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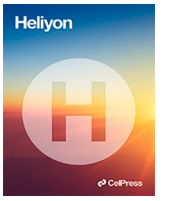

Research article

Associations among screen time, sleep, mental health and cognitive functioning in school-aged children during the COVID-19 pandemic, November 2020 through to August 2022

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ABSTRACT

Objective: To examine children's screen time use and sleep patterns over 2 years of the pandemic and the downstream associations with children's executive functions and behavioural problems, as well as the moderating effects of parental factors.
Method: This longitudinal cohort study examined school-aged children's lifestyle and behavioural changes over 2 years of the pandemic across 6 timepoints (November 2020 to August 2022). Latent growth modeling (LGM) was used to identify changes in screen time and sleep duration and multivariate LGM was used to determine how parental stress, positive parenting, changes in children's screen time and sleep over time were associated with children's executive functions and mental health outcomes at the final time point.
Results: A total of 198 parents (children's mean age = 9.14 years) were recruited and followed up. Non-school screen time was elevated at the initial timepoint (3.6 ± 2.3 h). Positive parenting at the initial timepoint was associated with lower screen time use in children ($\beta = -.19$, $p < .001$; $\beta = -.19$, $p < .001$, in internalizing and externalizing models). Children whose screen time use was constant during the pandemic had shorter sleep durations ($\beta = -.45$, $p < .05$ in internalizing model). Executive function was predicted by sleep duration at the first timepoint ($\beta = -.55$, $p < .001$; $\beta = .73$, $p < .001$, in internalizing and externalizing models) and changes in screen time during the pandemic was associated with both internalizing and externalizing symptoms ($\beta = .58$, $p < .05$; $\beta = .54$, $p < .05$, in internalizing and externalizing models).
Conclusion: Children's screen time decreased slightly but remained significantly higher than Canadian and International guidelines during 2 years of the pandemic. Positive parenting styles can have a significant impact on children's screen time use. Reducing excessive screen time can help improve sleep patterns and, consequently, cognitive, and emotional well-being in children.

1. Introduction

The COVID-19 pandemic brought abrupt constraints on children's lifestyles [1]. Restrictions such as school closures resulted in

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tremendous increases in screen time not only for educational needs, but also for recreational purposes across all age groups [2–4]. Moreover, in cross-sectional studies, increased screen time was associated with adverse children's mental health outcomes during the pandemic, including internalizing [5,6] and externalizing behaviours [7,8]. Although increased screen time was reported by most longitudinal studies or were based on retrospective ratings from the pre-pandemic period, few studies have followed rates of screen time throughout the pandemic and examined its association with children's cognitive and behavioural outcomes, along with key moderating factors.

A key protective factor against the adverse effects of screen time for children is getting sufficient sleep. Increased hours of sleep is closely linked to less screen time and better mental health outcomes in children [9]. According to the Canadian 24-h Movement Guidelines, 9–11 h of sleep are recommended for children aged 5–13 years and 8–10 h are recommended in adolescents aged 14–17 years [10], which are similar with worldwide guidelines [11]. Studies reported increases, decreases, or no changes in sleep duration during the pandemic [12–15] with inconclusive evidence on potential harms [5]. It is important to understand child's sleep patterns as this is strongly associated with other health-related behaviours, including screen time use [16].

Parents play a pivotal role in shaping children's lifestyles and routines [17], and this role becomes particularly important when children encounter unpredictable situations [18,19]. Positive parenting practices have emerged as a crucial protective factor for children's mental health outcomes during the pandemic. These practices encompass behaviours which foster positive and healthy routines, emotional support, modelling of emotion regulation, and moderating screen time effectivley [20,21]. By contrast, elevated levels of parental stress, which has been linked to school closures, can lead to harsh parenting behaviours [22], which is a risk factor for child psychopathology [23].

Excessive screen time use, and sleep disturbances have known associations with executive functioning in children. Executive functions can positively influence children's mental health outcomes; however, these processes are vulnerable to environmental adversity [24]. Several studies reported elevated concerns for children's executive function during the pandemic [24,25]. The mediating effect of lifestyle factors including screen time on executive functions and poor mental health outcomes has yet to be explored in the general child population; however, these associations were seen in children with neurodevelopmental disorders [26, 27].

The purpose of the study was to investigate how parental factors, children's screen time and sleep during the pandemic impacted children's executive function and mental health in a longitudinal cohort assessed from 2020–22. We examined (1) how parental factors (positive parenting and parenting stress) were associated with children's initial screen time use and sleep durations at the beginning of the pandemic and their rates of change over 2 years, (2) how children's initial screen time and its rate of change during the pandemic was associated with initial sleep durations and its change over 2 years of the pandemic, (3) how children's initial screen time and sleep durations and their change over 2 years impacted children's executive functions and mental health (internalizing and externalizing symptoms) and how children's executive functions predicted their mental health outcomes. We hypothesized that parents would demonstrate significant roles in adapting to the pandemic-enforced lifestyle changes, and not only children's lifestyles at the initial timepoint but also the changes throughout the pandemic would impact children's executive function and mental health outcomes after two years of the pandemic.

2. Methods

2.1. Study design, setting, and participants

Parents who had a child aged 6–12 years in Canada participated in online longitudinal survey. The first survey was launched in November 2020 that was followed by additional surveys with each time point (T) spaced ~6 weeks apart. Rolling recruitment for the study closed in April 2021, and the final surveys were completed in March 2022. Participants who did not complete more than 70% of surveys and/or responded falsely were excluded. Participants who completed at least 3 of the 5 original surveys were invited to complete an additional survey between June and August 2022. A total of 198 participants completed the first survey, 172 participants completed the 2nd survey, 161 participants completed the 3rd survey, 146 completed the 4th survey, 132 participants completed the 5th survey, and 110 participants completed the 6th survey. The participants who completed the 6th survey were included in the final analysis. Research ethics board approval was obtained at the participating institution.

2.2. Parental measures

Baseline parental factors were assessed at T1 only, as parenting styles and relationships with children remain consistent over time [28].

Parents completed the Alabama Parenting Questionnaire (APQ) [29] to assess parenting style. Total scores were used to represent a positive parenting style. Parenting stress was assessed with the Parent Stress Index- Fourth Edition Short Form (PSI-4) [30]. A higher total stress index is associated with higher stress levels in a parent's daily parenting experiences [31].

2.3. Child measures

Parents provided assessments of their child's sleep and media screen time use behaviours at every time point. Parents provided estimated sleep duration, calculated in minutes. Parents were asked how much time their child spent per day watching TV shows or content on a screen (TV, tablet, computer, phone), how much time their child spent on their phones (including, texting, social media,

and video calls), and how much time their child spent playing video games. All estimated times were provided in minutes and summed for further analyses.

2.4. Outcomes

2.4.1. Executive function

The total cognitive-executive functioning score from the Learning, Executive and Attention Functioning (LEAF) scale was used to estimate children's cognitive functioning at T6 [32].

2.4.2. Mental health

Children's mental health outcomes were assessed using the Strengths and Difficulties Questionnaire (SDQ) [33] at T6. An internalizing score was calculated by combining scores across the peer relationships and emotional difficulties scales and an externalizing score was generated by combining across the conduct problems and hyperactivity/inattention scales.

2.5. Statistical analysis

Descriptive and correlational analyses were used to describe characteristics of the participants and to examine associations and multicollinearity among the main variables using SPSS (version 29, Statistical Package for the Social Sciences, Chicago, IL: IBM SPSS). 12 subjects had at least one missing item in SDQ, LEAF, and PSI and we ran multiple imputations for missing data using SPSS.

To determine the interrelationships of variables and predictors among parental factors, children's lifestyle changes, executive function, and mental health outcomes after two years of the pandemic, latent growth modeling (LGM) was applied using AMOS (version 28, Chicago, IL: IBM SPSS). To assess longitudinal changes in children's lifestyles during the pandemic, we first ran univariate LGMs for screen time and sleep durations across all time points. We then employed multivariate latent growth curve models to examine the associations among pre-existing parental factors, children's lifestyle changes, and children's executive function and mental health outcomes. In this model, parenting factors were included as predictors for the initial values and rates of change in screen time and sleep duration during the pandemic. Executive function and mental health outcomes (internalizing and externalizing symptoms) measured at T6 were regressed on latent intercepts and rates of change for screen time and sleep duration.

To prevent selection bias caused by missing values, we used the full information maximum likelihood method (FIML) implemented in the AMOS program. Goodness of fit of all models was verified using chi-square (X^2), Comparative Fit Index (CFI $>.95$), Tucker-Lewis Index (TLI $>.95$), and Root Mean Square Error of Approximation (RMSEA $<.05$, acceptable $<.10$).

Table 1
Demographic information at baseline and descriptive analysis.

Demographic information at baseline		N(%) / Mean ± SD
Parent age (years)		38.19 ± 6.44
Parent gender (female)		47 (42.7%)
Parent education	High school / Some college or university	17 (15.5%)
	Bachelor's degree / College diploma	58 (52.7%)
	Master's degree / PhD degree / Professional degree	20 (18.2%)
	Prefer not to answer or missing	15 (13.6%)
Parent employment (yes/no)		83 (84.7%)
Parent income (thousands)		101.07 ± 45.68
Child age (years)		9.14 ± 4.75
Descriptive analysis		**Mean ± SD**
Positive parenting at TP1 (APQ total score)		90.14 ± 7.53
Parenting stress at TP1 (PSI total score)		77.34 ± 19.79
Screen time (Summed daily minutes)	TP1	215.80 ± 136.48
	TP2	214.49 ± 151.21
	TP3	239.08 ± 131.01
	TP4	213.29 ± 140.76
	TP5	215.88 ± 145.88
	TP6	204.06 ± 135.59
Sleep (Daily minutes)	TP1	536.21 ± 68.25
	TP2	550.06 ± 63.51
	TP3	543.75 ± 68.09
	TP4	539.65 ± 70.58
	TP5	540.29 ± 65.46
	TP6	527.47 ± 64.90
Executive function at T6 (LEAF cognitive executive function score)		21.09 ± 18.91
Mental health outcomes at TP6	Internalizing symptom (SDQ internalizing total score)	4.41 ± 3.56
	Externalizing symptom (SDQ externalizing total score)	6.36 ± 3.91

3. Results

3.1. Demographic information and descriptive statistics

In total, 110 cases completed all 6 surveys. The average age of the children at baseline was 9.14 ± 4.75 years at baseline (Table 1). Parents' mean age was 38.19 ± 6.44 years and the majority of the sample was male (57.3 %). Most parents had at least a bachelor's or college degree (70.9 %) and were employed (84.7 %).

Descriptive statistics for the variables included in the model and their correlations are presented in Table 1 and Supplementary Table 1. The average amount of screen time over the 6 Ts was 217.1 min/day with range of 204.1–239.8 min/d. The mean sleep duration across all Ts was 539.6 min/d with range of 527.5 to 55.1 min/d. Negative correlations between mean screen time use and the sleep durations were found across all time points (Supplementary Table 1).

3.2. Changes in screen time and sleep duration during the pandemic

Fit statistics for the model for screen time changes over two years of the pandemic indicated a good fit (PCMIN/DF = 1.707, CFI = .957, TLI = .944, RMSEA = .081). The initial mean screen time was 238.67 min/d ($p < .001$) and demonstrated significant variability among children ($p < .001$). The average rate of change in screen time was −5.25 min/d indicating a decreasing pattern over time ($p = .074$) and the interpersonal variability was also significant ($p = .034$).

The model for sleep duration changes over time approached a good fit (PCMIN/DF = 2.195, CFI = .927, TLI = .927, RMSEA = .105). The initial mean sleep duration was 544.9 min/d ($p < .001$) and demonstrated significant variability across children ($p < .001$). The mean change rate of sleep duration was −2.68 min/d ($p = .025$) but demonstrated variability at a marginal level ($p = .088$).

3.3. Associations among pre-existing parental factors, children's screen time, sleep, executive function, and mental health outcomes

3.3.1. Internalizing problems after two years of the pandemic

In the final multivariate LGM for the internalizing problems, the fitness indices of the final models were satisfactory (PCMIN/DF = 1.417, CFI = .937, TLI = .918, RMSEA = .062). The relationship of each variable was established based on the results of the analysis model (Fig. 1). Supplementary Table 2 presented the coefficients for each path.

Positive parenting at T1 had a negative effect on initial screen time ($\beta = -.185$, $p = .001$) and had positive effects on decreases in sleep duration over time ($\beta = .681$, $p = .017$). Parenting stress at T1 was not associated with the initial values or changes in screen time

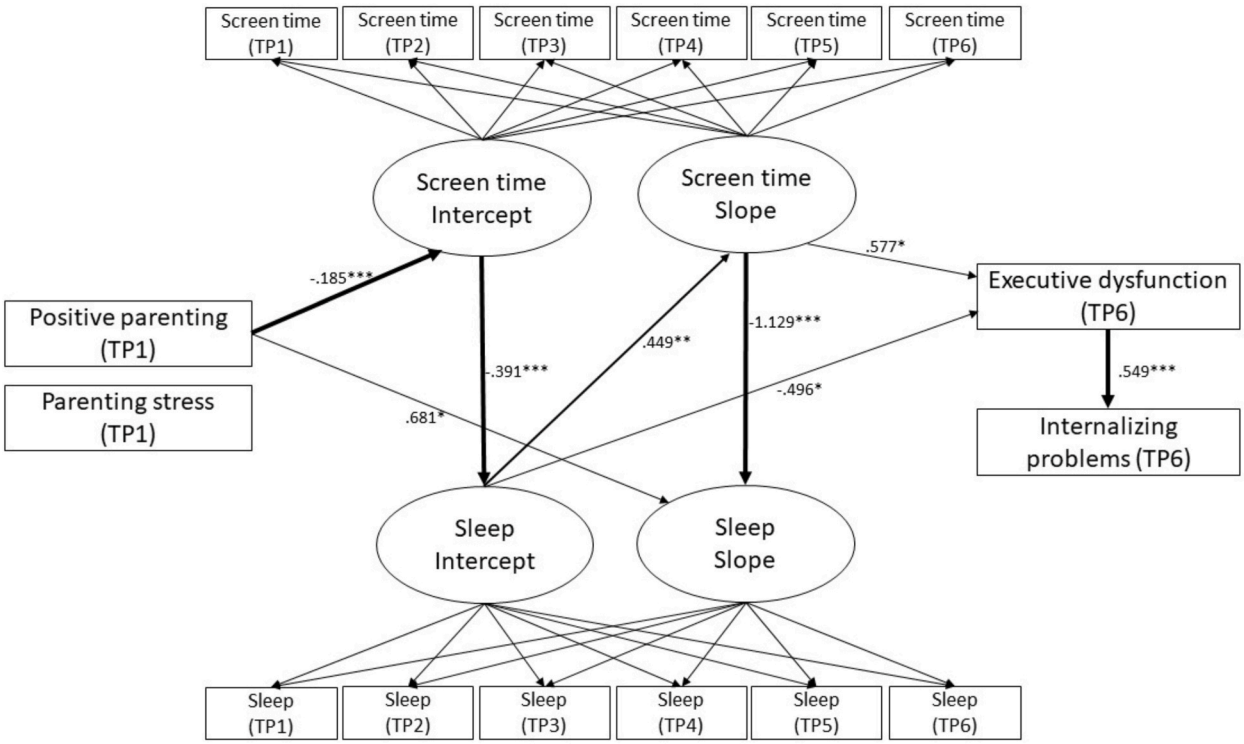

Fig. 1. Associations of pre-existing parental factors, child lifestyle changes during the pandemic, and executive function and internalizing problems after two years of the pandemic (Standardized coefficient presented, $p < .05$*, $p < .01$**, $p < .001$***).

or sleep duration.

Initial amounts of screen time had negative effect on initial sleep duration (β = −.391, p < .001). The initial sleep duration had a positive effect on screen time decreases over time (β = .449, p = .004), suggesting that children who slept less at T1 were less likely to show decreases in their screen time use over time. The changes in screen time rates negatively impacted sleep patterns, suggesting that children with smaller decreases in screen time tended to experience a more significant decrease in sleep duration over time (β = −1.129, p < .001).

Children's executive functions measured at T6 were influenced by their initial amount of time spent sleeping (β = −.496, p = .05) and changes in screen time rates (β = .577, p = .05), indicating that children who had shorter sleep durations at T1 or who experienced a greater change in screen time over time, exhibited greater difficulties in executive function at T6. Children's internalizing symptoms measured at T6 was not directly associated with the initial amounts or changes in screen time or sleep but was influenced by their executive function abilities (β = .549, p < .001).

3.3.2. Externalizing problems after two years of the pandemic

In the final multivariate LGM for children's externalizing problems, the fitness indices of the final models were a good fit (PCMIN/DF = 1.387, CFI = .944, TLI = .928, RMSEA = .060). The relationship of each variable was established based on the results of the analysis model (Fig. 2). Supplementary Table 3 illustrates the coefficients for each path.

Positive parenting at T1 had a negative effect on initial amounts of screen time (β = −.188, p = .001) and had positive effects on decreases in sleep duration over time (β = .799, p = .011). Parenting stress at T1 had a positive effect on changing rates of screen time, which indicated that higher levels of parenting stress at the beginning of the pandemic were associated with greater decreases in screen time over time (β = .808, p = .045).

Initial amounts of screen time had negative effects on initial sleep durations (β = −.391, p < .001) and the rate of change in sleep durations (β = −.447, p = .036), indicating that a child who had a higher screen time at T1 had shorter sleep duration at T1 and tended to show less decreases in sleep duration over time. Initial sleep durations had a positive effect on decreases in screen time over time (β = .431, p = .005), suggesting that a child who slept less at T1 tended to show less decreases in screen time over time. The change rate of screen time negatively effected the rate of change of sleep duration, indicating that children with smaller reductions in screen time tended to experience greater decreases in sleep duration over time (β = −1.180, p < .001).

Executive function measured at T6 was associated with the initial value of sleep duration (β = −.496, p = .034) and changes in the rates of screen time (β = .538, p = .042), indicating that children who already had shorter sleep durations at T1 or experienced greater changes in screen time exhibited difficulties in executive function at T6. Externalizing symptoms measured at T6 were not directly related to the initial amounts or changes in screen time and sleep durations, but were influenced by child's executive functioning (β =

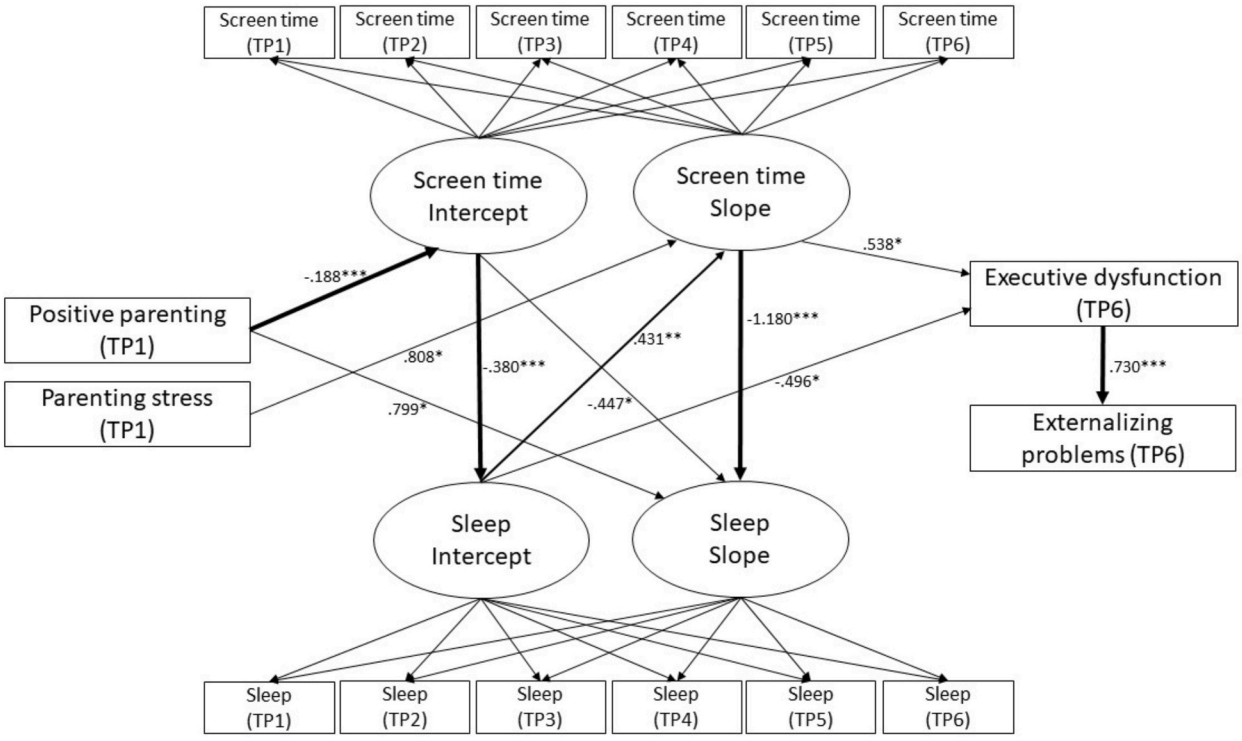

Fig. 2. Associations of pre-existing parental factors, child lifestyle changes during the pandemic, and executive function and externalizing problems after two years of the pandemic (Standardized coefficient presented, p < .05*, p < .01**, p < .001***).

.730, $p < .001$).

4. Discussion

In the present study, longitudinal associations amongst parental factors, changes in children's screen time, sleep, executive function, and mental health outcomes for two years of the pandemic were assessed. The average recreational screen time reached almost 4 h per day when the first survey was initiated. Positive parenting style was associated with fewer hours spent on screens at the first survey timepoint. Findings also revealed a close link between screen time and sleep duration. Shorter sleep durations were not only associated with more time spent on screens at the start of the survey but were also associated with fewer changes in screen time use over time. Children whose screen time remained constant during the pandemic had shorter sleep durations over the two years of the study. Both internalizing and externalizing behaviours were associated with executive function. Further, executive function was predicted by sleep durations at the first study timepoint and changes in children's screen time during the pandemic.

Negative associations between screen time use and sleep durations were observed throughout the pandemic, which aligns with previous literature [34]. Of note, initial sleep durations had a direct impact on executive function. Sleep is essential for executive functioning in the developing brain [35]. Studies have reported that sleep deprivation negatively impacted cognition across the lifespan [36,37]. Although this association was also seen during the pandemic in preschoolers, children, and adolescents [38–40], our findings further confirmed sleep's long-lasting impact on executive function. The COVID-19 pandemic resulted in substantial changes in children's lifestyle including changes in sleep habits. We found that sleep duration also exhibited an indirect effect on executive functions through changes in the hours spent on screens. Greater difficulties with executive function were seen in children who reduced their screen time over the two years of the study. However, greater parenting stress measured at the first survey also predicted greater decreases in screen time, and subsequent greater difficulties with executive function. During the initial lockdown, greater parental stress levels were associated with significantly more time spent on screens [17]. In previous studies, parents who experienced high levels of stress tended not to monitor or regulate children's screen time, resulting in longer durations of screen use [41,42]. However, another report indicated that when parents' stress levels were elevated, they enforced house rules, resulting in a sudden decrease of screen time [41]. The association between greater decreases in screen time and greater difficulties in executive function observed in our study may reflect high levels of parenting stress related to monitoring children's screen time during the pandemic.

Of note, the effect of parenting stress was only seen in relation to children's externalizing problems. A recent longitudinal study presented a dynamic and exchangeable nature of parent-child relationships and indicated bidirectional associations between parenting stress and externalizing problems in early adolescence [43]. Parenting stress often links to negative parenting behaviours including inconsistent discipline, which is associated with externalizing problems in children and youth [44,45]. Positive parenting in our models was negatively correlated with the initial screen time use but had no significant associations with changes in screen time over the two years of the study. Potentially, a positive parenting style had a measure of success in establishing new screen usage rules at the beginning of the pandemic, despite the widespread increases in screen time.

Our study underscores the significant role of children's executive functions in predicting internalizing and externalizing problems, and is aligned with previous research [46,47]. Executive function is defined as a set of higher-order cognitive processes including inhibitory control, working memory, and cognitive flexibility [48]. Neuroimaging findings also suggest that the neural networks supporting these skills (e.g., prefrontal cortex) are not fully mature until early adulthood [49], leaving them vulnerable during this developmental period [50]. In turn, abrupt lifestyle changes during the pandemic were risk factors for adverse executive function development.

4.1. Limitations

As this study used online survey responses, data representing families with no or limited internet usage were not collected. Online data collection may be biased towards parents who use social media and are comfortable participating in online studies, which may decrease the generalizability of these findings. We observed a decline in respondent numbers as the survey progressed. This tendency is typical in longitudinal studies; however, participants who continued till the sixth survey timepoint may have exhibited distinct sociodemographic characteristics, which could also limit the generalizability of our findings. We used parental reports for screen time and sleep duration; however, parents' perceptions may have been influenced by their expectations or ideals concerning appropriate and healthy habits for screen use and sleep routines. All variables were included in the LGM after checking the multicollinearity issues and all paths were set theoretically based on the literature. In turn the slopes of screen time and sleep are inherently correlated as both variables were measured in the same units (i.e., how many hours a day), representing certain patterns of lifestyle choices. Finally, the model did not account for variances in baseline executive function. Consequently, our results do not establish a causal or directional relationship between lifestyle factors and executive function. In turn, the interpretation and generalization of these findings should be considered, in light of this information.

5. Conclusions

In a 2-year longitudinal study with parents and school-aged children, assessed during the pandemic, we examined parental factors and the influence on children's screen time, sleep duration, executive functions, and mental health outcomes. Our findings confirmed that screen time was one of the most impactful changes on children's lives during the pandemic. Positive parenting was found to be an important protective factor against excessive screen time, which was associated with sleep durations. Difficulties in executive function

after two years of the pandemic was associated with screen time and initial sleep durations, with greater reductions in screen time being associated with longer initial sleep durations and higher parenting stress. This underscores the complex interplay between these factors during the pandemic, potentially impacting children's well-being.

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Declaration of generative AI and AI-assisted technologies in scientific writing

We did not use any types of AI and AI-assisted technologies in the writing process.

Data availability statement

Data will be made available upon request.

Ethics statement

The study received approval from the Non-Medical Research Ethics Board at Western University (Approval number #116741). All participants provided informed consent to participate in the study.

CRediT authorship contribution statement

Eun Jung Choi: Writing – original draft, Software, Methodology, Investigation, Formal analysis. **Diane Seguin:** Writing – review & editing, Resources, Project administration, Investigation, Data curation. **Amira Hmidan:** Writing – review & editing, Project administration, Investigation, Data curation. **Emma G. Duerden:** Writing – review & editing, Supervision, Software, Resources, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.heliyon.2024.e36889.

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