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The Impact Of Prolonged Screen Time On Children's Development: Exploring Associations With Obesity, Depression, Anxiety, Sleep And Attention Deficit Hyperactivity Disorder

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Abstract:

This research study investigates the multifaceted impact of prolonged screen time on the development of children, with a specific focus on its associations with obesity, depression, anxiety, sleep patterns, and attention deficit hyperactivity disorder.

This paper study relied on the method of a systematic review, where several 15 papers obtained from two database platforms (PubMed and Springer) were analyzed. The selected studies were longitudinal study, cohort study, and cross-sectional to identify patterns and trends in the associations between screen time and the specified developmental outcomes.

Our findings suggest that prolonged screen time is significantly associated with higher rates of childhood obesity, ADHD, depression, and anxiety along with a substantial decrease in sleep quality.

The findings of this study highlight the crucial importance of promoting a balanced approach to screen use in order to prevent many other issues in the development of children.

Keywords: Prolonged Screentime, Children development, Obesity, Depression, Anxiety, Sleep, attention deficit hyperactivity disorder.

Introduction:

Residing within an era characterized by advanced digitization, screens wield significant influence in the lives of young individuals. The availability of screens in daily routines has undoubtedly expanded opportunities for various purposes, including accessing educational information, aiding in professional tasks, and enhancing our social networking skills. However, excessive use and lack of regulation have raised concerns about its potential impact on children's cognition, physical health, and socio-emotional well-being. The objective is to shed light on the correlation of increased screen time and its impact on children's development, inspecting associations with obesity, depression, anxiety, sleep, and attention-deficit/hyperactivity disorder (ADHD).

This research paper explores multidimensional rapport of prolonged screen time. The World Health Organization has recommended guidelines for screen time in children which are as follows: 0-1 years old no screen time recommended, 2-4 years old should have no more than 1 hour of screen time per day, 5-18 years old are encouraged to have healthy habits with screen time usage (World Health Organization, 2019). Any amount of screen time beyond these recommendations are defined as prolonged screen time. It is encouraged for children 5-18 years old to find ways to monitor screen time usage such as parental controls, turn off screens during designated times, take screens out of the child's bedroom, and do not utilize them as a means to calm or distract the child (American Academy of Children and Adolescent Psychiatry, 2020).

Prolonged screen time is highly associated with obesity. Screen-based sedentary time has shown to increase the risk of obesity and directly accelerates the risk of metabolic dysfunctions such as hypertension, dyslipidemia, and type-two diabetes (Zhang, et al., 2022). Obesity has correspondingly shown to interfere with the maturation of children by impairing skeletal muscle strength and structure, language ability, cognitive and psychosocial development. (Zhang, et al., 2022). According to the World Health Organization (WHO), more than 1 billion people are obese worldwide, of which 39 million are children, and continues to rise (World Health Organization, 2022). Thus, this paper aims to study the effect of increased use of screens and its impact on obesity in children.

Sleep disturbance is another significant health concern linked to the increased use of screens. Screens affect children's development by delaying bedtime and poor sleep quality, particularly in the evening (Lisbeth, et al., 2021). As the amount of time spent on screens has increased in children, the total sleep duration has decreased (Tan, et al., 2021). Electronic devices emit blue light through the screen and have shown to reduce the secretion of melatonin (Ines, et al., 2022).

Excessive use of screens is negatively associated with behavioral and emotional well-being of children. This raises concerns regarding children's mental health, encompassing anxiety, depression, and attention-deficit/hyperactivity disorder (ADHD). A recent study implemented on children during 2020-2021, reported a positive correlation between excessive screen use and associated anxious and depressive symptoms (Amira, et al., 2023). Children who spent one hour per day on screens have shown to develop anxiety and depression less in comparison to children who spent more than an hour per day (Jean, et al., 2018). Some studies have also suggested a potential association between excessive screen use and its contribution to attention problems and impulsivity, which are hallmark symptoms of ADHD. A study performed in China on children aged zero to three years old concluded that early screen exposure in children under the age of three years old with more than 90 minutes of screen exposure was associated with ADHD with a 1.98 [95% confidence interval (C): 1.05, 3.78) (Wu, et al., 2022). Hence, this paper emphasizes the need for caregivers, educators, and healthcare professionals to be aware of the potential risks associated with excessive screen time and its negative impact on children's physical and mental well-being.

Method:

To explore and support the hypothesis of this systematic review paper, PubMed and Springer Link at https://pubmed.ncbi.nlm.nih.gov and https://link.springer.com/ were the databases used to search for and retrieve relevant published literature. Search strategies, including the use of keywords, were implemented to narrow down the quantity of search results. This paper systematically reviews studies to evaluate the relationship between The Impact of Prolonged Screen Time on Children's Development and Obesity, Depression, Anxiety, sleep, and ADHD. Keywords used in the search included, but were not limited, to (prolonged screen time on Children), (prolonged screen time on Children) AND (Obesity), (prolonged screen time on Children) AND (Depression), (prolonged screen time on Children) AND (Anxiety), (prolonged screen time on Children) AND (Sleep), (prolonged screen time on Children) AND (ADHD). Other keywords used also included: (Children's development) AND (prolong screen time), (Children's Development) AND (Lengthen screen time).

To come up with this research, the researchers used only two databases to source information from interment and literature. For example, the

specific databases used by the studies include; PubMed and Springer. The study was limited to specific databases that addressed scientific topics on the effects of prolonged screen time on children's development exploring Associations with Obesity, Depression, Anxiety, sleep, and ADHD.

An additional search strategy involved applying relevant filters in accordance with the predefined inclusion and exclusion criteria. The articles were selected based on specific inclusion criteria, which encompassed the following: being composed in the English language, having been published in the past 3 years (from 2020 to 2023) (relatively recent reports), being freely available to the general public through medical journals, adhering to rigorous research methodologies involving both experimental and control groups, having been conducted by qualified authors affiliated with reputable institutions without any evidence of bias or result manipulation, and lastly, containing an adequate amount of relevant information to fulfill the objectives of this paper. The exclusion criteria encompassed literature written in languages aside from English, publications that exceeded a three years in age, materials not available to the general public without cost, those lacking sound research methodologies and control groups, and any secondary literature such as meta-analyses, literature reviews, etc.

A thorough analysis of the papers was conducted, and we incorporated the findings and conclusions of each paper that pertained to the primary topic of our research. It is shown in Figure 1 PRISMA flow chart that can be found in the appendix of this paper.

Upon carefully reviewing research papers identified through the methodology outlined in the respective database sections, specific attention was given to those articles directly relevant to the variables and subject matter in question. These articles were then subjected to a systematic inclusion and exclusion process, guided by the criteria set forth in the methodology section. This step-by-step approach exclusion process was performed to reduce the result number of papers to only include the papers that directly related to our topic of interest. After careful analysis, fourteen papers were ultimately selected.

Following the initial retrieval of search records, duplicate entries were eliminated, reducing the number of papers. Subsequently, upon meticulous analysis of abstracts, additional articles were excluded due to their failure to meet the eligibility criteria and their lack of relevance to the objectives of this review. Evaluation of the entirety of each paper led to the further exclusion of more articles because some sections of the articles did not meet the eligibility criteria.

The focus of the studies of interest was The Impact of Prolonged Screen Time on Children's Development: Exploring Associations with Obesity, Depression, Anxiety, sleep and ADHD. fourteen relevant quantitative studies published within the last decade were selected for review in this paper. A summary of the number of studies and their corresponding study design may be found in Table 1 in the appendix. The evidence table, labeled Table 2 in the appendix, was created using the fourteen selected studies. The table's columns were filled out using information from each study's Materials and Methods and Results sections. Table 2 shows the selection of studies was based on a set of inclusion and exclusion criteria, which were categorized by criteria such as first author, date of publication, study design, level of evidence, study population, and outcomes.

Result:

The initial literature search yielded 3,086 results within the set time range of 2020-2023. The inclusion criteria was implemented to then give a result of 108 articles more specifically directed at prolonged screen time where 27 duplicates were removed. Of these results, 81 articles were

identified for abstract review and 39 articles excluded from this study based on the eligibility criteria. This led to 42 full text review articles where another 27 articles were removed based on criteria. In total, fourteen met the inclusion criteria and were included in this systematic analysis.

The correlation between obesity and prolonged screen time included three articles that carefully studied their relationship. The article published by Nagata et al. (2021), looked at a sample of 11,875 children between 9 to 11 years old and screened how often they utilize screens along with the correlated BMI. The study proved that each additional hour of screen time correlated with a 0.22 higher BMI percentile at the one year follow up (95% CI 0.10-0.34) (Nagata et al., 2021). In relation to the specific activities of screen time usage: texting (B=0.92, 95% CI 0.29-1.55), video chat (B=0.72, 95% CI 0.09-1.36), and video games (B=0.42, 95% CI 0.06-0.78) all displayed with an increased BMI in these children (Nagata et al., 2021). Another study examined 74 children to compare their physical activity levels, sleep duration, screen time, and diets pre and post the COVID-19 pandemic (Burkart et al., 2021). As expected, physical activity levels, screen time usage, sleep duration, and diet were significantly worse during the COVD-19 pandemic (Burkart et al., 2021). During the pandemic, sedentary behavior increased (+79 min; 95% CI = 60.6, 97.1), sleep onset shifted later in the night (+124 min; 95% CI = 112.9, 135.5), screen time increased (+97 min, 95% CI = 79.0, 115.4), and food intake increased (healthy: +0.3 foods, 95% CI = 0.2, 0.5; unhealthy: +1.2 foods, 95% CI = 1.0, 1.5) (Burkart et al., 2021). Each of these behaviors studied strongly correlated with an increased BMI in this study.

Depression in today's society seems to affect individuals at younger and younger age ranges. With the ever changing developments in technology, prolonged screen time in children may lead to an increased occurrence of depression. An article by Zhao et al. (2023), looked at 5,166 children aged 9-10 years old focusing on structural brain changes over two years. The study found that prolonged screen time displayed higher levels of internalized problems such as depression and anxiety (Zhao et al., 2023). With the relative increase in screen time these children demonstrated increased levels of apparent depression. Children with prolonged screen time also demonstrated architectural brain differences in the medial prefrontal cortex displaying low gray matter volume expansion with gray matter cortical volume decreases (Zhao et al., 2023). Not only is the escalation in screen time demonstrating higher rates of depression, but it also now anatomically changes their brain architecture. To continue with the association of increased screen time and its relationship to depression, 23,573 Japanese children from 8 to 15 years old took part in a cross sectional study proving that new forms of screen time like social media and video games increased the likelihood of depression in these children while watching TV did not have a strong correlation (Kidokoro et al., 2021). This study also proved that increased activity levels decreased the prevalence of depression (Kidokoro et al., 2021). The final article that examined the relationship between screen time and depression in children was conducted by Ma et al. (2021), which studied the types of screen activities (social media, video games, groups video games, watching TV), the range of depressive symptoms, and gender differences. This study used data from the Children of Immigrants Longitudinal Survey in Four European Countries (CILS4EU) that involved 3,556 children between 14-15 years of age (Ma et al., 2021). It found that social media use that exceeded two hours per day held a higher likelihood for depressive symptoms (Ma et al., 2021). The study also addressed the topic that not watching TV at all showed an increased risk of depression as compared with those who watched

at least two hours per day of TV (Ma et al., 2021). Solo video gaming and group video games were not associated with an increased likelihood of depressive symptoms in this study (Ma et al., 2021). Overall, prolonged screen time in children did display an increased propensity for depressive symptoms along with some effect on brain development.

When looking at prolonged screen time in children a possible correlation exists with increased levels of associated anxiety. A study by Charmaraman et al. (2021), evaluated 11-14 year old children's social media usage. The survey conducted included questions regarding: social media comparison, celebrity followings, frequency of usage, social anxiety, feelings of loneliness, symptoms of depression, and ease of connecting with new people (Charmaraman et al., 2021). Results of the survey concluded that 19% (N=70) of children felt negatively about themselves after using social media (Charmaraman et al., 2021). Both male (16%, N=11) and female (84%, N=59) children noted negative feelings towards their body shape, size, and attractiveness with females affected more (Charmaraman et al., 2021). Children who reported negative feelings towards their appearance after using social media recorded higher online check-in frequencies [F(1,354)=5.11, p=.024] (Charmaraman et al., 2021). Those who expressed a negative self-image perception due to social media displayed online social anxiety [F(1,324)= 35.15, p=.000], symptoms of depression [F(1,365)=29.36, p=.000], increased isolation [F(1,362)=5.80, p=.017], and challenges in creating new friendships [F(1,360)=9.34, p=.002] (Charmaraman et al., 2021). An interesting correlation existed among children who followed celebrities. Children who followed celebrities inherently checked social media more often [F(1,381)=27.89, p=.000], recorded increased online social anxiety [F(1,286)=8.82, p=.003], and experienced a greater degree of depressive symptoms {F(1,296)=5.04, p=.026] (Charmaraman et al., 2021). An additional study focused on the amount of time children spend playing video games and how that affects their anxiety levels (De pasquale et al, 2021). As far as the levels of reported associated anxiety, the test for anxiety and depression yielded a mean of 135 (SD 16.8) defined as moderate and a low average children's anxiety scale score of 2.2 (SD 2.1) (De pasquale et al, 2021). The outcome concluded that online video games were linked to state anxiety ($r=0.19$, $p<0.05$), frequency of usage ($r=0.17$, $p<0.05$), and reinforcement tactics ($r=0.21$, $p<0.01$) (De pasquale et al, 2021). State anxiety held a positive correlation with online video game usage in male children ($r=0.26$, $p<0.05$) and female children ($r=0.22$, $p<0.05$) (De pasquale et al, 2021). Comparing the two, trait anxiety displayed a small amount of significance (standardized beta 0.192, t=2.47, p=0.054) while state anxiety (standardized beta 0.152, t=1.94, p=0.01) demonstrated a higher degree of significance with online video games based on the regression analysis (De pasquale et al, 2021). The final article investigated the effect that prolonged screen time had on anxiety and more specifically FOMO (fear of missing out) (Tanrikulu et al., 2022). A path model explored the correlation between extrinsic and intrinsic goals, age, FOMO, social anxiety, study interference, in-school usage, GPA, and social media check-ins (CFI>0.950, RMSEA<0.050, SRMR<0.050) (Tanrikulu et al., 2022). The result yielded an adequate fit (p=0.069, CFI=0.974, SRMR=0.022, RMSEA=0.040 [90%-CI:0.000, 0.0711]) (Tanrikulu et al., 2022). Social anxiety and the adolescents extrinsic values positively correlated with FOMO (Tanrikulu et al., 2022). Female students displayed higher levels of FOMO (B=0.16, SE=0.06, z=2.58, p=0.010, B=0.11) along with better grades (B=2.20, SE=0.92, z=2.38, p=0.017, B=0.10) (Tanrikulu et al., 2022). An additional factor pertained to the age range where the older end of the age range

accounted for higher social media check-ins during school (B=0.06, SE=0.03, z=2.21, p=0.027, B=0.10) (Tanrikulu et al., 2022). A positive relationship exists between FOMO and social anxiety where social anxiety has also been linked to increased social media frequency (Tanrikulu et al., 2022). The sum of these articles portrays the fact that prolonged screen time in children holds a positive correlation with increased anxiety.

Three articles were included to address the relationship between prolonged screen time and sleep in children. A prospective cohort study conducted by Emond et. al. (2021), explored the relationship between sleep quantity and screen time exposure in infants. The study accounted for 558 mother-infant relationships where the infants were between 3-12 months old (Emond et. al., 2021). It used longitudinal observation to collect data to find that infants who watched more screen time had less sleep duration (Emond et. al., 2021). With this information, caution can be noted for how much screen time infants are allowed at such a pivotal point in their development. Another study examined prolonged screen time and its association with decreased sleep duration by collecting data from 4,835 overweight children from the IDEFICS/I.Family cohort where the parents reported the daily hours of screen time and their child's sleep duration (Guzman et al., 2022). It concluded for every additional hour of screen time and every hour lost sleeping children of an average weight had an increased risk of becoming overweight with an odds ratio of 1.16 and 1.23 (Guzman et al., 2022). In considering both factors, the odds ratio was 1.13 for screen time and 1.20 for sleep duration, where sleep duration had a slightly stronger association with overweight children (Guzman et al., 2022). The final study conducted by Lan et al. (2020), collected data through parent completed questionnaires from 2,903 preschool aged children about their electronic media use and sleep patterns including those of their parents (Lan et al., 2020). Of the preschool aged children studied, 40% of those children were not meeting the recommended sleep duration for the night (Lan et al., 2020).. For each additional hour of prolonged screen time use, an association existed with 11 (95% CI: -15 and -6) and 6 (95% CI: -10 and -2) minutes less average daily sleep along with the fact that having easier access to an electronic device or a TV in their bedrooms lead to an increased social jetlag in boys specifically (Lan et al., 2020). Overall, these studies addressed the topic that prolonged screen time in children leads to less nighttime sleep. More specifically, not only less sleep time but worse sleep time; with children waking up more throughout the night, taking longer to fall asleep, later bedtimes, and an overall worse sleep quality. The substantial increase in screen time in children leads to a dramatic decrease in their sleep patterns.

To investigate the association between prolonged screen time in children and ADHD, three articles were included in this study. The first article by Muppalla et al. (2023), highlighted how screen time can be beneficial for education and in moderation; however, excessive use of screen time has been linked with poorer executive function and academic performance. Early implementation of screens was also linked with potential delays in speech development, increased likelihood of obesity, sleep disorders, depression, and anxiety (Muppalla et al., 2023). Excessive screen time use in children can hinder children's adaptability when dealing with their emotions, displaying an increased potential of developing ADHD (Muppalla et al., 2023). Another article looked into the relationship between ADHD, screen time usage, and white matter microstructure in over 11,000 children aged 9-11 years old (Yang et al., 2022). Those children with an increased propensity for polygenic risk score for ADHD displayed increased screen time along with a higher severity of ADHD (Yang et al., 2022). It consequently

demonstrated a reduction in the white matter tracts of these children with ADHD thus displaying the negative association prolonged screen time has towards the development of ADHD in children (Yang et al., 2022). A cross-sectional study conducted by Wu et al. (2022), studied 42,841 three year old children to examine the relationship between prolonged screen time and ADHD providing the average daily screen time was 55.83 minutes only increasing with age. In children who exceed a daily 90 minutes of screen time, they demonstrated a higher likelihood of developing ADHD (Wu et al., 2022). These studies all examined the association that excessive use of screen time in children had with the development and severity of ADHD. It was proven that children who utilized screen time more often had a greater likelihood of not only developing ADHD, but having more severe symptoms.

Discussion:

This paper seeks to congregate the relevant information of potential negative health outcomes in children and adolescents as they pertain to prolonged screen time. The specific correlations congregated were in regards to screen time and obesity, depression, anxiety, sleep, and ADHD. It is important to note that the category "Screen Time (ST)" is very diverse and its subcategories can introduce confounding variables when analyzing the data and interpreting results. ST, for example, can range from social media use to watching TV to even playing interactive video games. These screen mediums exhibit varying effects on the behavioral psychology of users, implications in social hierarchies, and degrees of provided escapism which indicate varying levels of innate addictive properties. Because of differences such as these, over time, negative outcomes in obesity, depression, anxiety, sleep, or ADHD may arise in certain mediums more than others even if ST is held constant. Therefore, it is important to note what kind of ST medium was used in studies of prolonged ST in order to better inform parents and educators who are considering taking action in attempting to minimize the specific correlated negative outcomes.

Per the studies reviewed, obesity as a risk factor for prolonged ST has had the strongest and most robust correlation. Here, the subcategories of ST which do not lead to this outcome are few and far between. This is likely due to the predominantly sedentary nature of the activity. As the time spent in a sedentary activity increases, the time that could have been spent physically active decreases. This means less time in club sports or outdoor activities that typically serve as an excellent outlet for physical exercise in children. This is especially true for children of the current generation who now derive more and more entertainment, social interaction, and education from ST. Included studies have shown that children with shorter overall ST have lower BMIs and exhibit higher levels of physical activity (Mineshita et al., 2021). ST was set to include time on smartphones and tablets and not just TV. In addition, these changes in BMI do not take long to become statistically significant. Substantial increases in BMI were found to occur within a year for children with prolonged ST (Negata et al., 2023). These relatively quick body compositional changes may bear some association with the accompanying behaviors that follow ST such as food consumption. Delayed satiety signals and diverting attention from the habitual control of food intake have been shown to increase caloric intake while watching TV. This compounding effect not only increases the risk of children developing obesity in the short term but also in building negative associations between obesogenic behaviors; possibly leading to habitualization and thus increasing difficulty in the future to disassociate and rectify. While an argument can be made in favor of screen games that may be more interactive and incorporate exercise into their function such as Dance Dance

Revolution, they do not make up a significant portion of an average child's time spent on-screen entertainment. The limitation of total ST should therefore be considered among parents and educators for this category.

While the negative effects of prolonged ST may be more readily apparent in regards to BMI, sinister effects on the mental health of children and adolescents have also been noted. Most notably, the increase in depressive symptoms from new-generation media sources. More time spent engaging in newer types of screen behavior, including social media, online videos, and online games, have been associated with a higher prevalence of depression (Kidokoro et al., 2021). However, other studies have noted that social media use specifically and not watching TV were associated with higher odds of feeling depressed often (Ma, Li et al., 2021). In the same study, gaming alone and gaming in groups were also not found to be associated with higher levels of depressive symptoms. This leaves the online games, videos, and TV subcategories of ST still under debate for their overall effects on depression. We hypothesize this could be due to the positive downstream social effects games and TV shows or movies may have on children and adolescents. It is possible that there can be development of new social bonds over shared favorite games or TV series or the strengthening of existing bonds among friend groups. Nevertheless, more research regarding this correlation is required. Instead, the ST medium that is more frequently found to correlate with depression and depressive symptoms is social media usage. Extended social media use has been documented to have deleterious effects on the mental health of children and adolescents likely due to the unique aspects of behavioral psychology and socialization it draws upon to maintain interest and engagement in users. Amongst the hypotheses for the correlation of social media use and rising levels of depression, we find the social comparison hypothesis to be the most appealing. Social media allows children and adolescents to continually make upward social comparisons, creating feelings of inferiority. Between boys and girls, this study remains inconclusive in regards the possible differing depressive outcomes following excess ST. Elementary school boys were found to have a higher prevalence of depression than girls yet, girls in junior high who spent more than 2 h/day playing online games had a higher prevalence of depression (Kidokoro et al., 2021). Meanwhile, results from Ma, Li et al (2021) were completely unable to support sex differences in association between screen use and depressive symptoms. Additional studies examining these potential differences are required to better elucidate how ST may be uniquely impacting young girls in comparison to boys, especially new ST subcategories such as social media.

The prolonged ST subcategory of social media usage has not only been shown to impact depression but the development of anxiety as well. Studies included have shown that children who recorded higher social media check-in frequencies were found to be more likely to express negative feelings toward their appearance. Those who displayed these negative feelings were found to have higher levels of social anxiety as a result (Charmaraman et al., 2022). Increasing levels of social anxiety have also been shown to increase time spent on social media (Tanrikulu et al., 2022); thus creating a detrimental positive feedback loop between the frequency of social media usage and social anxiety. Interestingly, it was also found that among the students who displayed increased negative feelings toward their appearance from frequent checking of social media, they were more likely to be following celebrities. These results were further stratified by sex as more females (84%) from the study group reported negative feelings towards their appearance than males (16%). This finding gives additional

credence to the social media social comparison hypothesis for negative mental health outcomes of prolonged social media use particularly and its disproportionate impact on young females. Despite more research being required to study the impact of other ST sources on anxiety, early studies have suggested video games have an impact on the feelings of anxiety in children. Pasquale et al. (2021) details that increased feelings of anxiety result from increased video game playing. In addition, they also show that the increased anxiousness leads to increased time spent playing the games thus creating a loop of poor behavior and outcomes. It is possible that these feelings may increase the more immersive the game is as children often place themselves in the shoes of the character that they control. They may be indirectly relating to the danger or struggle the character they control is experiencing, which can serve as a form of increasingly desired escapism. In a recent discussion about managing anxiety, the focus was on non-pharmacological interventions. Participants highlighted the significance of addressing anxiety without resorting to medication.

As ST becomes more interwoven into the lives of children and adolescents extending from morning to night, it has become increasingly apparent that ST duration is not the only factor that matters but ST timing as well. Overall, the most encompassing negative effect ST can have is usage before bed leading to a decrease in sleep duration and quality. Decreased sleep in children and adolescents has a significant likelihood of negatively impacting each condition discussed in this paper. Lack of sufficient high-quality sleep has been shown to increase adiposity, increase propensity to feelings of depression and anxiety, and decrease concentration for not only children but adults as well. Since children are overwhelmingly ignorant of the importance of sleep, they are less likely to make the decision to end their ST at an appropriate time and go to sleep. Underlying the problem of poor sleep timing and quality is the fact that short wavelength (blue/green) light emitted from screens suppresses pineal melatonin secretion, influencing both circadian entrainment and sleep onset. Since the majority of devices utilize this kind of light, ST of any kind late at night has the potential to negatively impact sleep in children. Naturally, as you increase daily ST overall, you are likely to extend the use into hours of the night in which the absence of screens are important for hormonal sleep regulation. ST both in the bedroom with handheld devices and outside the bedroom have been associated with a shift in social jet lag in children (Qiu-Ye Lan et al. 2020). The shift in social jet lag has the potential to continually accrue sleep debt and over time, share the same poor health outcomes of sleep deprivation especially obesity (Guzman et al. 2021). Because a child's nighttime routine and sleep play an important role in their development, minimizing behaviors such as excessive or late ST helps prevent exacerbation of negative health outcomes. Having a set time before bed in which devices are no longer allowed is an example of a rule that may help mitigate the issue.

Emerging as an increasingly correlative condition to ST, ADHD as a diagnosis has seen its numbers continually rise alongside growing accessibility to various screen and media platforms. The condition itself is multifactorial involving a strong genetic and behavioral component which often influence each other. At the behavioral level, ST was found to have a significant bi-directional long-term correlation with ADHD-related behaviors. Given that children with ADHD tend to have reward oversensitivity and are intolerant of delay in rewards, screen-based activities like video gaming work to provide immediate feedback of reward (Yang et al., 2022). The positive reception of immediate feedback and reward consequently leads to an increased propensity for increasing the frequency and duration of ST. In regards to

genetics, children with increasing amounts of ADHD-related alleles, and thus at higher polygenic risk, were found to not only prolong their ST but also experience more severe ADHD symptoms. It is possible that the series of genes involved cause alterations in white matter tracts of the brain particularly, decreased fractional anisotropy in the frontal-striatal circuitry. It is here inhibitory control and executive function are linked and the decreased fractional anisotropy observed in children with ADHD in this area may explain why they find it difficult to remove themselves from the prominent visual sensory stimulation of screens. Nevertheless, even if a child does not have an abundance of polygenic risk, it has been found that simply introducing screen time too early (ages 0-3) can lead to the development of hyperactive behaviors (Wu et al., 2022). Because of the disproportionately high amount of neuroplasticity in our early years of life, it is possible that the introduction of screens during this time may cause similar, though less pronounced, changes in the same areas of the brain as a child diagnosed with ADHD with a strong genetic component. These early cognitive alterations may also cause changes to the reward pathways leading to long-term undesirable effects. While we may not know the perfect age to begin screen time or the perfect amount, as data continues to emerge we are able to piece together where negative outcomes are being concentrated and in turn, adjust our behaviors and establish more effective guardrails for our children.

Conclusion:

Overall, as education and leisure activities for children become more centralized around emerging technologies and time behind screens, it is important to take a step back and examine where guardrails may need to be placed in order to optimize their cognitive, social, and behavioral development. The replacement of time spent in outdoor activities and peer-peer socialization with video games, TV, and social media have demonstrated a trend toward increased childhood obesity, development of depression or depressive-like symptoms, increased feelings of anxiety, loss of sufficient high-quality sleep, and worsening of ADHD related symptoms amongst children diagnosed and at risk. Although emerging research is beginning to suggest certain forms of ST may be more detrimental than others, total ST across mediums remains the strongest predictor of negative developmental outcomes.

Since young children lack the ability to regulate their time behind screens, it is up to parents to set the rules for the house regarding where and how long screens can be used. Limiting the hours of ST allowed per day, keeping televisions or computers in the living room rather than the child's bedroom, and having set hours for physical activity such as after school sports can each serve to manage and minimize ST. Healthcare professionals and educators play an important role in staying up to date with the emerging literature of ST and its effects on childhood development in order to best inform parents of the risks involved. Working with parents individually on how they can implement strategies at home to develop healthy relationships around screens is crucial to reversing the worrying trend of negative child development outcomes with screen overuse.

Appendix

Table 1. Summary of study designs

Study design	Number of studies
Longitudinal study	**2**
Prospective Cohort study/ Cohort study	**6**
Cross-sectional	**6**

Figure 1: Inclusion and Exclusion upon Search:

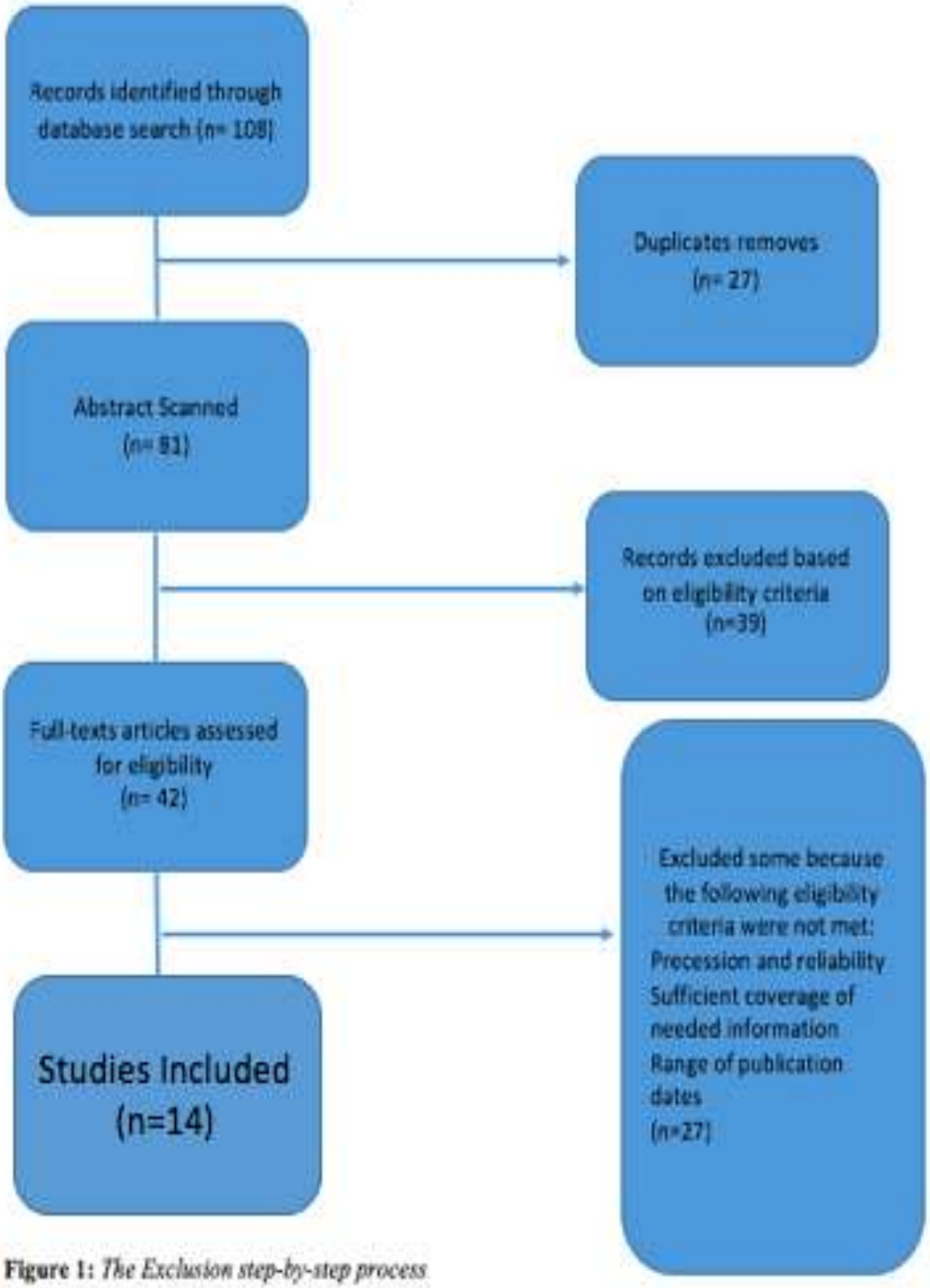

Figure 1: *The Exclusion step-by-step process*

First Author	Date of Publication	Study of population	Outcome/Results
Jason M. Nagata "Contemporary Screen Time Usage among Children 9–10-years-old is Associated with Higher BMI Percentile at One-Year Follow-Up: A Prospective Cohort Study"	June 28th, 2021	Prospective cohort study exploring the relationship among contemporary screen time modalities (e.g., video streaming, video chatting, texting, and social networking) and body mass index (BMI) percentile.	In fully adjusted models, each additional hour of total screen time per day was prospectively associated with a 0.22 higher BMI percentile at one-year follow-up (95% CI 0.10–0.34). (+ more correlative data)
Sarah Burkart "Impact of the COVID-19 pandemic on elementary schoolers' physical activity, sleep, screen time and diet: A quasi-experimental interrupted time series study"	August 18th, 2021	A quasi-experimental interrupted time series study examining children's obesogenic behaviours during spring and summer of the COVID-19 pandemic compared to previous data collected from the same children during the same calendar period in the 2 years prior.	Compared to pre-pandemic measures, children's PA, sleep timing, screen time, and diet were significantly worsened during the COVID-19 pandemic, even after accounting for previous maturational trends from years prior.

Yihong Zhao “Brain structural co-development is associated with internalizing symptoms two years later in the ABCD cohort”	March 20th, 2023	Longitudinal brain imaging and mediation analyses were used to examine relationships among Screen Media Activity (SMA), brain patterns, and internalizing problems. Data from Adolescent Brain Cognitive Development (ABCD) participants with baseline and 2-year follow-up structural imaging data that passed quality control (N 5 5,166; 2,385 girls) were analyzed.	A brain co-development pattern among 221 brain features was identified. SMA at baseline was related to internalizing psychopathology at year 2 (β . 0:020; SE . 0:008; P . 0:014) and a structural co-development pattern (β . 0:015; SE . 0:007; P . 0:029), where the co-development pattern suggested that rates of change in gray-matter volumes of the brainstem, gray-matter volumes and/or cortical thickness measures of bilateral superior frontal, rostral middle frontal, inferior parietal, and inferior temporal regions were more similar than those in other regions. This component partially mediated the relationship between baseline SMA and future internalizing problems (indirect effect 5 0.020, P-value 5 0.043, proportion mediated: 2.24%).
Tetsuhiro Kidokoro “Different Types of Screen Behavior and Depression in Children and Adolescents”	January 24th, 2022	A total of 23,573 Japanese children and adolescents (aged 8–15 years) participated in this cross-sectional study. Different types of screen behavior, weekly exercise time, sleep duration, and prevalence of depression were assessed using a questionnaire. Independent associations between various types of screen behavior and prevalence of depression were examined using logistic regression analyses. A two-way analysis of	High school students who spent more than 2 h/day on social media were associated with a higher prevalence of depression than the reference group. Girls in junior high school who spent more than 2 h/day playing online games had a higher prevalence of depression than the reference group. Boys in elementary school who spent more than 2 h/day of watching online videos had a higher prevalence of depression than the reference group. However, more time spent watching online videos was associated with a lower prevalence of depression among junior school boys. Furthermore, more time spent watching TV was associated with a lower prevalence of depression among boys and girls.

		covariance was conducted to examine whether exercise and sleep can attenuate the negative effects of screen behavior.	
Li Ma "The association between screen time and reported depressive symptoms among adolescents in Sweden"	December 6th, 2021	Longitudinal Survey in Four European Countries. The final sample consisted of 3556 eighth grade adolescents in 2011 (51% girls). A logistic regression analysis is used to estimate the odds ratio of feeling depressed often versus less often/not at all using time spent on different types of screen use as predictor variables.	Descriptive statistics of variables used for logistic regression analysis on the association between screen time and reported depressive symptoms reported: Five percent of adolescents (173 out of 3556) in the total sample felt depressed often, 16% felt depressed sometimes, 35% felt depressed rarely and 44% never felt depressed Those who spent > 2 hours on social media had significantly higher odds of feeling depressed often (P = 0.002). Girls had significantly higher odds of feeling depressed often than boys (P < 0.001).
Linda Charmaraman "Early Adolescent social media related body dissatisfaction: associations with depressive symptoms, social anxiety, peers, and celebrities".	July 1st, 2021	A cross sectional pilot survey was conducted between two subgroups of 11-14 year old children and included questions regarding: social media comparison, celebrity followings, frequency of usage, social anxiety, feelings of loneliness, symptoms of depression, and ease of connecting with new people.	Results of the survey concluded that 19% of children felt negatively about themselves after using social media.
Concetta De Pasquale	March 8th, 2021	A cross sectional study assessed the prevalence of online video games	As far as the levels of reported associated anxiety, the test for anxiety and depression yielded a mean of 135 (SD

"Online Videogames Use and Anxiety in Children during the COVID-19 Pandemic".		usage with anxiety in 162 8-10 year old children (84 females, 78 males) in Catania, Italy. Children were required to complete a series of three questionnaires screening about self reported anxiety and depression, online video game addiction, and a children's anxiety scale.	16.8) defined as moderate, and a low average children's anxiety scale score of 2.2 (SD 2.1). Trait anxiety displayed a small amount of significance (standardized beta 0.192, t=2.47, p=0.054) while state anxiety (standardized beta 0.152, t=1.94, p=0.01) demonstrated a higher degree of significance with online video games based on the regression analysis.
Gulfem Tanrikulu "Life aspirations, school engagement, social anxiety, social media use, and fear of missing out among adolescents".	November 9th, 2022	A group of 506 students ranging from 14-18 years old participated in this cross sectional study. Each student filled out a demographic form, an extrinsic and intrinsic life values questionnaire, a fear of missing out scale, a social media frequency form, and a social anxiety scale (including questions on fear of negative perspectives, social anxiousness, and social avoidance).	A path model explored the correlation between extrinsic and intrinsic goals, age, FOMO, social anxiety, study interference, in school usage, GPA, and social media check ins (CFI>0.950, RMSEA<0.050, SRMR<0.050). The result yielded an adequate fit (p=0.069, CFI=0.974, SRMR=0.022, RMSEA=0.040 [90%-CI:0.000, 0.0711]).
Jennifer A Emond "Associations between daily screen time and sleep in a racially and socioeconomically diverse sample of US infants prospective	June 24th, 2021	A longitudinal, observational birth cohort designed to examine feeding, activity and sleep in relation to excessive weight gain in infancy. Women reported their infants' screen time via questionnaire items at 3, 6, 9 and 12 months as the number of minutes their infants spent doing five	The median value of the average daily screen time over the study period was 50 (IQR: 10–141) min. Infant screen time was inversely associated with night-time sleep duration only when considering between-infant effects (adjusted beta: −2.9; 95% CI −5.9 to 0.0; p=0.054 for log-transformed screen time). Effects were stronger for television+DVD viewing specifically (adjusted beta: −5.2; 95% CI −9.1 to −1.4; p<0.01 for log-transformed television+DVD time). For example, an infant who averaged 1 hour of television+DVD viewing over the

cohort study”		screen activities on a typical weekday and typical weekend day, considering their infants’ typical use over the past 4 weeks: (1) watching TV on a TV set; (2) watching DVDs or videotapes; (3) streaming videos or shows on TV, watching on a computer or a handheld device; (4) playing games on a handheld device; or (5) using educational software.	study period slept, on average, 9.20 (95% CI 9.02 to 9.37) hours per night by 12 months compared with 9.60 (95% CI 9.41 to 9.80) hours per night for an infant with no screen time over the study period. There were no significant within-infant effects between screen time and night-time sleep, and screen time was not associated with daytime sleep or night-time awakenings.
Viveka Guzmán “Associations of Sleep Duration and Screen Time with Incidence of Overweight in European Children: The IDEFICS/I.Family Cohort”	November 1st , 2021	Data from 4,285 children of the IDEFICS/I.Family cohort who were followed up from 2009/2010 to 2013/2014 were analyzed. Hours per day of screen time and of sleep duration were reported by parents at baseline. Logistic regression analyses were carried out in separate and mutually adjusted models controlled for sex, age, European country region, parental level of education, and baseline BMI z-scores.	Among normal weight children at baseline (N = 3,734), separate models suggest that every hour increase in screen time and every hour decrease in sleep duration were associated with higher odds of the child becoming overweight or obese at follow-up (OR = 1.16, 95% CI: 1.02–1.32 and OR = 1.23, 95% CI: 1.05–1.43, respectively). In the mutually adjusted model, both associations were attenuated slightly (screen time OR = 1.13, 95% CI: 0.99–1.28; sleep duration OR = 1.20, 95% CI: 1.03–1.40), being consistently somewhat stronger for sleep duration
Qiu-Ye Lan “Sleep duration in preschool children and impact of screen time”	September 24th, 2020	2903 preschoolers were included. Parent-completed questionnaire provided information on socioeconomic status, electronic media use of the children and sleep patterns of both parents	40% of preschoolers in the cohort did not achieve the recommended sleep duration. Subjects who adhered to the screen time recommendations were from families of higher socioeconomic status, had longer sleep duration and better sleep habits. Each hour increase on portable electronic device use was associated with 11

		and children. Preschoolers were divided according to whether they met the international screen time recommendations for their age. Comparisons between the two groups in various sleep measures and effects of different devices on sleep were evaluated.	(95%CI: -15 to -6) and 6 (95%CI: -10 to -2) minutes less of average daily sleep duration in boys and girls, respectively. Every additional hour of non-portable electronic devices use was associated with a 3 min shift in social jetlag in boys. Presence of electronic devices in the bedroom and their use at bedtime increased risk of social jetlag in boys with an OR of 1.40 (95%CI: 1.01 to 1.92) and 1.39 (95%CI: 1.00 to 1.95).
Sudheer Kumar Muppalla "Effects of Excessive Screen Time on Child Development: An Updated Review and Strategies for Management."	June 18th, 2023	Cohort study. This study investigates how screen time impacts various aspects of child development and includes strategies for managing and regulating children's screen usage.	The outcome of this study suggests that an extended duration of screen time has a detrimental impact on language development. Problems with sleep, excessive screen time, and exposure to fast-paced, violent content can activate dopamine and reward pathways in the brain. These factors have all been linked to attention-deficit/hyperactivity disorder (ADHD).
Jian-Bo Wu "Association between screen time and hyperactive behaviors in children under 3 years in China."	November 9th, 2022	Cross-sectional study. 42,841 3-year-old children. A several logistic regression models were used to investigate the link between screen time and hyperactive behaviors.	The average daily screen time for children under the age of 3 years was approximately between 55.83 minutes and 58.54 minutes. Additionally, as children age, their screen time tends to increase. Furthermore, this research revealed a strong correlation between increased screen time and heightened levels of hyperactive behaviors. The risk values for hyperactive behaviors were 1.98

Anyi Yang "Longer screen time utilization is associated with the polygenic risk for Attention-deficit/hyperactivity disorder with mediation by brain white matter microstructure."	May 1st, 2022	Cross-sectionally and Longitudinal analyses. 11,000+ 9-11 year-old children. The focus of this study is to explore the connections between polygenic risk and traits associated with ADHD, screen time utilization (STU), and the microstructure of white matter in the brain.	The findings of this article indicate that there exists a connection between children possessing elevated polygenic risk scores for ADHD and experiencing extended screen time usage (STU), along with more severe symptoms of ADHD. Elevated screen time has adverse effects on multiple white matter pathways, ultimately resulting in the diminished integrity and reduction of these white matter tracts.

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