



## Article

# Cognitive Dysfunction among U.S. High School Students and Its Association with Time Spent on Digital Devices: A Population-Based Study

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**Abstract:** Introduction: Cognitive dysfunction is a hallmark feature of many psychiatric disorders. We aimed to study the prevalence and predictors of cognitive dysfunction (CD) among U.S. high school students and its association with time spent on digital devices. Methods: We performed a cross-sectional survey study using YRBSS 2019 data of U.S. high school students in grades 9–12. Cognitive dysfunction was defined by difficulties with remembering, concentrating, and making decisions due to emotional, physical, or mental problems. Digital screen time was described by daily time spent on TV, computers, tablets, and phone. We performed univariate and multivariable survey logistic regression analysis to identify the prevalence of cognitive dysfunction and its association with time spent on digital devices. Results: Out of 10,317 total participants, 3914 (37.9%) reported CD. The prevalence of CD was higher in females compared to males (46.0% vs. 29.9%). Compared to participants with no CD, participants with CD reported substance abuse, such as alcohol (35.8% vs. 26.6%), marijuana (28.3% vs. 17.6%), cigarette (8.1% vs. 4.7%), and illicit drugs (18.9% vs. 9.0%) and they reported a higher prevalence ( $p < 0.0001$  for all substances). Participants who felt sad and hopeless (62.8 vs. 22.1%) reported a high prevalence of CD, whereas participants with adequate sleep reported low prevalence (15.7% vs. 25.6%). In a regression, daily video game/internet use for non-work-related activities for 4 h (aOR:1.27;  $p = 0.03$ ) and  $\geq 5$  h (aOR:1.70;  $p < 0.0001$ ) demonstrated higher odds of CD, compared to participants with no daily use. Female sex, substance use, and depressed mood were additional predictors of CD. Conclusion: The prevalence of CD is high in U.S. high-school students. Female sex, substance abuse, depressed mood, and excessive VG/PC

use is associated with high odds of cognitive dysfunction. Further research is needed to explore the complex relationship between screen time and cognitive dysfunction.

**Keywords:** YRBSS; adolescents; cognitive dysfunction; digital device

## 1. Introduction

Cognitive dysfunction refers to any deficits in attention, verbal and nonverbal learning, short-term and working memory, visual and auditory processing, problem-solving, processing speed, and motor functioning [1]. Cognitive dysfunction is a secondary manifestation of many psychiatric illnesses. In the pediatric population, ADHD, behavior problems, anxiety, and depression are the most commonly diagnosed psychiatric illnesses. In children aged between 2 and 17 years (~6.1 million), 9.4% of them reported ADHD, and between 3 and 17 years (approximately 1.9 million), 3.2% of them experienced depression [2]. Many of these conditions are associated with secondary cognitive dysfunction as a feature. Research has shown that ADHD is a prevalent condition associated with cognitive dysfunction, especially impaired inhibitory control [3]. Adolescent major depressive disorder (MDD) is associated with impulsivity and cognitive dysfunction [4].

With a steady increase in screen time in the past decade, the focus has been on studying the effects of screen time on mental health, and developmental and educational outcomes. For example, a study by Twenge et al. found that adolescents who spent more time on screen media were at increased risk of depression and suicide [5]. A study by Hu et al. found that excessive passive screen time in preschool children was negatively associated with executive functioning and social skills [6]. In 2019, teenagers (13–18 years) spent an average of seven hours per day on screen media; 18% of them reported more than 10 h of usage. Of the total daily screen time, teens spent an average of 2.4 h watching TV/DVDs/Videos, 1.2 h playing mobile, computer, or video games, and 1.1 h on social media [7]. Additional studies have explored the effects of problematic internet use and video game addictions on mental health, and cognitive and educational outcomes. Problematic internet use is defined as repetitive impairing behaviors, such as excessive video game playing, cybersex, online buying, streaming, social media use, and the inability to control the amount of time spent on the internet [8]. Problematic internet use is associated with decrements across a range of neuropsychological domains, irrespective of geographical location, supporting its cross-cultural and biological validity [9]. Individuals with severe ADHD symptoms may be at great risk of developing symptoms of video game addiction, regardless of the type of video game played or preferred [10]. Increased screen time is associated with a sedentary lifestyle and high depression rates [11]. Specifically, research has shown that frequent daily cellphone and tablet use causes sleep problems in adolescents [12]. Thus, the relationship between screen time, mental health, and cognitive and educational outcomes needs further exploration.

Many studies have used data from youth risk behavior surveys to determine the impact of screen time, video games, and internet usage on various health outcomes, including obesity, suicide, depression, and violence. Messias et al. used YRBSS 2007 and 2009 data to find associations between sadness, suicide, and excessive internet/video game use [13]. However, Lee et al. found that the association between video game/internet use and mental health varied by sex [14]. To our knowledge, no studies have been done using the YRBSS database to assess the prevalence and predictors of cognitive dysfunction among U.S. high school students. To further explore the relationship between screen time and cognitive dysfunction while adjusting for mental illness as a potential confounder, we decided to perform a retrospective cross-sectional study using the YRBSS 2019 database to identify the prevalence and predictors of cognitive dysfunction in U.S. high school students and its association with digital screen time.

## 2. Methods

### 2.1. Details of Data

The Youth Risk Behavior Surveillance System (YRBSS) contains statistics collected by the CDC to monitor health behaviors that contribute to the leading cause of morbidity and mortality among youth and adults. The six main categories monitored by the YRBSS include: (1) behaviors that contribute to unintentional injury and violence; (2) tobacco use; (3) alcohol and other drug use; (4) sexual behaviors that contribute to unintended pregnancy and STD/HIV infection; (5) dietary behaviors; and (6) physical inactivity. The YRBSS also monitors the prevalence of asthma, obesity, and other health factors. The YRBSS uses a 3-stage cluster sample design to produce a national representative sample of 9th to 12th-grade students. A new YRBSS database is released every 2 years. The latest YRBSS database at the time of this study was the YRBSS 2019 database.

### 2.2. Study Population/Study Type/Patient Characteristics

Using the YRBSS 2019 database, we performed a retrospective cross-sectional study to evaluate the prevalence of self-reported cognitive dysfunction in U.S. high school students. Participants in grades 9 to 12 were closely examined, excluding participants with missing or unknown grades (Q3) from the study. Variables, such as age, sex, race/ethnicity, grades, substance abuse, sleep duration, sadness or hopelessness, and self-reported cognitive impairment, were included in the study. Participants with missing information in these variables were excluded from the analysis.

### 2.3. Outcomes (Definitions) Primary, Secondary

The primary aim of this study was to evaluate the prevalence and predictors of self-reported cognitive impairment amongst 9–12th grade participants. The secondary aim of this study was to identify the association between digital screen time and self-reported cognitive impairment.

## 3. Measures

### 3.1. Digital Device Use & Screen Time

To identify the amount of time spent on digital devices, we used the following questions from the YRBSS 2019 database: “Q79. On an average school day, how many hours do you watch TV?” and “Q80. On an average school day, how many hours do you play video or computer games or use a computer for something that is not school work? (Count time spent playing games, watching videos, texting, or using social media on your smartphone, computer, Xbox, PlayStation, iPad, or other tablets)”. We believe that these two questions helped us gather conclusive information to quantify the digital screen time factor appropriately.

### 3.2. Cognitive Dysfunction

To identify cognitive dysfunction, we used the following question from the YRBSS 2019 database: “Q98. Because of a physical, mental, or emotional problem, do you have serious difficulty concentrating, remembering, or making decisions?”.

### 3.3. Adequate Sleep

Although adequate sleep can include a range of hours, for our study, we decided to use a precomputed sleep variable from the YRBSS data that divides participants into less than or greater than eight hours of sleep per night. To identify whether this criterion was met, we used the following question from the YRBSS 2019 database. “Q88. On an average school night, how many hours of sleep do you get?”. Responses indicating  $\geq 8$  h and those  $< 8$  h were dichotomized as “yes” or “no” to separate individuals who met the 8 h of sleep criterion vs. individuals who did not.

### 3.4. Substance Use

To identify current substance use, we used the following questions from the YRBSS 2019 database. For current cigarette smoking: "Q32. During the past 30 days, how many days did you smoke cigarettes?". For current alcohol use: "Q41. During the past 30 days, on how many days did you have at least one drink of alcohol?". For current marijuana use: "Q47. During the past 30 days, how many times did you use marijuana?". For illicit drug use during lifetime: "QNILLICT" was used corresponding to participants who reported using cocaine, inhalants, heroin, methamphetamine, ecstasy, or hallucinogens during their lifetime. All participants' reported responses to current substance use questions were dichotomized as "yes" or "no."

### 3.5. Depressed Mood

To identify depressed mood, we used the following question from the YRBSS 2019 database. "Q25. During the past 12 months, did you ever feel so sad or hopeless almost every day for 2 weeks or more in a row that you stopped doing some usual activities?". Responses were dichotomized as "yes" or "no."

### 3.6. Covariates and Confounders

Demographic characteristics included sex, age, grade, and race/ethnicity. Substance use, sleep duration, and feeling sad and hopeless were added to the analysis as predictors and potential confounders.

### 3.7. Statistical Analysis

All the analyses were performed using IBM SPSS, version 25. To account for the complex survey design of the YRBSS 2019 database, a complex sample analysis method in SPSS was used, accounting for strata, clusters, and sample weight. Descriptive statistics were derived using complex sample crosstabs with a chi-square test to determine a statistically significant association. Strata, clusters, and weight-accounted-for multivariable logistic regression analysis were used to determine the association between time spent on digital devices and self-reported cognitive dysfunction after adjusting for previously defined covariates and confounders. All statistical tests used were 2-tailed *t*-tests. The alpha level was set at 0.05, which means that *p*-values had to be equal to or less than 0.05 to indicate significance. c-index (area under the ROC curve) to evaluate the goodness of fit was calculated for the regression model.

## 4. Results

### 4.1. Demographic Characteristics

Of the total 10,317 U.S. high school students from YRBSS 2019 included in the analysis, 3914 (37.9%) of them reported cognitive dysfunction. Females reported cognitive dysfunction in higher percentages compared to males (46.0% vs. 29.9%,  $p < 0.0001$ ). Prevalence of cognitive dysfunction was higher in Hispanic (9.5% vs. 9.0%,  $p = 0.001$ ) and Multiple-Hispanic (19.7% vs. 17.5%,  $p = 0.001$ ). Among the participants with concurrent conditions, current alcohol users (35.8% vs. 26.6%,  $p < 0.0001$ ), current marijuana users (28.3% vs. 17.6%,  $p < 0.0001$ ), current cigarette smokers (8.1% vs. 4.7%,  $p < 0.0001$ ), and individuals who had ever tried illicit drugs (18.9% vs. 9.0%,  $p < 0.0001$ ) reported high frequencies of cognitive dysfunction. Participants feeling sad or hopeless reported high frequencies of cognitive dysfunction (62.8% vs. 22.1%,  $p < 0.0001$ ) (Table 1).

**Table 1.** Epidemiological characteristics and weighted prevalence of cognitive dysfunction among U.S. high school students-YRBSS 2019.

|                                   | Cognitive Dysfunction<br>N = 3914 (37.9%) | No Cognitive Dysfunction<br>N = 6403 (62.1%) | Total<br>N = 10,317 (100%) | p-Value |
|-----------------------------------|---|--|----------------------------|---------|
| Age                               |   |  |                            | 0.754   |
| 14 years old or younger           | 464 (11.9% *)                             | 763 (11.9%)                                  | 1227 (11.9%)               |         |
| 15 years old                      | 945 (24.2)                                | 1618 (25.3)                                  | 2563 (24.9)                |         |
| 16 years old                      | 1035 (26.5)                               | 1607 (25.1)                                  | 2642 (25.6)                |         |
| 17 years old                      | 944 (24.2)                                | 1506 (23.5)                                  | 2450 (23.8)                |         |
| 18 years old or older             | 519 (13.3)                                | 902 (14.1)                                   | 1420 (13.8)                |         |
| Sex                               |   |  |                            | <0.0001 |
| Female                            | 2341 (60.1)                               | 2753 (43.1)                                  | 5094 (49.6)                |         |
| Male                              | 1553 (39.9)                               | 3633 (56.9)                                  | 5186 (50.4)                |         |
| Race/Ethnicity                    |   |  |                            | 0.001   |
| Am Indian/Alaska Native           | 28 (0.7)                                  | 31 (0.5)                                     | 59 (0.6)                   |         |
| Asian                             | 185 (4.8)                                 | 305 (4.8)                                    | 490 (4.8)                  |         |
| Black or African American         | 301 (7.8)                                 | 658 (10.4)                                   | 958 (9.4)                  |         |
| Native Hawaiian/Other PI          | 6 (0.2)                                   | 25 (0.4)                                     | 31 (0.3)                   |         |
| White                             | 1995 (51.9)                               | 3385 (53.7)                                  | 5380 (53.0)                |         |
| Hispanic/Latino                   | 364 (9.5)                                 | 567 (9.0)                                    | 931 (9.2)                  |         |
| Multiple-Hispanic                 | 757 (19.7)                                | 1103 (17.5)                                  | 1860 (18.3)                |         |
| Multiple-Non-Hispanic             | 210 (5.5)                                 | 232 (3.7)                                    | 443 (4.4)                  |         |
| Grade                             |   |  |                            | 0.176   |
| 9th grade                         | 1000 (25.6)                               | 1797 (28.1)                                  | 2797 (27.1)                |         |
| 10th grade                        | 1027 (26.2)                               | 1593 (24.9)                                  | 2619 (25.4)                |         |
| 11th grade                        | 980 (25.0)                                | 1475 (23.0)                                  | 2454 (23.8)                |         |
| 12th grade                        | 907 (23.2)                                | 1539 (24.0)                                  | 2446 (23.7)                |         |
| Concurrent conditions             |   |  |                            |         |
| Current alcohol use               | 1296 (35.8)                               | 1595 (26.6)                                  | 2891 (30.0)                | <0.0001 |
| Current cigarette smoking         | 310 (8.1)                                 | 298 (4.7)                                    | 608 (6.0)                  | <0.0001 |
| Current marijuana use             | 1088 (28.3)                               | 1108 (17.6)                                  | 2195 (21.6)                | <0.0001 |
| Ever illicit drug use             | 730 (18.9)                                | 570 (9.0)                                    | 1300 (12.8)                | <0.0001 |
| Currently feeling sad or hopeless | 2433 (62.8)                               | 1403 (22.1)                                  | 3836 (37.5)                | <0.0001 |
| Currently having adequate sleep   | 609 (15.7)                                | 1626 (25.6)                                  | 2235 (21.8)                | <0.0001 |

\* The percentage (%) in the table above is column %, describing a comparison between cognitive dysfunction vs. no cognitive dysfunction.

#### 4.2. Digital Screen Time

Participants who watched TV daily for 4 h (4.9% vs. 3.9%,  $p = 0.002$ ) and 5 h or more (7.1% vs. 5.0%,  $p = 0.002$ ) reported high prevalence of cognitive dysfunction. Among the participants who played video games/used computer for non-work-related activities every day, individuals with 4 h (11.1% vs. 9.4%,  $p < 0.0001$ ) and five or more hours of usage (28.2% vs. 16.8%,  $p < 0.0001$ ) reported cognitive dysfunction in high frequencies (Table 2).

#### 4.3. Multivariable Regression Analysis

The multivariate regression analysis showed that the odds of reporting cognitive dysfunction was high in participants who played video games/used computer for non-work-related activities daily for 4 h (aOR: 1.27, 95% CI 1.02–1.58%;  $p = 0.035$ ) and five or more hours (1.70, 1.39–2.08;  $p < 0.0001$ ). Female participants were at high odds of reporting cognitive dysfunction (1.65, 1.49–1.82;  $p < 0.0001$ ). Substance abuse and depressed mood were additional significant predictors of cognitive dysfunction (Table 3).

**Table 2.** Prevalence of cognitive dysfunction among U.S. high school students with daily digital screen time-YRBSS 2019.

|   | <b>Cognitive Dysfunction<br/>N = 3914 (37.9%)</b> | <b>No Cognitive Dysfunction<br/>N = 6403 (62.1%)</b> | <b>Total<br/>N = 10,317 (100%)</b> | <b>p-Value</b>    |
|---|---|--|------------------------------------|-------------------|
| <b>Current Video Game/Non-Work-Related Computer Use</b> |   |  |                                    | <b>&lt;0.0001</b> |
| No playing video/computer game                          | 617 (15.9)  | 1138 (18.0)  | 1755 (17.2)                        |                   |
| <1 h per day  | 365 (9.4)   | 671 (10.6)   | 1037 (10.2)                        |                   |
| 1 h per day   | 277 (7.2)   | 723 (11.4)   | 1001 (9.8)                         |                   |
| 2 h per day   | 531 (13.7)  | 1139 (18.0)  | 1670 (16.4)                        |                   |
| 3 h per day   | 561 (14.5)  | 1001 (15.8)  | 1562 (15.3)                        |                   |
| 4 h per day   | 432 (11.1)  | 595 (9.4)  | 1027 (10.1)                        |                   |
| 5 h or more per day                                     | 1096 (28.2)                                       | 1065 (16.8)  | 2161 (21.2)                        |                   |
| <b>Current TV Use</b>                                   |   |  |                                    | <b>0.002</b>      |
| No TV on use  | 1135 (29.2)                                       | 1721 (27.1)  | 2857 (27.9)                        |                   |
| <1 h per day  | 774 (19.9)  | 1383 (21.8)  | 2157 (21.1)                        |                   |
| 1 h per day   | 499 (12.8)  | 987 (15.5)   | 1485 (14.5)                        |                   |
| 2 h per day   | 647 (16.7)  | 1084 (17.1)  | 1732 (16.9)                        |                   |
| 3 h per day   | 361 (9.3)   | 604 (9.5)  | 966 (9.4)                          |                   |
| 4 h per day   | 190 (4.9)   | 250 (3.9)  | 440 (4.3)                          |                   |
| 5 h or more per day                                     | 278 (7.1)   | 316 (5.0)  | 594 (5.8)                          |                   |

**Table 3.** Multivariable logistic regression establishes an association of cognitive dysfunction with digital screen time.

| <b>Parameter</b>  | <b>Adjusted Odds Ratio</b> | <b>Confidence Interval Lower Limit</b> | <b>Confidence Interval Upper Limit</b> | <b>p-Value</b> |
|---|----------------------------|--|--|----------------|
| <b>Current Video Game/Non-Work-Related Computer Use</b> |                            |  |  |                |
| No use  | Reference                  |  |  |                |
| <1 h per day  | 1.11                       | 0.87                                   | 1.400                                  | 0.399          |
| 1 h per day   | 0.80                       | 0.61                                   | 1.05                                   | 0.099          |
| 2 h per day   | 1.01                       | 0.82                                   | 1.23                                   | 0.957          |
| 3 h per day   | 1.05                       | 0.82                                   | 1.35                                   | 0.676          |
| 4 h per day   | 1.27                       | 1.02                                   | 1.58                                   | 0.035          |
| 5 h or more per day                                     | 1.70                       | 1.39                                   | 2.08                                   | <0.0001        |
| <b>Current TV Use</b>                                   |                            |  |  |                |
| No TV use   | Reference                  |  |  |                |
| <1 h per day  | 0.98                       | 0.81                                   | 1.18                                   | 0.832          |
| 1 h per day   | 0.98                       | 0.79                                   | 1.22                                   | 0.861          |
| 2 h per day   | 1.01                       | 0.81                                   | 1.26                                   | 0.908          |
| 3 h per day   | 0.88                       | 0.68                                   | 1.13                                   | 0.295          |
| 4 h per day   | 1.05                       | 0.82                                   | 1.35                                   | 0.676          |
| 5 h or more per day                                     | 1.05                       | 0.79                                   | 1.39                                   | 0.727          |
| <b>Age</b>  |                            |  |  |                |
| 14 years old or younger                                 | Reference                  |  |  |                |
| 15 years old  | 0.99                       | 0.75                                   | 1.30                                   | 0.932          |
| 16 years old  | 0.99                       | 0.71                                   | 1.37                                   | 0.930          |
| 17 years old  | 1.00                       | 0.67                                   | 1.50                                   | 0.983          |
| 18 years old or older                                   | 0.99                       | 0.61                                   | 1.60                                   | 0.95           |

Table 3. Cont.

| Parameter                                      | Adjusted Odds Ratio | Confidence Interval Lower Limit | Confidence Interval Upper Limit | p-Value |
|--|---------------------|---------------------------------|---------------------------------|---------|
| Sex  |                     |                                 |                                 |         |
| Female   | 1.65                | 1.49                            | 1.82                            | <0.0001 |
| Male   | Reference           |                                 |                                 |         |
| Race/Ethnicity                                 |                     |                                 |                                 |         |
| Am Indian/Alaska Native                        | 1.49                | 0.70                            | 3.16                            | 0.289   |
| Asian  | 1.25                | 0.91                            | 1.73                            | 0.166   |
| Black or African American                      | 0.78                | 0.62                            | 0.99                            | 0.039   |
| Native Hawaiian/Other PI                       | 0.44                | 0.15                            | 1.33                            | 0.140   |
| Hispanic/Latino                                | 0.96                | 0.75                            | 1.24                            | 0.759   |
| Multiple-Hispanic                              | 1.09                | 0.92                            | 1.28                            | 0.320   |
| Multiple-Non-Hispanic                          | 1.36                | 1.10                            | 1.70                            | 0.007   |
| White  | Reference           |                                 |                                 |         |
| Grade  |                     |                                 |                                 |         |
| 9th  | Reference           |                                 |                                 |         |
| 10th   | 1.13                | 0.89                            | 1.42                            | 0.303   |
| 11th   | 1.05                | 0.73                            | 1.51                            | 0.790   |
| 12th   | 0.85                | 0.55                            | 1.32                            | 0.465   |
| Concurrent conditions                          |                     |                                 |                                 |         |
| Current Alcohol Use (Yes vs. No)               | 0.99                | 0.83                            | 1.18                            | 0.876   |
| Current Cigarette Smoking (Yes vs. No)         | 0.96                | 0.70                            | 1.32                            | 0.798   |
| Current Marijuana Use (Yes vs. No)             | 1.43                | 1.22                            | 1.68                            | <0.0001 |
| Ever Illicit Drug Use (Yes vs. No)             | 1.45                | 1.12                            | 1.88                            | 0.006   |
| Currently Feeling Sad or Hopeless (Yes vs. No) | 4.95                | 4.12                            | 5.95                            | <0.0001 |
| Currently Having Adequate Sleep (Yes vs. No)   | 0.77                | 0.65                            | 0.91                            | 0.003   |
| C-Value (area under the ROC curve)             |                     |                                 |                                 | 0.759   |

## 5. Discussion

We found that 37.9% of U.S. high school students reported cognitive dysfunction. Females and participants with concurrent substance abuse reported high frequencies of cognitive dysfunction. The prevalence of cognitive dysfunction is significantly higher in participants currently feeling sad and hopeless. In the adjusted regression model, besides the excessive screen time spent on video games/internet, female sex, substance abuse, and depressed mood were significant predictors of cognitive dysfunction.

Regarding the association between screen time and cognitive dysfunction, our results based on the adjusted regression model indicate that the relationship between digital screen time and cognitive dysfunction depends on the amount of time spent and the type of device used. For example, we found that playing video games or using the internet on computers/tablets for non-work-related activities for four or more hours per day is associated with increased odds of reporting cognitive dysfunction. However, we did not find such an association for daily TV use. In support of our findings, an NIH funded cohort study performed by Vohr et al. found that high screen time was independently associated with defects in executive functioning and adverse behavioral outcomes at the age of 6 to 7 years in children born at less than 28 weeks [15]. Similarly, McHarg et al. found that screen time at the age of 2 was negatively associated with the development of executive functioning in toddlerhood from age 2 to 3 [16]. Both of these studies explored the effects of excessive screen time during the critical brain development period and hypothesized that sensory deprivation and social exclusion from excessive screen time could be the reason behind adverse cognitive and behavioral development. While there is some evidence to link excessive screen time directly to cognitive dysfunction, there is plenty of evidence



and theories to explain how excessive screen time could lead to mental illness directly or indirectly, which could then lead to cognitive dysfunction as a result of mental illness. Thus, both cognitive impairment and adverse behavioral outcomes remain inseparable when studying the effects of excessive screen time.

While there is no cutoff separating healthy video game/internet use from pathological use, based on our results, 4 or more hours of daily video game/internet use on computers/tablets for non-work-related activities might fall under pathological or excessive usage. A study by Gentile et al. found that pathological video game use was associated with poor school performance in children aged 8–18 [17]. Poor school performance in children could be explained by cognitive impairment secondary to pathological video game usage. Similarly, previous studies have shown that problematic internet use in adolescents is also associated with impaired decision-making, impulsivity, and memory deficit. Such a deficit in decision-making areas of the brain among people with an Internet gaming disorder could potentially increase the risk of substance abuse and subsequent depression [18–20]. Our results support this notion as we found that, along with excessive usage of video games/internet (four hours or more per day), concurrent substance abuse and currently feeling sad and hopeless were associated with high odds of cognitive dysfunction. Another possibility is that excessive screen time could lead to a sedentary lifestyle that could increase the odds of developing depression and subsequent cognitive dysfunction [11]. The argument against this theory is that pathological TV use is not associated with cognitive dysfunction as per our results. Similarly, Messias et al. found an association between excessive video game use, sadness, and suicidality, but they reported no statistically significant association between TV use, sadness, and suicidality using the YRBSS 2007 and 2009 data [13]. These results suggest that excessive video games/internet use on computers/tablets for non-work-related activities are uniquely associated with sadness, suicidality, and cognitive dysfunction. The high odds of cognitive dysfunction in females could be explained by higher social media usage, making females more vulnerable to cyberbullying, and increasing insecurities about body image, leading to depression and eventually cognitive dysfunction as a result [21–23].

Our results indicate that only pathological use of video games/internet use on computers/tablets for non-work-related activities were associated with increased odds of cognitive dysfunction. The high prevalence rate of self-reported cognitive dysfunction in U.S. high school students necessitates further screening of these individuals. Cognitive dysfunction associated with many pediatric psychiatric disorders is either reversible with treatment or reduced symptomatically with treatment. Thus, it is crucial to identify them early to prevent the adverse effects of cognitive dysfunction on academic and social settings and relationships.

#### *Strengths and Limitations*

The strength of our study is that we have used nationally representative data with a large sample size; thus, improving the generalizability of our results. Despite these strengths, our study has some limitations. First, the YRBSS questionnaire asks about the number of hours spent daily on TV, video games/internet use on computers/tablets, but it does not ask about the type of content seen and activities performed on these devices. Second, YRBSS groups video game use and internet use on computers/tablets together. Thus, it was not possible to study the individual effects of each activity. Third, the type of cognitive dysfunction that we used for our study was self-reported (subjective), and no objective neurocognitive test was used to identify cognitive dysfunction. Finally, due to our study's cross-sectional design, we could not establish a temporal relationship between cognitive dysfunction and digital screen time.

#### **6. Conclusions**

There is a high prevalence of cognitive dysfunction among U.S. high school students. Female sex, substance use, depressed mood, and video game/internet use for 4 or more



hours daily were significant predictors of cognitive dysfunction. Further screening of such students is needed to identify reversible causes of cognitive dysfunction, identify and treat underlying psychiatric illnesses, and substance abuse, and reduce such impairment's academic and psycho-social impact. The association between digital screen time and cognitive dysfunction is complex. Only those who played video games/used computers for non-work-related activities for four hours or more per day were at higher odds of reporting cognitive dysfunction. We found no association between TV use and cognitive dysfunction. Further research is needed to explore the relationship between digital screen time and cognitive dysfunction.

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