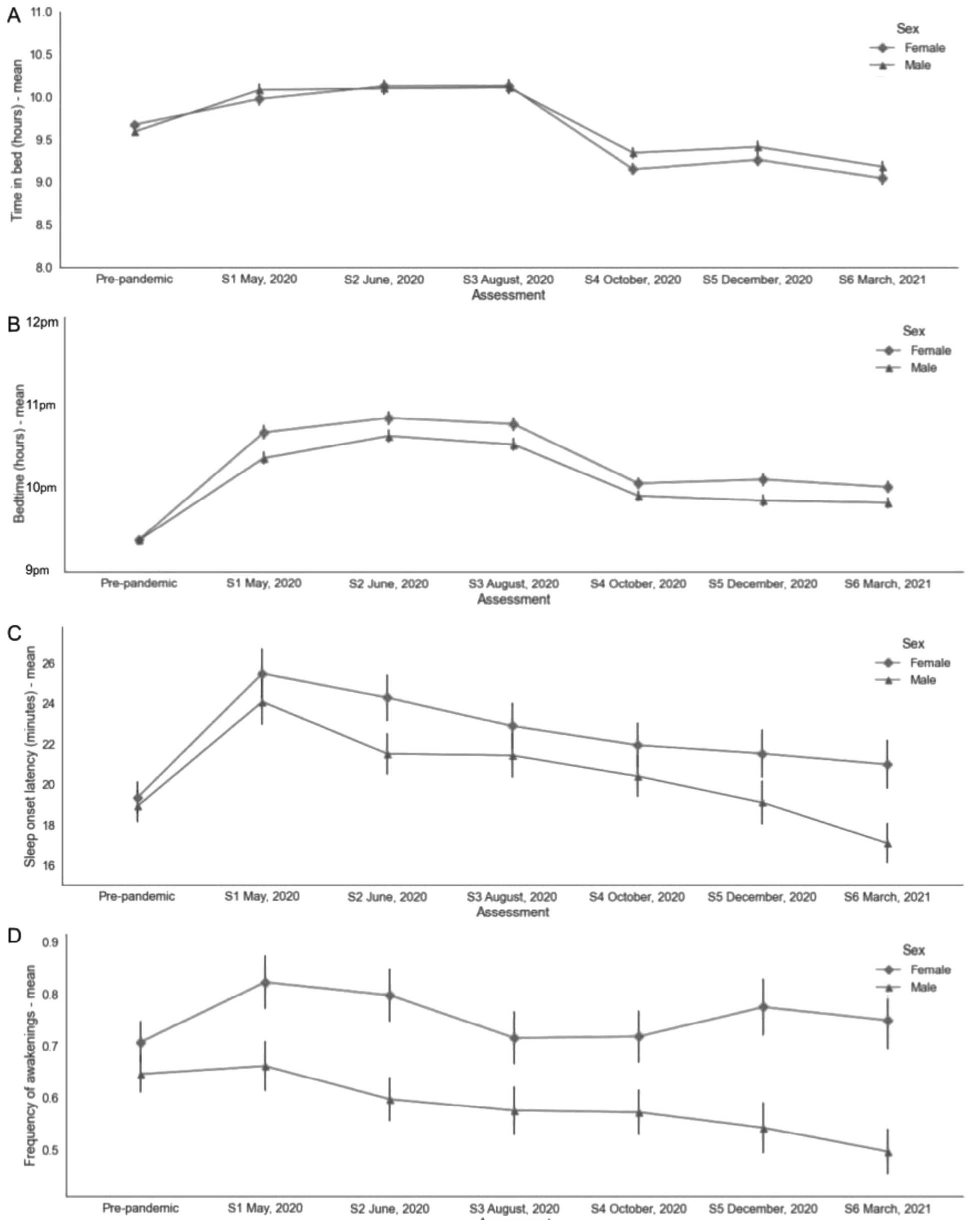
There was no main effect of *sex* on TIB, however, the *sex* × *assessment* interaction effect, $\chi^2(6) = 21.29$, $p = .001$, was significant. Girls had shorter TIB than boys during the second part of the COVID-19 assessments (see Figure 1A).

In addition, there was a main effect of *age*, $\chi^2(1) = 91.84$, $p < .01$, and an interaction effect of *age* × *assessment*, $\chi^2(6) = 28.53$, $p < .01$. The simple slope analysis showed that the effect of *age* was significant at all time points, with older adolescents spending less TIB than younger adolescents. However, the effect of age was less pronounced in assessments from May to August 2020 (less steep slope) than in those between October 2020 and March 2021, when the participants were more likely to have school (simple $\text{slope}_{\text{Pre-pandemic}} = -0.24$, $p < .01$, simple $\text{slope}_{\text{May}} = -0.08$, $p < .01$, simple $\text{slope}_{\text{June}} = -0.07$, $p < .01$, simple $\text{slope}_{\text{August}} = -0.05$, $p = .02$, simple $\text{slope}_{\text{October}} = -0.15$, $p < .01$, simple $\text{slope}_{\text{December}} = -0.13$, $p < .01$, simple $\text{slope}_{\text{March}} = -0.12$, $p < .01$).

The *time spent on social media platforms*, $\chi^2(1) = 114.56$, $p < .01$, and the *time spent on single player video games*, $\chi^2(1) = 6.13$, $p = .013$, were significantly associated with TIB. There were no significant interactions with *sex*. However, both screen time variables had significant interactions with *assessment*; *time spent on social media platforms*: $\chi^2_{\text{social media} \times \text{assessment}}(6) = 29.39$, $p < .01$; *time spent on single player video games*: $\chi^2_{\text{single player video games} \times \text{assessment}}(6) = 27.81$, $p < .01$. These results indicate that social media and video game playing were associated with shorter TIB (Figures S4 and S5 in the online supplemental materials);

Figure 1

The Interaction Effect of Sex and Assessment on (A) Adolescent's Time in Bed (Markers: Mean ± CI), (B) Bedtime (Markers: Mean + CI), (C) Sleep Onset Latency (Markers: Mean + CI), and (D) Frequency of Awakenings (Markers: Mean + CI), Shown Separately for Boys (Blue) and Girls (Red)



Note. CI = confidence interval. See the online article for the color version of this figure.

however, the slope of the social media–TIB relationship was steeper for the pre-pandemic assessment, and for the October 2020–March 2021 period, when the adolescents had shorter TIB than at earlier pandemic assessments (simple $slope_{Pre-pandemic} = -0.24$, $p < .01$, simple $slope_{May} = -0.08$, $p = .01$, simple $slope_{June} = -0.07$, $p < .01$, simple $slope_{August} = -0.05$, $p = .02$, simple $slope_{October} = -0.15$, $p < .01$, simple $slope_{December} = -0.13$, $p < .01$, simple $slope_{March} = -0.12$, $p < .01$). The impact of video gaming was similar to social media use but the slope was significant only at the pre-pandemic assessment (simple $slope_{Pre-pandemic} = -0.14$, $p < .01$).

Bedtime

Prior to the pandemic, 20% of adolescents went to bed earlier than 9 p.m. (~76% between 9 and 11 p.m.; ~4% later than 11 p.m.). During the pandemic, 6% of the participants had their bedtime earlier than 9 p.m. (76%: 9–11 p.m.; ~16%: >11 p.m.).

Model outputs are shown in Table S3 in the online supplemental materials. The LMM analysis showed a significant main effect of *assessment*, $\chi^2(6) = 5{,}090.15$, $p < .01$, with adolescents going to bed later across pandemic assessments relative to pre-pandemic (Figure 1B). Wake-up time also varied across the pandemic (see Figure S13 in the online supplemental materials for details).

There was also a main effect of *sex*, $\chi^2(1) = 12.34$, $p < .01$, and a *sex* × *assessment* interaction, $\chi^2(6) = 27.29$, $p < .01$, with girls having a larger delay in bedtimes during the pandemic. There was a main effect of *age*, $\chi^2(1) = 187.47$, $p < .01$, and an *age* × *assessment* interaction, $\chi^2(6) = 17.47$, $p = .008$. Older adolescents went to bed later than younger adolescents at all assessments, with a steeper relationship during the pandemic (simple $\text{slope}_{\text{Pre-pandemic}} = 0.17$, $p < .01$, simple $\text{slope}_{\text{May}} = 0.25$, $p < .01$, simple $\text{slope}_{\text{June}} = 0.19$, $p = .01$, simple $\text{slope}_{\text{August}} = 0.20$, $p < .01$, simple $\text{slope}_{\text{October}} = 0.24$, $p < .01$, simple $\text{slope}_{\text{December}} = 0.22$, $p < .01$, simple $\text{slope}_{\text{March}} = 0.23$, $p < .01$). The main effect of *school*, $\chi^2(1) = 188.80$, $p < .01$, and its interaction with *assessment*, $\chi^2(5) = 34.96$, $p < .01$, suggest that adolescents had different bedtimes based on school (Figure S3B in the online supplemental materials), with a later bedtime during school breaks.

There were main effects for both *social media use*, $\chi^2(1) = 456.52$, $p < .01$, and *video game time*, $\chi^2(1) = 74.03$, $p < .01$, on bedtime, with longer screen time being associated with later bedtime. Interaction effects with sex were not significant. Both screen time variables interacted with assessment, $\chi^2_{\text{social media} \times \text{assessment}}(6) = 117.19$, $p < .01$, $\chi^2_{\text{single player video game} \times \text{assessment}}(6) = 64.13$, $p = < .01$. The single slope analysis showed that social media use had significant slopes with bedtime at each assessment (simple $\text{slope}_{\text{Pre-pandemic}} = 0.19$, $p < .01$, simple $\text{slope}_{\text{May}} = 0.24$, $p < .01$, simple $\text{slope}_{\text{June}} = 0.27$, $p < .01$, simple $\text{slope}_{\text{August}} = 0.23$, $p < .01$, simple $\text{slope}_{\text{October}} = 0.10$, $p < .01$, simple $\text{slope}_{\text{December}} = 0.10$, $p < .01$, simple $\text{slope}_{\text{March}} = 0.09$, $p < .01$, Figure S6A in the online supplemental materials). For single player video game time, the slope analysis showed a significant effect only at the pre-pandemic, May, June, and August 2020 assessments (simple $\text{slope}_{\text{Pre-pandemic}} = 0.11$, $p < .01$, simple $\text{slope}_{\text{May}} = 0.13$, $p < .01$, simple $\text{slope}_{\text{June}} = 0.13$, $p = .01$, simple $\text{slope}_{\text{August}} = 0.08$, $p < .01$), indicating that video game time was associated with bedtime at these time points but not during the latter part of 2020 and early 2021 (Figure S6B in the online supplemental materials).

Sleep Onset Latency (Minutes to Sleep)

Model outputs are shown in Table S4 in the online supplemental materials. The results of the LMM showed a significant main effect of *sex*, $\chi^2(1) = 16.03$, $p < .01$, and *assessment*, $\chi^2(6) = 277.96$, $p < .01$, along with a significant *sex* × *assessment* effect, $\chi^2(6) = 21.87$, $p = .001$; Figure 1C. Adolescents had a longer sleep onset latency in May 2020 than at other time points and it was longer for girls than boys at all time points.

There was a significant main effect of *age* and interaction effect of *age* × *assessment* for sleep onset latency, $\chi^2_{\text{age}}(1) = 8.41$, $p = .004$, $\chi^2_{\text{age} \times \text{assessment}}(6) = 22.46$, $p = .001$, Figure S7 in the online supplemental materials, indicating that younger adolescents had longer sleep onset latency, with slope analysis showing that this association was only significant at May, June, August, and October 2020 ($\text{slope}_{\text{May}} = -1.10$, $p = .01$, $\text{slope}_{\text{June}} = -1.18$, $p = .01$, simple $\text{slope}_{\text{August}} = -1.33$, $p < .01$, simple $\text{slope}_{\text{October}} = -1.07$, $p = .01$). In addition, there was a significant interaction between *age* and *single player video game use*, $\chi^2_{\text{single player video game use} \times \text{age}}(1) = 5.16$, $p = .023$, with a stronger relationship between video gaming and sleep onset latency for younger participants.

Furthermore, *time spent on social media platforms* was associated with longer sleep onset latency, $\chi^2_{\text{social media}}(1) = 33.74$, $p < .01$, Figure S8A in the online supplemental materials. Finally, *Time spent on single player video games* was associated with longer sleep onset latency, $\chi^2(1) = 23.83$, $p < .01$, Figure S8B in the online supplemental materials, and there was also a significant interaction between *single player video game use* and *sex*, $\chi^2_{\text{single player video game use} \times \text{sex}}(1) = 9.75$, $p = .002$. The slope between video gaming and sleep onset latency was significant only for girls ($\text{slope}_{\text{Female}} = 1.35$, $p < .01$).

Number of Awakenings

The GLMM analysis showed that younger compared with older adolescents, $\chi^2_{\text{age}}(1) = 4.90$, $p = .027$; see Figure S9 in the online supplemental materials, and girls compared with boys woke up more frequently during the night, especially during the pandemic, $\chi^2_{\text{sex}}(1) = 47.00$, $p < .01$, $\chi^2_{\text{assessment}}(6) = 44.57$, $p < .01$, $\chi^2_{\text{sex} \times \text{assessment}}(6) = 19.25$, $p = .004$ (Figure 1D; Table S5 in the online supplemental materials).

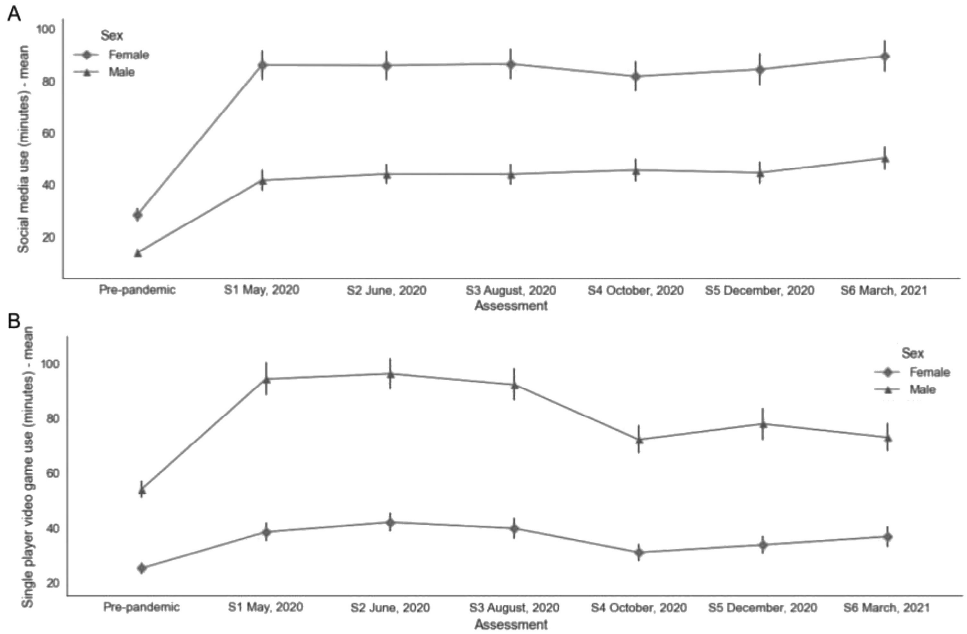
Social media use, $\chi^2_{\text{social media use}}(1) = 6.94$, $p = .008$, was associated with higher frequency of awakenings (Figure S10 in the online supplemental materials). Also, time spent on *single player video games* was associated with higher frequency of awakenings, $\chi^2_{\text{single player video game}}(1) = 3.99$, $p = .046$, $\chi^2_{\text{single player video game} \times \text{assessment-}}(6) = 21.32$, $p = .002$, specifically at the pre-pandemic assessment and in December 2020 (simple $\text{slope}_{\text{Pre-pandemic}} = 0.08$, $p < .01$, simple $\text{slope}_{\text{December}} = 0.06$, $p = .02$; see Figure S11 in the online supplemental materials).

Screen Time Analysis: Social Media and Single Player Video Games

The ratio of participants reporting social media usage between 2 and 6 hr/day increased from 2% at the pre-pandemic assessment to 12% during the pandemic (average across all six COVID-19 assessments), and the proportion of participants who had more than 6 hr of social media use per day increased from 0.5% to 2%. Conversely, the proportion of participants reporting <1 hr of social media use decreased from 92% before, to 72% during, the pandemic. Similarly, the proportion of adolescents with single player video time between 2 and 6 hr/day increased from 6% before, to 10% during, the pandemic, and the proportion reporting <1 hr gaming time decreased from 84% before, to 75% during, the pandemic. As confirmed by the GLMM (Figure 2A, B, Tables S6 and S7 in the online supplemental materials), participants increased their screen time during all pandemic assessments relative to pre-pandemic, social media: $\chi^2_{\text{assessment}}(6) = 968.2$, $p < .01$, video games: $\chi^2_{\text{assessment}}(6) = 395.95$, $p < .01$. There were sex and sex × assessment effects for social media use, social media: $\chi^2_{\text{sex}}(1) = 338.41$, $p < .01$, $\chi^2_{\text{sex} \times \text{assessment}}(6) = 118.57$, $p < .01$, with girls showing a preference for social media during the pandemic. There was a main effect of sex for single player video games, video games: $\chi^2_{\text{sex}}(1) = 751.24$, $p < .01$, and a *sex* × *assessment* interaction; video games: $\chi^2_{\text{sex} \times \text{assessment}}(6) = 102.27$, $p < .01$, with boys

Figure 2

Social Media and Video Game Use Before and Across The First Year of the Pandemic



Note. (A) Time Spent on Social Media Platforms (Markers: Mean $\pm$ CI) and (B) Time Spent on Single Player Video Games (Markers: Mean $\pm$ CI) at Different Assessments (One Pre-Pandemic Assessment and Six Pandemic Assessments), Shown Separately for Boys (Blue) and Girls (Red). CI = confidence interval. See the online article for the color version of this figure.

showing a preference for video gaming at all assessments, with a larger effect at the first three pandemic assessments.

The main effect of school and the assessment × schoolinteraction shows that adolescents had more social media use and single player video gaming when they had no school, social media: χ^2school (1) = 18.30, $p < .01$, χ^2school × assessment(5) = 19.72, $p = .001$, single player video game use: χ^2school × assessment(5) = 19.00, $p = .002$.

There was also a main effect of age, $\chi^2_{age}(1) = 106.03$, $p < .01$, and *age* × *assessment* interaction effect, $\chi^2_{age \times assessment}(6) = 17.75$, $p < .01$, for social media, Figure S12 in the online supplemental materials) with significant slopes at all time points (simple $\text{slope}_{\text{Pre-pandemic}} = 7.12$, $p < .01$, simple $\text{slope}_{\text{May}} = 12.13$, $p < .01$, simple $\text{slope}_{\text{June}} = 12.58$, $p = .01$, simple $\text{slope}_{\text{August}} = 10.49$, $p < .01$, simple $\text{slope}_{\text{October}} = 10.59$, $p < .01$, simple $\text{slope}_{\text{December}} = 9.01$, $p < .01$, simple $\text{slope}_{\text{March}} = 11.40$, $p < .01$), showing that older adolescents spent more time on social media platforms. In addition, the sex × age interaction (social media: simple $\text{slope}_{\text{Female}} = 9.66$, $p < .01$, simple $\text{slope}_{\text{Male}} = 4.68$, $p < .01$) shows that the age-related association with social media was stronger for girls. Age and age-interaction effects were not significant for single player video games.

Additional cross-sectional comparisons showed that 12-year-olds in May 2020 had a delayed bedtime ($t = -13.75$, $p < .01$, CI = [−0.87, −0.65]) and a longer TIB ($t = -11.75$, $p < .01$, [−0.75, −0.54]), than 12-year-olds assessed pre-pandemic. These results indicate that the pandemic effect is reflected in a delayed bedtime and lengthened TIB beyond developmental effects. Similarly, 12-year-olds in May 2020 had more social media ($t = -9.96$, $p < .01$, [−38.85, −26.08]) and single player video game use ($t = -8.22$, $p < .01$, [−37.51, −23.06]) than 12-year-olds assessed pre-pandemic, reflecting a pandemic effect.

Discussion

Data analyzed here from a large, diverse cohort of early adolescents across the United States show, for the first time, longitudinal changes in both sleep and screen time, and their relationship, from before and across the first year of the COVID-19 pandemic. TIB was longer at the first three pandemic assessments, then shortened for the second half of the assessments. Furthermore, participants increased screen usage during the pandemic. More screen time was associated with shorter TIB and later bedtimes and with poorer sleep quality, as reflected by longer sleep onset latency and more frequent awakenings. This relationship between screen time and sleep behavior was evident across the age range, for both boys and girls, before and during the pandemic; however, it was stronger for social media use during the second half of the pandemic assessments, when more children were involved in school activities, which may have competed with their time for recreational activities and sleep. Given the increase in screen usage during the pandemic, there is an urgent need for more awareness and education about balanced screen usage in adolescents to minimize negative effects on sleep and other health behaviors.

Sleep behavior was dramatically different, with increased TIB and later bedtimes, in May 2020 relative to pre-pandemic, which supports the findings of others (Bruni et al., 2021; Roitblat et al., 2020), and is likely due to the substantial changes in schedules during the early stages of the pandemic (e.g., youth no longer attending school in-person). Within the pandemic year of 2020, sleep behavior fluctuated, partially depending on school breaks, with participants reporting longer TIB and later bedtimes when not also completing school activities. These data support a substantial body of research conducted before the pandemic showing that sleep duration and timing are strongly influenced by school versus vacation periods (Crowley et al., 2006). In our sample, participants continued to maintain later bedtimes but woke up earlier after starting the new school year, which likely contributed to their shorter TIB in the latter part of 2020 and early 2021. It is well known that school schedules that force early wake-up times for adolescents curtail sleep periods in adolescents (Colrain & Baker, 2011), and our results suggest that this effect persisted in 2020, transcending pandemic school formats (that included online, hybrid, and in-person learning).

Sleep behavior differed according to age, with later sleep timing, shorter TIB, faster sleep onset latency, and fewer awakenings in older compared with younger adolescents, even across this relatively small age range of the ABCD study. These differences likely reflect normal developmental sleep changes (Colrain & Baker, 2011; Short et al., 2013). The age effect was less pronounced in the pandemic period of June–August 2020, when all adolescents tended to sleep longer than pre-pandemic. Sleep behavior also varied according to sex. Girls took longer to fall asleep, and had more frequent awakenings, especially during the pandemic, than did boys. Also, girls were more likely than boys to have shorter TIB and later bedtimes during the pandemic. Others have reported sex differences in sleep during adolescence, such as poorer sleep quality and greater prevalence of insomnia (de Zambotti et al., 2018). Sex differences in sleep duration and bedtimes have also been reported, although findings are inconsistent and may differ according to weekdays versus weekends, as well as age (Lin et al., 2018). Whether the sex differences in sleep that we found specific to the pandemic reflect normal sex differences in sleep or vulnerability to pandemic-related stress and mood effects in girls remain to be determined; in another analysis of the ABCD cohort (Kiss et al., 2022), female sex was a risk factor for greater vulnerability to depressed mood during the pandemic.

Older participants reported longer screen time. Similar to sleep, screen time also varies as a function of age (Rideout & Robb, 2019) and school schedule, with mid-late adolescents having longer screen time than early adolescents, and adolescents having longer screen time during the summer break (Staiano et al., 2015). There were also marked differences in screen modality preference according to sex, with girls being more likely to spend time on social media platforms and less likely to play single player video games, than boys. These findings are similar to other reports, including the ABCD Study (Nagata et al., 2022; Twenge & Martin, 2020). Regardless of age and sex, however, time spent on social media and single player video games was associated with shorter TIB, later bedtime, and more frequent awakenings, with some variation across pandemic assessments in the strength of these relationships. As documented by a systematic review on screen time and sleep in adolescents, 90% of studies have shown associations between screen time domains and shortened sleep duration and delayed bedtimes (Hale & Guan, 2015). However, the current data are the first to show the links between adolescents' screen time use and sleep during the pandemic.

Our results are particularly concerning in the context of the pandemic considering that participants' screen time was high at almost all pandemic time points, and there was no indication of any spontaneous decline into 2021. It is inevitable and adaptive that adolescents initiated reconnections of peer relationships to maintain social connectedness (Magson et al., 2021), using social media and gaming platforms as restrictions on social distancing were introduced to control the spread of the COVID-19 virus (Jebril, 2020). However, emerging data suggest that this increased screen usage is associated with poorer mood (Kiss et al., 2022) whereas less passive screen time, lower exposure to news about the pandemic, and getting sufficient sleep were associated with less psychopathology (Rosen et al., 2021) during the pandemic. The direction of causality between screen time and sleep is unclear, and it is possible that they share a bidirectional relationship. Future research is needed to explore the potential long-term effects of the increased online presence of adolescents, as people gradually resume pre-pandemic activities and daily routines, as well as directionality of the screen time–sleep relationship.

While this study used a longitudinal design to show changes in sleep, screen use, and their relationship in adolescents across the pandemic, there are limitations. Screen time measures in our dataset reflect recreational use only and do not include school-related online activities. Owing to pandemic-related restrictions, many participants had online school programs, which would have added substantially to their total daily screen time. Furthermore, while we considered whether any school activities influenced sleep, we did not examine the potentially nuanced effects of different schooling formats (e.g., remote, hybrid, in-person). Our measures of both sleep and screen time rely solely on self-report (with relatively low resolution) and may be subject to recall bias or underestimation, as self-reported measures are likely influenced by the social desirability bias (Wade et al., 2021). More precise, potentially objective sleep measurements (total sleep time, wake after sleep onset) could reveal important information about sleep health of early adolescents. We used TIB, calculated based on bedtimes and wake-up times, which is reported to be less biased than self-reported sleep duration (Lauderdale, 2015); however, teens could be in bed and yet engaged in some other activity than trying to sleep. Furthermore, the measures of screen time do not consider whether usage is a positive or negative experience, or active or passive. An advantage of the current analysis, however, was differentiation between screen time spent on video games versus social media, rather than a catch-all total screen time measure. Although results indicate that different screen modality user patterns (longer social media vs. longer single player video game time) have distinguishable effects on sleep, adolescents do not engage exclusively in one particular activity, but rather use different electronic devices and media platforms in turn or even simultaneously (Wade et al., 2021), and combined total screen usage can easily exceed 7 hr/day (Rideout & Robb, 2019). Another limitation is that we did not consider time of day of screen use, and others have shown that heavy evening screen time, in particular, delays sleep (Kubiszewski et al., 2014).

Given that adolescence is a critical period for emotional development (Shlafer et al., 2014), peer interactions (Orben et al., 2020), and emergence of mental health problems (Rosen et al., 2021), the impact of the pandemic on this age group could be particularly dramatic, shaping academic ambitions (Maestrales et al., 2021), and altering developmental trajectories for an entire generation (Hussong et al., 2021). Therefore, there is a need to implement public policy that supports positive health behaviors, such as sleep, particularly in this cohort of adolescents. Our findings show changes in sleep quantity and quality and screen time across the pandemic, and critically, that screen time increased across the pandemic beyond developmental effects and was associated with poorer sleep. It would be beneficial to increase awareness and education directed to adolescents, to promote the balanced and informed use of social media platforms, video games, and other screen usage. Also, clinicians should assess for screen time use and sleep during the pandemic and help adolescents with individual treatment plans when necessary. There is a need to increase parental awareness and help families to formulate age-appropriate media use plans (Reid Chassiakos et al., 2016). As such, the American Academy of Pediatrics endorses the development of a Family Media Use Plan (https://www.healthychildren.org/English/fmp/Pages/MediaPlan.aspx) in which families can discuss issues important for their child's health including sleep, such as turning off devices an hour before bedtime.

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