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Screen time and mental health: a prospective analysis of the Adolescent Brain Cognitive Development (ABCD) Study

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Abstract

Background Despite the ubiquity of adolescent screen use, there are limited longitudinal studies that examine the prospective relationships between screen time and child behavioral problems in a large, diverse nationwide sample of adolescents in the United States, which was the objective of the current study.

Methods We analyzed cohort data of 9,538 adolescents (9–10 years at baseline in 2016–2018) with two years of follow-up from the Adolescent Brain Cognitive Development (ABCD) Study. We used mixed-effects models to analyze associations between baseline self-reported screen time and parent-reported mental health symptoms using the Child Behavior Checklist, with random effects adjusted for age, sex, race/ethnicity, household income, parent education, and study site. We tested for effect modification by sex and race/ethnicity.

Results The sample was 48.8% female and racially/ethnically diverse (47.6% racial/ethnic minority). Higher total screen time was associated with all mental health symptoms in adjusted models, and the association was strongest for depressive (B = 0.10, 95% CI 0.06, 0.13, $p < 0.001$), conduct (B = 0.07, 95% CI 0.03, 0.10, $p < 0.001$), somatic (B = 0.06, 95% CI 0.01, 0.11, $p = 0.026$), and attention-deficit/hyperactivity symptoms (B = 0.06, 95% CI 0.01, 0.10, $p = 0.013$). The specific screen types with the greatest associations with depressive symptoms included video chat, texting, videos, and video games. The association between screen time and depressive, attention-deficit/hyperactivity, and oppositional defiant symptoms was stronger among White compared to Black adolescents. The association between screen time and depressive symptoms was stronger among White compared to Asian adolescents.

Conclusions Screen time is prospectively associated with a range of mental health symptoms, especially depressive symptoms, though effect sizes are small. Video chat, texting, videos, and video games were the screen types with the greatest associations with depressive symptoms. Future research should examine potential mechanisms linking screen use with child behavior problems.

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Keywords Screen time, Adolescents, Depression, Anxiety, Oppositional defiant disorder, Conduct disorder, ADHD, Somatic, Social media, Video games, Television, Digital technology, Digital media

Introduction

Globally, mental disorders are significant contributors to disease burden and the leading cause of disability in adolescents (10–19 years) [1]. Research has documented the rising prevalence of adolescent mental health concerns in the United States. Adolescents are 50% more likely to experience a major depressive episode today than in the early 2000s [2]. Between 2000 and 2018, suicide rates increased by 30% in this population [3]. Internalizing (e.g., anxiety, depression) and externalizing (e.g., aggression, inattention) problems in childhood or adolescence have been linked to substance use and cognitive, psychosocial, and physical health impairments later in life [4–7]. Given that the peak and median age at onset for any mental disorder worldwide is 14.5 and 18 years, respectively [8], underlying factors contributing to the development of mental health problems during this developmental period may be important to target in interventions. Furthermore, the COVID-19 pandemic led to worse mental health among adolescents, with 42% of high school students reporting persistent feelings of sadness or hopelessness, a 50% increase from 2011 [9]. Despite the increasing prevalence and burden of mental health problems in adolescents, these factors are complex, intertwined, and poorly understood [1, 10].

An increase in the amount of time spent on screen-based technologies has been hypothesized to contribute to observed increases in the prevalence of mental health problems and suicide among adolescents [11–13]. Smartphones, tablets, television, and other screen-based technologies have become increasingly ubiquitous and embedded into family life [14]. On average, 8- to 12-year-olds spend 5.5 h per day using screen media, excluding time spent online for educational and homework purposes. For teenagers aged 13 to 18 years, screen time rises to 8.5 h per day [14]. Screen time in adolescents rose by 52% on average during the pandemic [15, 16]. Some research has demonstrated a link between self-reported screen time (total amount of time spent on screens; default measure of digital technology use in most studies to date) and poor mental health outcomes [17–20]. Increased screen time may be a possible reflection of problematic screen use, including difficulty self-regulating use and consequent personal, familial, social, and school-related functional impairments. Studies have linked increased screen exposure to decreased inhibitory control neurologically and behaviorally [21, 22]. Problematic screen use has been shown to be associated with poorer mental health in adolescents [23]. However, it should be noted that higher levels of screen exposure can represent both a cause and manifestation of behavioral and emotional symptoms [24].

This positive association between screen time and poorer mental health symptoms has prompted calls for guidelines to limit screen use among adolescents [25]. Some intervention studies, conducted primarily among adults, have shown that reductions in digital media use are associated with improvements in mental health outcomes, but other studies have also found no effect or negative consequences for well-being [26, 27]. A recent cluster randomized controlled trial found that adults who were allocated to reduce their household recreational digital screen use to less than three hours per week per person reported significantly improved mental well-being and mood at two-week follow-up [28]. Another randomized controlled trial found that reducing smartphone social media use in undergraduate students aged 16 to 24 years yielded significant improvements in appearance esteem and anxiety symptoms over four weeks [29].

However, the field has relied largely on cross-sectional and correlational data, with much of the conversation on screen time and mental health treating adolescents as a relatively uniform category without recognition of the potential differential impacts of screen time based on factors such as digital media modality, sex, and race/ethnicity [20]. Furthermore, a more detailed investigation of the associations between screen time and specific domains or even disorders of adolescent psychopathology is needed to provide more targeted recommendations and strategies.

The Child Behavior Checklist (CBCL), one of the most widely used and investigated tools for detecting emotional and behavioral symptoms in children and adolescents [30], provides a dimensional assessment of child psychopathology [31]. The CBCL includes *Diagnostic and Statistical Manual of Mental Disorders* (DSM)-oriented scales, which were developed based on expert consensus to be consistent with diagnostic categories from the DSM [32]. The DSM-oriented scales are as follows: affective/depressive, anxiety, attention-deficit/hyperactivity (ADHD), somatic, oppositional defiant (ODD), and conduct symptoms [31]. Studies have demonstrated an acceptable correspondence between the DSM-oriented scales and DSM diagnoses [33–40]. Although the scores in the clinical range for specific DSM-oriented scales of the CBCL are not directly equivalent to the corresponding specific diagnosis [41, 42], the CBCL's DSM-oriented scales for depression, anxiety disorders, ADHD, somatic symptoms, ODD, and conduct disorders can be used in clinical settings for screening for psychopathology based

on the DSM classification system and enhancing diagnostic assessment [40].

Depression

Of the disorders included in the CBCL's DSM-oriented scales, depression has been the most investigated in association with screen time. More screen time has been associated with depressive symptoms among children and adolescents in several systematic reviews [11, 12, 43–50]. In a systematic review of longitudinal studies examining the relationship between screen time and internalizing mental health symptoms, Tang et al. (2021) found a small but significant correlation between screen time and subsequent depressive symptoms among adolescents aged 10 to 24 years.

Anxiety

In contrast to depressive symptoms, there are relatively few cross-sectional studies and even fewer longitudinal studies examining the association of screen time with anxiety, ADHD, somatic symptoms, ODD, and conduct disorders among children and adolescents [12, 51]. Some studies support a positive cross-sectional and longitudinal association between screen time and anxiety symptoms in adolescents [52, 53], but others found no significant association between screen time at baseline and changes in anxiety over time [54, 55]. Given the limited number of studies with mixed findings, systematic reviews have deemed the existing literature insufficient to draw conclusions [12, 45].

Attention-deficit/hyperactivity disorder

Synthesizing data from eight cross-sectional and three longitudinal studies, a systematic review from 2015 concluded that there was strong evidence to support a positive association between screen time and hyperactivity/inattention symptoms in children and adolescents [56]. A more recent review evaluating the longitudinal associations between digital media use and ADHD symptoms found reciprocal associations between digital media use and ADHD symptoms [57].

Somatic symptoms

Somatic symptom disorder is a psychiatric condition characterized by a significant focus on one or more physical symptoms, such as pain in different locations of the body, weakness, dizziness, nausea, and shortness of breath [58, 59]. Prior cross-sectional studies have examined the relationship between screen time and somatic symptoms in children, adolescents, and young adults [60–66], with the majority finding a positive association between screen time and somatic symptoms. To our knowledge, analyses of the longitudinal associations between screen time and somatic symptoms have not been published.

Conduct disorder and oppositional defiant disorder

Similarly, previous cross-sectional studies have found potential associations between screen time and symptoms of conduct disorder and ODD among adolescents [67–72]. One study of 151 adolescents at risk for mental health symptoms found an association between average daily digital technology use and more conduct disorder symptoms both on the same day and 18 months later [73]. Consistent with these findings, our group has previously found higher screen time to be prospectively associated with higher odds of conduct disorder and ODD at one-year follow-up, based on longitudinal data from a larger (n=11,875), national cohort of adolescents who participated in the ABCD Study [74].

Gaps in prior literature

Certain methodological issues, such as sampling strategies and cross-sectional design, limit the generalizability of results across studies. For instance, few existing studies feature longitudinal time frames and account for additional demographic factors, particularly race/ethnicity and sex [12, 75, 76]. Accounting for potential moderators (e.g., sex and race/ethnicity) on the impact of screen exposure on adolescent mental health could help explain the heterogeneity seen across study findings. Additionally, investigating these potential moderators may improve the identification of at-risk populations and aid in the development of more targeted interventions [51, 76]. Prior studies have identified sex differences in the relationship between screen time and mental health outcomes, but this evidence remains inconsistent across studies [11, 12, 51], calling for additional longitudinal analyses to provide further insight into the moderating effect of sex. The moderating effect of race/ethnicity in the relationship between screen time and mental health has not been as extensively studied, although there are documented disparities in screen use [77–79] and mental health outcomes [80–83] across race/ethnicity in children and adolescents. For instance, data from the ABCD Study showed that, compared to White adolescents, Black adolescents reported greater total screen time use and Asian adolescents reported lower screen time use [77]. The same analysis found that, while male adolescents reported higher overall screen time than female adolescents, female adolescents reported higher daily use of social networking, texting, and video chatting [77]. Such differences by sex and race/ethnicity could be reflected in differences in associations between screen time and mental health outcomes which warrant further investigation.

Few studies examining longitudinal links between screen time and mental health symptoms have included large national cohorts of adolescents in North America. In a recent systematic review and meta-analysis on screen time and internalizing and externalizing behaviors among children and adolescents aged 12 years or younger [84], only three North American studies included a national cohort with a sample size of 10,000 or more [62, 85, 86]. Further, all three studies featured a cross-sectional study design and did not investigate the longitudinal relationship between screen time and internalizing and externalizing behaviors in adolescents. The cross-sectional design of the majority of these studies limits the ability to establish causal and temporal effects. Longitudinal studies provide more robust data and enable the examination of correlations over time [12].

Furthermore, it remains unclear whether specific modalities of screen time (e.g., device type, digital media type, and specific websites and applications) are differentially associated with adolescent mental health outcomes, prompting a call for researchers to conduct more nuanced measurements and analyses of screen use that focus on the contents, contexts, and environments in which digital media exposures occur [11, 51, 87–90]. To address such methodological limitations in existing studies, we aim to examine the longitudinal relationships between screen time (total aggregate screen time and specific types of screen time) and mental health symptoms measured by the CBCL's DSM-oriented scales in a national cohort of adolescents in the United States [85]. Participants in the current analysis were 9 to 10 years old at baseline and were followed for two years. We hypothesized that higher screen time would be prospectively associated with higher scores on all CBCL DSM-oriented scales (anxiety, affective/depressive, somatic, ADHD, ODD, and conduct symptoms) at one- and two-year follow-up.

Methods

Study population

We used longitudinal data from baseline to Year 2 from the Adolescent Brain Cognitive Development (ABCD) Study (4.0 release). The ABCD Study is an ongoing prospective cohort study of health and cognitive development including 11,875 participants (ages 9–10 years at baseline in 2016–2018) from 21 recruitment sites across the U.S. The ABCD Study participants, recruitment, protocol, and measures are described in detail elsewhere [91]. Among 11,875 participants, 2,337 had missing data for total screen time and confounders, especially in Year 2, leaving 9,538 participants for the current analysis. Appendix A shows sociodemographic characteristics of participants who were included versus excluded from the current analysis. Institutional review board approval was received from the University of California, San Diego, and the respective IRBs of each study site. Written assent was obtained from participants, and written informed consent was obtained from their caregivers.

Variables

Independent variable: screen time

Screen time was obtained from the ABCD Youth Screen Time Survey [92]. Participants were asked to answer questions about the number of hours per weekday/weekend day they spent on six different screen modalities (excluding school use), including watching/streaming TV shows or movies, watching/streaming videos [e.g., YouTube], playing videogames, texting, video chatting [e.g., Skype, Facetime], and social media [e.g., Facebook, Instagram, Twitter]. Total screen time was calculated separately for weekdays and weekend days, based on a previously validated measure [93–95]. The following formula was used to calculate the weighted average: [(weekday average x 5) + (weekend average x 2)/7] [62]. The weighted average of total screen time was reported as a continuous variable.

Dependent variables: Child Behavior Checklist (CBCL)

The CBCL is a screening tool consisting of 112 items asking a parent/caretaker about multiple behavioral, emotional, and mental health symptoms in children and adolescents aged 4 to 18 years [96, 97]. The CBCL included six DSM-oriented scales, including depressive, anxiety, somatic, attention-deficit/hyperactivity, oppositional defiant, and conduct symptoms. Parents/caretakers responded to statements about their child's behavior using a scale from 0 (not true) to 2 (very true/often true) over the past six months. T-scores were calculated based on the CBCL scoring rubric. The CBCL has high test-retest reliability (ICC=0.95), strong validity (ability of all items to discriminate significantly $p<0.01$) [98], and acceptable internal consistency with alphas ranging from 0.63 to 0.79 [99]. Confirmatory factor analysis results for the DSM-oriented scales indicated good fit (Comparative Fit Index [CFI] of 0.96 and Root Mean Square Error of Approximation [RMSEA] of 0.045 [100, 101].

Confounders

The following variables were used in statistical models as potential confounders of the association between baseline screen time and CBCL measures including age (years), sex (female, male), race/ethnicity (White, Latino/Hispanic, Black, Asian, Native American, and other), household income (U.S. dollars, six categories: less than $25,000, $25,000 through $49,999, $50,000 through $74,999, $75,000 through $99,999, $100,000 through $199,999, and $200,000 and greater), highest parent education (high school or less vs. college or more), and

study site. Because the two-year follow-up data collection period (2018–2020) coincided with the COVID-19 pandemic, which affected both screen time and mental health, we controlled for the data collection period (before or during the COVID-19 pandemic, using March 13, 2020 as the start date of the COVID-19 pandemic in the US) in the analyses of the Year 2 data. In addition, sleep and physical activity could mediate the association between screen time and mental health, as more time on screens could displace time for sleep and physical activity, which are both beneficial for mental well-being. Sleep duration was measured by parent report based on an item from the Sleep Disturbance Scale for Children [102].

Table 1 Sociodemographic, screen time, and mental health characteristics of 9,538 Adolescent Brain Cognitive Development (ABCD) Study participants at baseline (2016–2018)

Sociodemographic and behavioral characteristics	Mean (SD) / %
Age (years), mean (SD)	9.9 (0.6)
Sex (%)	
Female	48.8%
Male	51.2%
Race/ethnicity (%)	
White	52.4%
Latino / Hispanic	20.1%
Black	17.3%
Asian	5.5%
Native American	3.2%
Other	1.5%
Household income (%)	
Less than $25,000	18.1%
$25,000 through $49,999	20.7%
$50,000 through $74,999	18.0%
$75,000 through $99,999	15.6%
$100,000 through $199,999	20.9%
$200,000 and greater	6.7%
Parent with college education or more (%)	79.7%
Recreational screen time variables	
Total screen time, hours per day, mean (SD)	4.0 (3.2)
Television shows/movies, hours per day, mean (SD)	1.3 (1.1)
Videos (e.g. YouTube), hours per day, mean (SD)	1.3 (1.2)
Video games, hours per day, mean (SD)	1.2 (1.1)
Texting, hours per day, mean (SD)	0.2 (0.6)
Video chat, hours per day, mean (SD)	0.3 (0.7)
Social media, hours per day, mean (SD)	0.1 (0.1)
Mental health symptoms (Child Behavior Checklist t-score)	
Depressive symptoms	53.9 (6.1)
Anxiety symptoms	53.6 (6.3)
Somatic symptoms	55.4 (6.6)
Attention-deficit/hyperactivity symptoms	53.2 (5.6)
Oppositional defiant symptoms	53.4 (5.4)
Conduct symptoms	52.9 (5.4)

Propensity weights were applied to yield representative estimates based on the American Community Survey from the US Census. SD = standard deviation

Physical activity was measured based on adolescent reports of the number of days in the last 7 days of spending at least 60 min per day physically active (the recommended daily level for children and adolescents from the Physical Activity Guidelines for Americans) [91, 103].

Statistical analysis

We used total screen time and each of the six screen time components at baseline as the primary independent variable. The dependent variables were repeated measures from CBCL DSM-oriented scale scores derived as repeated measures of t-scores at each year, from baseline to Year 2. We used mixed-effects models with random effects to assess the association of baseline screen time with each CBCL DSM-oriented scale. Model 1 was unadjusted. In Model 2, the outcomes were CBCL DSM-oriented scale t-scores from Year 1 and Year 2, adjusted for baseline CBCL DSM-oriented scale t-scores and the following confounders at baseline: age, sex, race/ethnicity, household income, parent education, data collection period, and study site. We also conducted a supplemental analysis adjusting for sleep and physical activity in addition to age, sex, race/ethnicity, household income, parent education, data collection period, and study site. We tested for effect modification by sex and race/ethnicity in the association between screen time and CBCL DSM-oriented scales. We present results stratified by sex or race/ethnicity for behavioral outcomes where there was evidence of effect modification by sex or race/ethnicity, respectively (p for interaction < 0.05). P-values < 0.05 were considered to indicate statistical significance. Data analyses were performed using Stata 18.0 (College Station, TX) and applied propensity weights based on the American Community Survey [104].

Results

Characteristics of the 9,538 participants are shown in Table 1. The mean age at baseline was 9.9 ± 0.6 years; 51.2% of the participants were male, and 47.6% were non-White. The average total screen time at baseline was 4.0 ± 3.2 h per day, with most time spent watching television shows/movies (1.3 ± 1.1 h/day), watching/streaming videos (1.3 ± 1.2 h/day) and playing video games (1.2 ± 1.1 h/day). Furthermore, somatic symptoms had the highest t-score (55.4), among the CBCL DSM-oriented scales (Table 1).

Table 2 shows the unadjusted (Model 1) and adjusted (Model 2) models for associations between total screen time and CBCL DSM-oriented symptom scale t-scores. Higher total screen time was associated with all DSM-oriented scales in adjusted models (Model 2), and the association was strongest for depressive symptoms (B = 0.10, 95% CI 0.06, 0.13, $p < 0.001$), conduct symptoms (B = 0.07, 95% CI 0.03, 0.10, $p < 0.001$), somatic symptoms

Table 2 Prospective associations between screen time and its subtypes with mental health symptoms in the Adolescent Brain Cognitive Development (ABCD) Study

	Depressive symptoms		Anxiety symptoms		Somatic symptoms		Attention-deficit/hyperactivity symptoms		Oppositional defiant symptoms		Conduct symptoms	
Model 1: Unadjusted	Coefficient (95% CI)	*p*	Coefficient (95% CI)	*p*	Coefficient (95% CI)	*p*	Coefficient (95% CI)	*p*	Coefficient (95% CI)	*p*	Coefficient (95% CI)	*p*
Total screen time	**0.18 (0.14, 0.22)**	**< 0.001**	**0.12 (0.06, 0.17)**	**< 0.001**	**0.10 (0.05, 0.14)**	**< 0.001**	**0.27 (0.22, 0.31)**	**< 0.001**	**0.21 (0.15, 0.27)**	**< 0.001**	**0.28 (0.21, 0.36)**	**< 0.001**
Television shows/ movies	**0.32 (0.15, 0.48)**	**0.001**	0.19 (-0.02, 0.39)	0.428	0.17 (-0.003, 0.36)	0.055	**0.50 (0.32, 0.69)**	**< 0.001**	**0.43 (0.27, 0.57)**	**< 0.001**	**0.57 (0.32, 0.82)**	**< 0.001**
Videos (e.g. YouTube)	**0.50 (0.37, 0.64)**	**< 0.001**	**0.36 (0.22, 0.51)**	**< 0.001**	**0.34 (0.22, 0.47)**	**< 0.001**	**0.56 (0.46, 0.65)**	**< 0.001**	**0.42 (0.29, 0.55)**	**< 0.001**	**0.52 (0.41, 0.65)**	**< 0.001**
Video games	**0.48 (0.37, 0.60)**	**< 0.001**	**0.30 (0.16, 0.44)**	**< 0.001**	**0.19 (0.07, 0.32)**	**0.003**	**0.61 (0.50, 0.72)**	**< 0.001**	**0.48 (0.32, 0.63)**	**< 0.001**	**0.53 (0.38, 0.68)**	**< 0.001**
Texting	**0.22 (0.06, 0.37)**	**0.008**	0.04 (-0.15, 0.22)	0.690	0.18 (-0.19, 0.54)	0.331	**0.46 (0.27, 0.65)**	**< 0.001**	**0.38 (0.11, 0.66)**	**< 0.001**	**0.75 (0.37, 1.13)**	**< 0.001**
Video chat	**0.29 (0.07, 0.51)**	**0.012**	0.02 (-0.22, 0.28)	0.536	0.07 (-0.21, 0.36)	0.589	**0.51 (0.29, 0.74)**	**< 0.001**	**0.43 (0.07, 0.80)**	**0.023**	**0.80 (0.43, 1.17)**	**< 0.001**
Social media	**0.44 (0.24, 0.64)**	**< 0.001**	0.08 (-0.19, 0.37)	0.536	0.28 (-0.04, 0.60)	0.078	**0.68 (0.40, 0.96)**	**< 0.001**	**0.71 (0.44, 0.98)**	**< 0.001**	**1.15 (0.86, 1.46)**	**< 0.001**
Model 2: Adjusted for sociodemographic factors and baseline mental health												
Total screen time	**0.10 (0.06, 0.13)**	**< 0.001**	**0.05 (0.01, 0.09)**	**0.029**	**0.06 (0.01, 0.11)**	**0.026**	**0.06 (0.01, 0.10)**	**0.013**	**0.04 (0.01, 0.07)**	**0.011**	**0.07 (0.03, 0.10)**	**< 0.001**
Television shows/ movies	**0.13 (0.01, 0.26)**	**0.036**	0.06 (-0.09, 0.21)	0.397	0.04 (-0.09, 0.16)	0.559	0.11 (-0.01, 0.24)	0.067	**0.10 (0.01, 0.19)**	**0.032**	0.11 (-0.01, 0.22)	0.063
Videos (e.g. YouTube)	**0.22 (0.13, 0.31)**	**< 0.001**	**0.17 (0.08, 0.25)**	**0.001**	**0.19 (0.09, 0.29)**	**0.001**	**0.09 (0.004, 0.17)**	**0.042**	0.07 (-0.02, 0.15)	0.114	**0.10 (0.02, 0.18)**	**0.018**
Video games	**0.20 (0.03, 0.37)**	**0.022**	0.08 (-0.02, 0.17)	0.099	0.13 (-0.001, 0.27)	0.05	**0.11 (0.05, 0.18)**	**0.001**	0.07 (-0.01, 0.15)	0.07	**0.10 (0.05, 0.16)**	**0.001**
Texting	**0.26 (0.09, 0.44)**	**0.005**	0.10 (-0.07, 0.27)	0.231	0.19 (-0.04, 0.42)	0.101	0.18 (-0.02, 0.39)	0.080	0.12 (-0.04, 0.28)	0.151	**0.33 (0.11, 0.56)**	**0.006**
Video chat	**0.35 (0.19, 0.51)**	**< 0.001**	0.12 (-0.06, 0.30)	0.189	0.05 (-0.21, 0.31)	0.683	**0.22 (0.03, 0.41)**	**0.022**	0.11 (-0.09, 0.33)	0.246	**0.35 (0.14, 0.57)**	**0.002**
Social media	0.14 (-0.09, 0.33)	0.230	0.004 (-0.24, 0.25)	0.971	0.11 (-0.16, 0.38)	0.421	0.04 (-0.31, 0.39)	0.805	0.07 (-0.19, 0.33)	0.617	0.22 (-0.02, 0.47)	0.071

Models represent the abbreviated outputs from mixed effects models examining associations between screen time and its subtypes (independent variable at baseline) and mental health symptoms (dependent variable at one- and two-year follow-up based on the Child Behavior Checklist [CBCL]). Propensity weights from the ABCD Study were applied based on the American Community Survey from the US Census

Model 1 is unadjusted

Model 2 includes random effects adjusted for age, race/ethnicity, household income, parent education, study site, baseline CBCL score, and date of CBCL administration

w(B=0.06, 95% CI 0.01, 0.11, p=0.026), and attention-deficit/hyperactivity symptoms (B=0.06, 95% CI 0.01, 0.10, p=0.013). Supplemental analyses adjusting for sleep and physical activity in addition to the covariates adjusted for in Model 2 showed similar results although some associations were slightly attenuated (Appendix B).

We stratified results by race/ethnicity for outcomes where there was evidence of significant effect modification by race/ethnicity on the associations between total screen time and CBCL DSM-oriented symptom scales. In adjusted models (Table 3), screen time was associated with higher depressive (B=0.13, 95% CI 0.09, 0.17), attention-deficit/hyperactivity (B=0.07, 95% CI 0.02, 0.13), and oppositional defiant (B=0.05, 95% CI 0.01, 0.10) symptom scores in White adolescents but not among Black adolescents. The association between screen time and depressive symptoms was stronger among White compared to Asian adolescents. There was no evidence of effect modification of screen time by sex for any of the outcomes (p for screen time*sex interaction > 0.05).

Discussion

In a demographically diverse, nationwide, longitudinal cohort of 9,538 early adolescents in the United States, the current study found that higher total screen time was prospectively associated with higher scores on all DSM-oriented scales of the CBCL at both one- and two-year follow-up, even after adjusting for confounders. These results were held after adjusting for CBCL DSM-oriented scores at baseline. The specific DSM-oriented scale most strongly associated with total screen time was depressive symptoms. In this study, the average total screen time at baseline, when participants were 9 to 10 years old, was 4.0±3.2 h per day. While the digital and in-person socialization landscape during the study's baseline period (2016 to 2018) is distinct from that of the contemporary context, the average total screen time of this study's sample is comparable to more recent national statistics for average screen time among children and younger adolescents aged 8 to 12 years in 2021 (5.5 h per day) [14].

The present study adds to the current literature on the relationship between screen time and adolescent mental health by assessing the longitudinal impact of different screen time modalities on specific domains of adolescent psychopathology that have clinical relevance. Recent reviews and meta-analyses have concluded that the literature on the mental health impacts of screen time among adolescents presents mixed findings that are difficult to collectively interpret [75, 105, 106], highlighting the need to consider different modalities of screen time [11, 51, 87, 89, 90], control for demographic variables and other potential confounders [107], and include more longitudinal perspectives [75, 108, 109].

Consistent with previous analyses, which have included longitudinal data and larger cohorts other than the ABCD Study cohort, we found weak but significant correlations between screen time and adolescents' internalizing and externalizing behavior symptoms, including depression, anxiety, ADHD, somatic, ODD, and conduct symptoms [12, 57, 84, 110, 111]. There are various factors to consider when interpreting the small effect sizes. While some have suggested that the small effect sizes suggest a small or even negligible impact of increased screen time on the prevalence of mental health

Table 3 Prospective associations between total screen time and mental health symptoms in the Adolescent Brain Cognitive Development (ABCD) Study, stratified by race/ethnicity

	Stratified by race/ethnicity										
	White subsample		**Black subsample**			**Asian subsample**			**Native American subsample**		
	Coefficient (95% CI)	***p***	**Coefficient (95% CI)**	***p***	***p*[a]**	**Coefficient (95% CI)**	***p***	***p*[a]**	**Coefficient (95%*p* CI)**		***p*[a]**
Depressive symptoms	0.13 (0.09, 0.17)	< 0.001	0.02 (-0.04, 0.09)	0.387	0.003	0.02 (-0.08, 0.13)	0.882	0.034	--	--	--
Anxiety symptoms	--	--	--	--	--	--	--	--	--	--	--
Somatic symptoms	0.10 (0.04, 0.16)	0.001	--	--	--	--	--	--	-0.17 (0.32, -0.01)	0.036	0.003
Attention-deficit/hyperactivity symptoms	0.07 (0.02, 0.13)	0.015	0.01 (-0.04, 0.06)	0.604	0.017	--	--	--	--	--	--
Oppositional defiant symptoms	0.05 (0.01, 0.10)	0.024	-0.02 (-0.07, 0.03)	0.395	0.019	--	--	--	--	--	--
Conduct symptoms	--	--	--	--	--	--	--	--	--	--	--

Models represent the abbreviated outputs from mixed effects models examining associations between screen time (independent variable at baseline) and mental health symptoms (dependent variable at one- and two-year follow-up based on the Child Behavior Checklist [CBCL]). Models include random effects adjusted for age, household income, parent education, study site, baseline CBCL score, and date of CBCL administration. Propensity weights from the ABCD Study were applied based on the American Community Survey from the US Census. Results stratified by race/ethnicity are only presented for mental health symptoms where there was evidence of effect modification by race/ethnicity

[a] *P*-value for the screen time*race/ethnicity interaction term coefficient

symptoms among adolescents [12], others have suggested that the consequences of screen time at a population level are likely meaningful despite small effect sizes [84, 112]. Regarding the interpretation of longitudinal effect sizes, it has been argued that even small associations may be of importance when controlling for baseline levels [113]. Controlling for stability effects often attenuates the magnitude of effect size coefficients in longitudinal designs. It is thus misleading to apply the same guidelines for interpreting longitudinal effect size coefficients in models that control for stability effects versus cross-sectional effect size coefficients in analyses that control for confounds, but not stability effects [113]. Further, the effect sizes reported are for each hour of screen time; given that average screen time for adolescents rose to nearly eight hours per day during the COVID-19 pandemic, these effects could be magnified [16]. These effect sizes per hour of screen time are similar in magnitude to the effect sizes previously reported on screen time and nutrition as measured by the MIND (Mediterranean-DASH [Dietary Approaches to Stop Hypertension] Intervention for Neurodegenerative Delay) diet score [114].

In this study, the specific DSM-oriented scale most strongly associated with screen time was depressive symptoms. These findings may be explained, in part, by some combination of various media effects theories that have been proposed [115], including the displacement hypothesis [116, 117]. The displacement hypothesis posits that screen time may replace time adolescents spend engaging in physical activity, sleep, in-person interactions, and other beneficial pursuits demonstrated to help reduce depression and anxiety symptoms [118–120]. Studies have also shown that higher levels of screen time were associated with reduced sleep duration and more sleep disturbances, which were in turn associated with internalizing, externalizing, and peer problems [62, 121]. The weaker but still significant associations between screen time and depressive symptoms, along with the other assessed CBCL DSM-oriented scales found after adjusting for sleep and physical activity (i.e., displacement hypothesis) in Appendix B suggest that displacement theory partially accounts for, but does not fully explain, the relationship between screen time and early adolescents' mental health symptoms.

The specific screen types with the greatest associations with depression include video chat, texting, videos (e.g., YouTube), and video games. Of note, there was not a statistically significant association between social media and depression or any of the mental health outcomes, although the coefficients were all in the positive direction. This may be due to the fact that participants' age during the data collection period for social media screen time (9–10 years old) is younger than the minimum age requirement to have a social media account (13 years old). Thus, participants on average reported spending the least screen time on social media, out of all the screen types assessed.

Moderating effect of race/ethnicity in the prospective relationship between screen time and mental health

The present study investigated the impact of race/ethnicity as a moderator in the association between screen time and mental health symptoms, demonstrating a significant association between total screen time and depressive, ADHD, and ODD symptoms in White adolescents, but not in Black adolescents. This suggests that the longitudinal associations between screen time and several mental health symptoms are significantly weaker among Black adolescents than White adolescents. In addition, the association between total screen time and depressive symptoms was stronger among White compared to Asian adolescents. The extant literature on the impact of screen exposure on the psychosocial outcomes of racial and ethnic minority adolescents in the United States is sparse [122–124]. However, it is possible that adolescents from racial/ethnic minority backgrounds who might experience isolation, bullying, or discrimination in person may use screens to connect with others with similar backgrounds, which could buffer from depression, anxiety, and other symptoms of poor mental health [125]. Further research is needed to further elucidate potential differences by race/ethnicity. Other possible explanations include cultural variability in symptom presentation, which may not be comprehensively captured by the diagnostic classification system [126]. Furthermore, as parents complete rating scales in the CBCL, they may make implicit comparisons to a culturally-based standard for how children should behave or to their child's local peers [127]. Internalized stigma about mental health may dissuade individuals from reporting symptoms or seeking help and services [126].

Strengths and limitations

Strengths of this study include the longitudinal data spanning two years of follow-up in a large, nationwide sample of adolescents in the US that was diverse, allowing the examination of moderation of effects by sex and race/ethnicity between screen time and mental health symptoms. Limitations should also be noted. Screen time was based on self-report which could be subject to response, recall, and social desirability bias. Screen time does not capture the content or context of screen use, which could be examined in future research [20, 128]. The current analysis was limited by the availability of data from the ongoing ABCD Study and could only follow adolescents for two years, starting from age 9 to 10. However, given that digital technology use among children increases with age, particularly during adolescence

[129, 130], it is important to continue characterizing the relationships between digital technology use and mental health over time. Although we examined the prospective association of screen time leading to mental health outcomes, there is the possibility of inverse causality. Bidirectional associations between screen time and mental health could be supported by the self-perpetuating feedback loop model [131], whereby screen use leads to worsening mental health and poor mental health leads to increasing reliance on screens to cope [132]. Although we controlled for age, sex, race/ethnicity, household income, parent education, and study site, there is the possibility of unmeasured confounders. The effect sizes were relatively small.

Conclusion

Our longitudinal study identified several important prospective associations between screen time and DSM-oriented symptoms in a national sample of adolescents, most notably depression and conduct symptoms. These findings can help to inform developmentally appropriate guidance related to screen use, especially for adolescents and their parents. The American Academy of Pediatrics advocates for a Family Media Use plan for children 5 to 18 years old [133], which could be individualized for adolescents based on some of the associations noted in the current study, and nuances in some associations by sex and race/ethnicity. Education, prevention, and intervention efforts may be particularly important in early adolescence given that depression and other mental health conditions increase in mid- to late-adolescence; therefore, acting of modifiable behaviors in early adolescence could be protective. Future research could examine longer-term associations with additional years of follow-up as the ABCD Study cohort ages through mid-to-late adolescence.

Abbreviations

ABCD	Adolescent Brain Cognitive Development Study
ADHD	Attention-deficit/hyperactivity
CBCL	Child Behavior Checklist
CFI	Comparative Fit Index
DSM	Diagnostic and Statistical Manual of Mental Disorders
IRB	Institutional review board
ODD	Oppositional defiant
RMSEA	Root Mean Square Error of Approximation

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12889-024-20102-x.

Supplementary Material 1

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Author contributions

Jason Nagata - conceptualization, analysis, writing-original draft and revisions, supervision Abubakr Al-shoaibi – conceptualization, data analysis, writing – original draft and revisions Alicia Leong – conceptualization, writing –original draft and revisions Gabriel Zamora – conceptualization, writing –original draft and revisions Kyle Ganson, Alexander Testa – writing -critical revisions Fiona Baker - conceptualization, data acquisition, writing-original draft and revisionsAll authors approve of the final submitted version.

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Data availability

Data used in the preparation of this article were obtained from the ABCD Study (https://abcdstudy.org), held in the NIMH Data Archive (NDA). Investigators can apply for data access through the NDA (https://nda.nih.gov/).

Declarations

Ethics approval and consent to participate

Written informed consent and assent were obtained from the parent/guardian and adolescent, respectively, to participate in the ABCD Study. The University of California, San Diego provided centralized institutional review board (IRB) approval and each participating site received local IRB approval:
- Children's Hospital Los Angeles, Los Angeles, California.
- Florida International University, Miami, Florida.
- Laureate Institute for Brain Research, Tulsa, Oklahoma.
- Medical University of South Carolina, Charleston, South Carolina.
- Oregon Health and Science University, Portland, Oregon.
- SRI International, Menlo Park, California.
- University of California San Diego, San Diego, California.
- University of California Los Angeles, Los Angeles, California.
- University of Colorado Boulder, Boulder, Colorado.
- University of Florida, Gainesville, Florida.
- University of Maryland at Baltimore, Baltimore, Maryland.
- University of Michigan, Ann Arbor, Michigan.
- University of Minnesota, Minneapolis, Minnesota.
- University of Pittsburgh, Pittsburgh, Pennsylvania.
- University of Rochester, Rochester, New York.
- University of Utah, Salt Lake City, Utah.
- University of Vermont, Burlington, Vermont.
- University of Wisconsin—Milwaukee, Milwaukee, Wisconsin.
- Virginia Commonwealth University, Richmond, Virginia.
- Washington University in St. Louis, St. Louis, Missouri.
- Yale University, New Haven, Connecticut.

All methods were carried out in accordance with relevant guidelines and regulations.

Consent for publication

Not applicable.

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Competing interests

The authors declare no competing interests.

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References

1. Erskine HE, Moffitt TE, Copeland WE, Costello EJ, Ferrari AJ, Patton G, et al. A heavy burden on young minds: the global burden of mental and substance use disorders in children and youth. Psychol Med. 2015;45:1551–63.
2. Curtin S, Heron M. Death rates due to suicide and homicide among persons aged 10–24: United States, 2000–2017. Centers for Disease Control and Prevention; 2019.
3. Curtin S. State suicide rates among adolescents and young adults aged 10–24: United States 2000–2018. Centers for Disease Control and Prevention; 2020.
4. Colder CR, Frndak S, Lengua LJ, Read JP, Hawk LW, Wieczorek WF. Internalizing and externalizing problem behavior: a test of a latent variable interaction predicting a two-part growth model of adolescent substance use. J Abnorm Child Psychol. 2018;46:319–30.
5. Otto C, Reiss F, Voss C, Wüstner A, Meyrose A-K, Hölling H, et al. Mental health and well-being from childhood to adulthood: design, methods and results of the 11-year follow-up of the BELLA study. Eur Child Adolesc Psychiatry. 2021;30:1559–77.
6. Schlack R, Peerenboom N, Neuperdt L, Junker S, Beyer A-K. The effects of mental health problems in childhood and adolescence in young adults: results of the KiGGS cohort. J Health Monit. 2021;6:3–19.
7. Rock PL, Roiser JP, Riedel WJ, Blackwell AD. Cognitive impairment in depression: a systematic review and meta-analysis. Psychol Med. 2014;44:2029–40.
8. Solmi M, Radua J, Olivola M, Croce E, Soardo L, Salazar de Pablo G, et al. Age at onset of mental disorders worldwide: large-scale meta-analysis of 192 epidemiological studies. Mol Psychiatry. 2022;27:281–95.
9. Centers for Disease Control and Prevention. Youth Risk Behavior Survey Data Summary & Trends Report: 2011–2021. Centers for Disease Control and Prevention National Center for HIV, Viral Hepatitis, STD, and TB Prevention Division of Adolescent and School Health; 2023.
10. Merikangas KR, Nakamura EF, Kessler RC. Epidemiology of mental disorders in children and adolescents. Dialogues Clin Neurosci. 2009;11:7–20.
11. Santos RMS, Mendes CG, Sen Bressani GY, de Alcantara Ventura S, de Almeida Nogueira YJ, de Miranda DM, et al. The associations between screen time and mental health in adolescents: a systematic review. BMC Psychol. 2023;11:127.
12. Tang S, Werner-Seidler A, Torok M, Mackinnon AJ, Christensen H. The relationship between screen time and mental health in young people: a systematic review of longitudinal studies. Clin Psychol Rev. 2021;86:102021.
13. Oswald TK, Rumbold AR, Kedzior SGE, Moore VM. Psychological impacts of screen time and green time for children and adolescents: a systematic scoping review. PLoS ONE. 2020;15:e0237725.
14. Rideout V, Peebles A, Mann S, Robb M. The Common Sense Census: media use by tweens and teens 2021. San Francisco: Common Sense; 2022.
15. Madigan S, Eirich R, Pador P, McArthur BA, Neville RD. Assessment of changes in child and adolescent screen time during the COVID-19 pandemic: a systematic review and meta-analysis. JAMA Pediatr. 2022;176:1188.
16. Nagata JM, Cortez CA, Cattle CJ, Ganson KT, Iyer P, Bibbins-Domingo K, et al. Screen time use among U.S. adolescents during the COVID-19 pandemic: findings from the Adolescent Brain Cognitive Development (ABCD) Study. JAMA Pediatr. 2022;176:94–6.
17. Herman KM, Hopman WM, Sabiston CM. Physical activity, screen time and self-rated health and mental health in Canadian adolescents. Prev Med. 2015;73:112–6.
18. Maras D, Flament MF, Murray M, Buchholz A, Henderson KA, Obeid N, et al. Screen time is associated with depression and anxiety in Canadian youth. Prev Med. 2015;73:133–8.
19. Twenge JM, Joiner TE, Rogers ML, Martin GN, Corrigendum. Increases in depressive symptoms, suicide-related outcomes, and suicide rates among U.S. adolescents after 2010 and links to increased new media screen time. Clin Psychol Sci. 2019;7:397.
20. Odgers CL, Schueller SM, Ito M. Screen time, social media use, and adolescent development. Annu Rev Dev Psychol. 2020;2:485–502.
21. Chen Y-Y, Yim H, Lee T-H. Negative impact of daily screen use on inhibitory control network in preadolescence: a two-year follow-up study. Dev Cogn Neurosci. 2023;60:101218.
22. Lewin KM, Meshi D, Aladé F, Lescht E, Herring C, Devaraju DS et al. Children's screentime is associated with reduced brain activation during an inhibitory control task: a pilot EEG study. Front Cogn. 2023;2.
23. Shannon H, Bush K, Villeneuve PJ, Hellemans KG, Guimond S. Problematic social media use in adolescents and young adults: systematic review and meta-analysis. JMIR Ment Health. 2022;9:e33450.
24. Xu KY, Tedrick T, Gold JA. Screen use and social media addiction in the era of TikTok: what generalists should know. Mo Med. 2023;120:440–5.
25. Browne D, Thompson DA, Madigan S. Digital media use in children: clinical vs scientific responsibilities. JAMA Pediatr. 2020;174:111–2.
26. Plackett R, Blyth A, Schartau P. The impact of social media use interventions on mental well-being: systematic review. J Med Internet Res. 2023;25:e44922.
27. Radtke T, Apel T, Schenkel K, Keller J, von Lindern E. Digital detox: an effective solution in the smartphone era? A systematic literature review. Mob Media Commun. 2022;10:190–215.
28. Pedersen J, Rasmussen MGB, Sørensen SO, Mortensen SR, Olesen LG, Brage S, et al. Effects of limiting digital screen use on well-being, mood, and biomarkers of stress in adults. Npj Ment Health Res. 2022;1:1–10.
29. Thai H, Davis CG, Stewart N, Gunnell KE, Goldfield GS. The effects of reducing social media use on body esteem among transitional-aged youth. J Soc Clin Psychol. 2021;40:481–507.
30. Warnick EM, Bracken MB, Kasl S. Screening efficiency of the Child Behavior Checklist and Strengths and Difficulties questionnaire: a systematic review. Child Adolesc Ment Health. 2008;13:140–7.
31. Achenback TM, Rescorla LA. Manual for the ASEBA school-age forms & profiles. In: Manual for the ASEBA school-age forms & profiles. Burlington, VT: University of Vermont Research Centre for Children, Youth and Families. p. 80.
32. Achenbach TM, Dumenci L, Rescorla LA. DSM-oriented and empirically based approaches to constructing scales from the same item pools. J Clin Child Adolesc Psychol off J Soc Clin Child Adolesc Psychol Am Psychol Assoc Div. 2003;53:32:328–40.
33. Bellina M, Brambilla P, Garzitto M, Negri GAL, Molteni M, Nobile M. The ability of CBCL DSM-oriented scales to predict DSM-IV diagnoses in a referred sample of children and adolescents. Eur Child Adolesc Psychiatry. 2013;22:235–46.
34. Cianchetti C, Faedda N, Pasculli M, Ledda MG, Diaz G, Peschechera A, et al. Predictive validity for the clinical diagnosis of a new parent questionnaire, the CABI, compared with CBCL. Clin Child Psychol Psychiatry. 2020;25:507–19.
35. Dingle K, Alati R, Williams GM, Najman JM, Bor W, Clavarino A. The ability of YSR DSM-oriented depression scales to predict DSM-IV depression in young adults: a longitudinal study. J Affect Disord. 2010;121:45–51.
36. Ebesutani C, Bernstein A, Martinez JI, Chorpita BF, Weisz JR. The youth self report: applicability and validity across younger and older youths. J Clin Child Adolesc Psychol off J Soc Clin Child Adolesc Psychol Am Psychol Assoc Div. 2011;53:40:338–46.
37. Ferdinand RF. Validity of the CBCL/YSR DSM-IV scales anxiety problems and affective problems. J Anxiety Disord. 2008;22:126–34.
38. Krol NPCM, De Bruyn EEJ, Coolen JC, van Aarle EJM. From CBCL to DSM: a comparison of two methods to screen for DSM-IV diagnoses using CBCL data. J Clin Child Adolesc Psychol off J Soc Clin Child Adolesc Psychol Am Psychol Assoc Div. 2006;53:35:127–35.
39. Lacalle M, Ezpeleta L, Doménech JM. DSM-oriented scales of the Child Behavior Checklist and Youth Self-Report in clinically referred Spanish children. Span J Psychol. 2012;15:377–87.
40. Skarphedinsson G, Jarbin H, Andersson M, Ivarsson T. Diagnostic efficiency and validity of the DSM-oriented Child Behavior Checklist and

Youth Self-Report scales in a clinical sample of Swedish youth. PLoS ONE. 2021;16:e0254953.
41. Rishel CW, Greeno C, Marcus SC, Shear MK, Anderson C. Use of the Child Behavior Checklist as a diagnostic screening tool in community mental health. Res Soc Work Pract. 2005;15:195–203.
42. Bordin IA, Rocha MM, Paula CS, Teixeira MCTV, Achenbach TM, Rescorla LA, et al. Child Behavior Checklist (CBCL),Youth Self-Report (YSR) and Teacher's Report Form (TRF): an overview of the development of the original and Brazilian versions. Cad Saude Publica. 2013;29:13–28.
43. Cai Z, Mao P, Wang Z, Wang D, He J, Fan X. Associations between problematic internet use and mental health outcomes of students: a meta-analytic review. Adolesc Res Rev. 2023;8:45–62.
44. Costigan SA, Barnett L, Plotnikoff RC, Lubans DR. The health indicators associated with screen-based sedentary behavior among adolescent girls: a systematic review. J Adolesc Health off Publ Soc Adolesc Med. 2013;52:382–92.
45. Hoare E, Milton K, Foster C, Allender S. The associations between sedentary behaviour and mental health among adolescents: a systematic review. Int J Behav Nutr Phys Act. 2016;13:108.
46. Keles B, McCrae N, Grealish A. A systematic review: the influence of social media on depression, anxiety and psychological distress in adolescents. Int J Adolesc Youth. 2020;25:79–93.
47. McCrae N, Gettings S, Purssell E. Social media and depressive symptoms in childhood and adolescence: a systematic review. Adolesc Res Rev. 2017;2:315–30.
48. Stiglic N, Viner RM. Effects of screentime on the health and well-being of children and adolescents: a systematic review of reviews. BMJ Open. 2019;9.
49. Wang X, Li Y, Fan H. The associations between screen time-based sedentary behavior and depression: a systematic review and meta-analysis. BMC Public Health. 2019;19:1524.
50. Liu M, Wu L, Yao S. Dose–response association of screen time-based sedentary behaviour in children and adolescents and depression: a meta-analysis of observational studies. Br J Sports Med. 2016;50:1252–8.
51. Zink J, Belcher BR, Imm K, Leventhal AM. The relationship between screen-based sedentary behaviors and symptoms of depression and anxiety in youth: a systematic review of moderating variables. BMC Public Health. 2020;20:472.
52. Zink J, Belcher BR, Kechter A, Stone MD, Leventhal AM. Reciprocal associations between screen time and emotional disorder symptoms during adolescence. Prev Med Rep. 2019;13:281–8.
53. Khouja JN, Munafò MR, Tilling K, Wiles NJ, Joinson C, Etchells PJ, et al. Is screen time associated with anxiety or depression in young people? Results from a UK birth cohort. BMC Public Health. 2019;19:82.
54. Gunnell KE, Flament MF, Buchholz A, Henderson KA, Obeid N, Schubert N, et al. Examining the bidirectional relationship between physical activity, screen time, and symptoms of anxiety and depression over time during adolescence. Prev Med. 2016;88:147–52.
55. Boers E, Afzali MH, Conrod P. Temporal associations of screen time and anxiety symptoms among adolescents. Can J Psychiatry. 2020;65:206–8.
56. Suchert V, Hanewinkel R, Isensee B. Sedentary behavior and indicators of mental health in school-aged children and adolescents: a systematic review. Prev Med. 2015;76:48–57.
57. Thorell LB, Burén J, Ström Wiman J, Sandberg D, Nutley SB. Longitudinal associations between digital media use and ADHD symptoms in children and adolescents: a systematic literature review. Eur Child Adolesc Psychiatry. 2024;33:2503–26.
58. Henningsen P. Management of somatic symptom disorder. Dialogues Clin Neurosci. 2018;20:23–31.
59. D'Souza RS, Hooten WM. In: StatPearls, editor. Somatic syndrome disorders. Treasure Island (FL): StatPearls Publishing; 2023.
60. Cerutti R, Presaghi F, Spensieri V, Valastro C, Guidetti V. The potential impact of internet and mobile wse on Headache and other somatic symptoms in adolescence. A Population-based cross-sectional study. Headache J Head Face Pain. 2016;56:1161–70.
61. Cerutti R, Spensieri V, Amendola S, Presaghi F, Fontana A, Faedda N, et al. Sleep disturbances partially mediate the association between problematic internet use and somatic symptomatology in adolescence. Curr Psychol. 2021;40:4581–9.
62. Guerrero MD, Barnes JD, Chaput J-P, Tremblay MS. Screen time and problem behaviors in children: exploring the mediating role of sleep duration. Int J Behav Nutr Phys Act. 2019;16:105.
63. Iannotti RJ, Kogan MD, Janssen I, Boyce WF. Patterns of adolescent physical activity, screen-based media use, and positive and negative health indicators in the U.S. and Canada. J Adolesc Health. 2009;44:493–9.
64. Lee DS, Jiang T, Crocker J, Way BM. Social media use and its link to physical health indicators. Cyberpsychology Behav Soc Netw. 2022;25:87–93.
65. Taehtinen RE, Sigfusdottir ID, Helgason AR, Kristjansson AL. Electronic screen use and selected somatic symptoms in 10–12 year old children. Prev Med. 2014;67:128–33.
66. Torsheim T, Eriksson L, Schnohr CW, Hansen F, Bjarnason T, Välimaa R. Screen-based activities and physical complaints among adolescents from the Nordic countries. BMC Public Health. 2010;10:324.
67. Kronenberger WG, Mathews VP, Dunn DW, Wang Y, Wood EA, Larsen JJ, et al. Media violence exposure in aggressive and control adolescents: differences in self- and parent-reported exposure to violence on television and in video games. Aggress Behav. 2005;31:201–16.
68. Liu M, Ming Q, Yi J, Wang X, Yao S. Screen time on school days and risks for psychiatric symptoms and self-harm in mainland Chinese adolescents. Front Psychol. 2016;7(APR):574.
69. Möller-Nehring E, Moach A, Castell R, Weigel A, Meyer M. Conditions facilitating social behavior disorder in children and adolescents in a clinic referred sample. Prax Kinderpsychol Kinderpsychiatr. 1998;47:36–47.
70. Mundy LK, Canterford L, Olds T, Allen NB, Patton GC. The association between electronic media and emotional and behavioral problems in late childhood. Acad Pediatr. 2017;17:620–4.
71. Paulich KN, Ross JM, Lessem JM, Hewitt JK. Screen time and early adolescent mental health, academic, and social outcomes in 9- and 10- year old children: utilizing the Adolescent Brain Cognitive Development [SM] (ABCD) study. PLoS ONE. 2021;16:e0256591.
72. Shenoi RP, Linakis JG, Bromberg JR, Casper TC, Richards R, Chun TH, et al. Association of physical activity, sports, and screen time with adolescent behaviors in youth who visit the pediatric emergency department. Clin Pediatr (Phila). 2022;61:335–46.
73. George MJ, Russell MA, Piontak JR, Odgers CL. Concurrent and subsequent associations between daily digital technology use and high-risk adolescents' mental health symptoms. Child Dev. 2018;89:78–88.
74. Nagata JM, Chu J, Ganson KT, Murray SB, Iyer P, Gabriel KP, Garber AK, Bibbins-Domingo K, Baker FC. Contemporary screen time modalities and disruptive behavior disorders in children: a prospective cohort study. J Child Psychol Psychiatry. 2023;64:125–35.
75. Orben A. Teenagers, screens and social media: a narrative review of reviews and key studies. Soc Psychiatry Psychiatr Epidemiol. 2020;55:407–14.
76. Vuorre M, Orben A, Przybylski AK. There is no evidence that associations between adolescents' digital technology engagement and mental health problems have increased. Clin Psychol Sci. 2021;9:823–35.
77. Nagata JM, Ganson KT, Iyer P, Chu J, Baker FC, Pettee Gabriel K, et al. Sociodemographic correlates of contemporary screen time use among 9- and 10-year-old children. J Pediatr. 2022;240:213–e2202.
78. Fakhouri THI, Hughes JP, Brody DJ, Kit BK, Ogden CL. Physical activity and screen-time viewing among elementary school–aged children in the United States from 2009 to 2010. JAMA Pediatr. 2013;167:223–9.
79. Anderson SE, Economos CD, Must A. Active play and screen time in US children aged 4 to 11 years in relation to sociodemographic and weight status characteristics: a nationally representative cross-sectional analysis. BMC Public Health. 2008;8:366.
80. Martin R, Banaag A, Riggs DS, Koehlmoos TP. Minority adolescent mental health diagnosis differences in a national sample. Mil Med. 2022;187:e969–77.
81. Alegria M, Vallas M, Pumariega AJ. Racial and ethnic disparities in pediatric mental health. Child Adolesc Psychiatr Clin. 2010;19:759–74.
82. Nguyen L, Huang LN, Arganza GF, Liao Q. The influence of race and ethnicity on psychiatric diagnoses and clinical characteristics of children and adolescents in children's services. Cultur Divers Ethnic Minor Psychol. 2007;13:18–25.
83. Fan Q, DuPont-Reyes MJ, Hossain MM, Chen L-S, Lueck J, Ma P. Racial and ethnic differences in major depressive episode, severe role impairment, and mental health service utilization in U.S. adolescents. J Affect Disord. 2022;306:190–9.
84. Eirich R, McArthur BA, Anhorn C, McGuinness C, Christakis DA, Madigan S. Association of screen time with internalizing and externalizing behavior problems in children 12 years or younger: a systematic review and meta-analysis. JAMA Psychiatry. 2022;79:393–405.
85. Lin S-Y, Eaton NR, Schleider JL. Unpacking associations between mood symptoms and screen time in preadolescents: a network analysis. J Abnorm Child Psychol. 2020;48:1635–47.

86. Zhu X, Haegele JA, Healy S. Movement and mental health: behavioral correlates of anxiety and depression among children of 6–17 years old in the U.S. Ment Health Phys Act. 2019;16:60–5.
87. Perlmutter E, Dwyer B, Torous J. Social media and youth mental health: assessing the impact through current and novel digital phenotyping methods. Curr Treat Options Psychiatry. 2024;11:34–51.
88. Sanders T, Parker PD, del Pozo-Cruz B, Noetel M, Lonsdale C. Type of screen time moderates effects on outcomes in 4013 children: evidence from the longitudinal study of Australian children. Int J Behav Nutr Phys Act. 2019;16:117.
89. Sanders T, Noetel M, Parker P, Del Pozo Cruz B, Biddle S, Ronto R, et al. An umbrella review of the benefits and risks associated with youths' interactions with electronic screens. Nat Hum Behav. 2024;8:82–99.
90. Twenge JM, Farley E. Not all screen time is created equal: associations with mental health vary by activity and gender. Soc Psychiatry Psychiatr Epidemiol. 2021;56:207–17.
91. Barch DM, Albaugh MD, Avenevoli S, Chang L, Clark DB, Glantz MD, et al. Demographic, physical and mental health assessments in the Adolescent Brain and Cognitive Development Study: rationale and description. Dev Cogn Neurosci. 2018;32:55–66.
92. Bagot KS, Tomko RL, Marshall AT, Hermann J, Cummins K, Ksinan A, et al. Youth screen use in the ABCD® study. Dev Cogn Neurosci. 2022;57:101150.
93. Bagot KS, Matthews SA, Mason M, Squeglia LM, Fowler J, Gray K, et al. Current, future and potential use of mobile and wearable technologies and social media data in the ABCD study to increase understanding of contributors to child health. Dev Cogn Neurosci. 2018;32:121–9.
94. Gray JC, Schvey NA, Tanofsky-Kraff M. Demographic, psychological, behavioral, and cognitive correlates of BMI in youth: findings from the Adolescent Brain Cognitive Development (ABCD) Study. Psychol Med. 2020;50:1539–47.
95. Paulus MP, Squeglia LM, Bagot K, Jacobus J, Kuplicki R, Breslin FJ, et al. Screen media activity and brain structure in youth: evidence for diverse structural correlation networks from the ABCD study. NeuroImage. 2019;185:140–53.
96. Achenbach TM, Ruffle TM. The Child Behavior Checklist and related forms for assessing behavioral/emotional problems and competencies. Pediatr Rev. 2000;21:265–71.
97. Barch DM, Albaugh MD, Baskin-Sommers A, Bryant BE, Clark DB, Dick AS, et al. Demographic and mental health assessments in the Adolescent Brain and Cognitive Development Study: updates and age-related trajectories. Dev Cogn Neurosci. 2021;52:101031.
98. Achenbach TM, Rescorla LA. Manual for the ASEBA Preschool forms and profiles. Burlington, VT: Research Center for Children, Youth, & Families; 2000.
99. Taber KS. The use of Cronbach's alpha when developing and reporting research instruments in science education. Res Sci Educ. 2018;48:1273–96.
100. Hu LT, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. Struct Equ Model. 1999;6:1–55.
101. Price M, Higa-McMillan C, Ebesutani C, Okamura K, Nakamura BJ, Chorpita BF, et al. Symptom differentiation of anxiety and depression across youth development and clinic-referred/nonreferred samples: an examination of competing factor structures of the Child Behavior Checklist DSM-oriented scales. Dev Psychopathol. 2013;25:1005–15.
102. Bruni O, Ottaviano S, Guidetti V, Romoli M, Innocenzi M, Cortesi F, et al. The Sleep Disturbance Scale for Children (SDSC). Construction and validation of an instrument to evaluate sleep disturbances in childhood and adolescence. J Sleep Res. 1996;5:251–61.
103. U.S. Department of Health and Human Services. Physical activity guidelines for Americans, 2nd Edition. Department of Health and Human Services; 2018.
104. Heeringa S, Berglund P. A guide for population-based analysis of the Adolescent Brain and Cognitive Development (ABCD) Study baseline data. bioRxiv. 2020. 2020.02.10.942011.
105. Dickson K, Richardson M, Kwan I, MacDowall W, Burchett H, Stansfield C, et al. Screen-based activities and children and young people's mental health and psychosocial wellbeing: a systematic map of reviews. London: EPPI-Centre, Social Science Research Unit, UCL Institute of Education, University College London; 2018.
106. Odgers CL, Jensen MR. Annual Research Review: adolescent mental health in the digital age: facts, fears, and future directions. J Child Psychol Psychiatry. 2020;61:336–48.
107. Ophir Y, Lipshits-Braziler Y, Rosenberg H. New-media screen time is not (necessarily) linked to depression: comments on Twenge, Joiner, Rogers, and Martin (2018). Clin Psychol Sci. 2020;8:374–8.
108. Hawkes N. CMO report is unable to shed light on impact of screen time and social media on children's health. BMJ. 2019;364:l643.
109. Viner RM, Davie M, Firth A. The health impacts of screen time: a guide for clinicians and parents. Edinburgh, Scotland: Royal College of Paediatrics and Child Health; 2019.
110. Orben A, Przybylski AK. The association between adolescent well-being and digital technology use. Nat Hum Behav. 2019;3:173–82.
111. Przybylski AK, Orben A, Weinstein N. How much is too much? Examining the relationship between digital screen engagement and psychosocial functioning in a confirmatory cohort study. J Am Acad Child Adolesc Psychiatry. 2020;59:1080–8.
112. Mougharbel F, Chaput J-P, Sampasa-Kanyinga H, Colman I, Leatherdale ST, Patte KA et al. Longitudinal associations between different types of screen use and depression and anxiety symptoms in adolescents. Front Public Health. 2023;11.
113. Adachi P, Willoughby T. Interpreting effect sizes when controlling for stability effects in longitudinal autoregressive models: implications for psychological science. Eur J Dev Psychol. 2015;12:116–28.
114. Nagata JM, Weinstein S, Bashir A, Lee S, Al-Shoaibi AAA, Shao IY et al. Associations of contemporary screen time modalities with early adolescent nutrition. Acad Pediatr. 2024;24:748–54.
115. Boers E, Afzali MH, Newton N, Conrod P. Association of screen time and depression in adolescence. JAMA Pediatr. 2019;173:853–9.
116. Kraut R, Patterson M, Lundmark V, Kiesler S, Mukophadhyay T, Scherlis W. Internet paradox: a social technology that reduces social involvement and psychological well-being? Am Psychol. 1998;53:1017–31.
117. Nie NH. Sociability, interpersonal relations, and the internet: reconciling conflicting findings. Am Behav Sci. 2001;45:420–35.
118. Philippot A, Dubois V, Lambrechts K, Grogna D, Robert A, Jonckheer U, et al. Impact of physical exercise on depression and anxiety in adolescent inpatients: a randomized controlled trial. J Affect Disord. 2022;301:145–53.
119. Rodriguez-Ayllon M, Cadenas-Sánchez C, Estévez-López F, Muñoz NE, Mora-Gonzalez J, Migueles JH et al. Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: a systematic review and meta-analysis. Sports Med 2019 499. 2019;49:1383–410.
120. Wang X, Cai Z, Jiang W, Fang Y, Sun W, Wang X. Systematic review and meta-analysis of the effects of exercise on depression in adolescents. Child Adolesc Psychiatry Ment Health. 2022;16:16.
121. Parent J, Sanders W, Forehand R. Youth screen time and behavioral health problems: the role of sleep duration and disturbances. J Dev Behav Pediatr. 2016;37:277–84.
122. Barr-Anderson DJ, Fulkerson JA, Smyth M, Himes JH, Hannan PJ, Holy Rock B, et al. Associations of American Indian children's screen-time behavior with parental television behavior, parental perceptions of children's screen time, and media-related resources in the home. Prev Chronic Dis. 2011;8:A105.
123. Foulds HJA, Rodgers CD, Duncan V, Ferguson LJ. A systematic review and meta-analysis of screen time behaviour among North American indigenous populations. Obes Rev off J Int Assoc Study Obes. 2016;17:455–66.
124. Grant VM, Tomayko EJ, Kingfisher RD. Sleep and physical activity patterns in urban American Indian children. Am J Health Behav. 2020;44:67–75.
125. Kowalski RM, Dillon E, Macbeth J, Franchi M, Bush M. Racial differences in cyberbullying from the perspective of victims and perpetrators. Am J Orthopsychiatry. 2020;90:644–52.
126. Mennies RJ, Birk SL, Norris LA, Olino TM. The main and interactive associations between demographic factors and psychopathology and treatment utilization in youth: a test of intersectionality in the ABCD Study. Res Child Adolesc Psychopathol. 2021;49:5–17.
127. Lansford JE, Godwin J, Bornstein MH, Chang L, Deater-Deckard K, Di Giunta L, et al. Parenting, culture, and the development of externalizing behaviors from age 7 to 14 in nine countries. Dev Psychopathol. 2018;30:1937–58.
128. Kaye LK, Orben A, Ellis DA, Hunter SC, Houghton S. The conceptual and methodological mayhem of screen time. Int J Environ Res Public Health. 2020;17:3661.
129. Houghton S, Hunter SC, Rosenberg M, Wood L, Zadow C, Martin K, et al. Virtually impossible: limiting Australian children and adolescents daily screen based media use. BMC Public Health. 2015;15:5.
130. Atkin AJ, Corder K, van Sluijs EMF. Bedroom media, sedentary time and screen-time in children: a longitudinal analysis. Int J Behav Nutr Phys Act. 2013;10:137.
131. Flannery JS, Maza MT, Kilic Z, Telzer EH. Cascading bidirectional influences of digital media use and mental health in adolescence. Adv Child Dev Behav. 2023;64:255–87.

132. Hartanto A, Quek FYX, Tng GYQ, Yong JC. Does social media use increase depressive symptoms? A reverse causation perspective. Front Psychiatry. 2021;12.
133. Hill D, Ameenuddin N, Chassiakos YR, Cross C, Radesky J, Hutchinson J et al. Media use in school-aged children and adolescents. Pediatrics. 2016;138.

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