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Screen time exposure and executive functions in preschool children

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Increased screen time (ST) among preschool children is becoming a matter of concern globally. Although gadgets such as phones, tablets and computers might be of educational use in this population, excessive ST might impair cognitive function among preschoolers. As data on this topic in preschool children are scarce, this study sought to investigate the relationship between ST and executive functions (EFs) in this population. A total of 1016 preschool children aged 5–6 years (M = 70.8 months, SD = 4.5) were tested using the Developmental Neuropsychological Assessment (NEPSY-II) and the Dimensional Change Card Sort tests for cognitive flexibility (CF), visual working memory (WM), verbal WM, inhibition and motor persistence with parental consent, while ST was reported via a questionnaire completed by their mothers. Participants spent approximately 2 h in both active and passive ST per day, with boys spending much more time in active ST than girls. There was a very weak negative correlation between CF and both active and passive ST, and a weak negative correlation between verbal WM and both active and passive ST. Additionally, there was a very weak negative correlation between inhibition and passive ST on weekday. To ensure proper development of EFs in preschool children, ST should be limited to ≤ 1 h per day of high-quality educational/interactive content as previously determined by eminent pediatric institutions worldwide. Proven remedies that enhance EFs in children, such as physical activity and cognitive training, should be practiced regularly.

Keywords Working memory, Cognitive flexibility, Inhibition, Kindergarten, Phones

The modern era pervades households through an ever-increasing number of different devices and gadgets that are based on the latest technology. Although many of these tools are helpful in making human life easier and more convenient, some have taken a toll on various forms of human behavior[1]. Currently, many people cannot imagine a single day without screen time (ST) exposure, especially phones, tablets and television. ST can be divided into passive and active whereby passive ST includes watching video content that requires no interaction or no input from the user and active ST involves interactive engagement with a media (e.g., videogaming, exergaming, messaging, using learning and creative applications)[2]. Children might be particularly vulnerable to ST exposure because their regulatory mechanisms are underdeveloped, which consequently leads to increased ST on a daily basis[3]. However, greater ST comes at a cost in children, particularly relative to poor academic performance[4], inadequate language performance[5] and behavior problems[6]. A global analysis of ST in ~ 90,000 children revealed that only a quarter of children younger than 2 years met the guidelines to avoid ST, and only one third of children aged 2 to 5 years met the guidelines of no more than 1 h daily of ST[7]. In a rather older sample of schoolchildren aged 6 to 14, the average ST was 2.77 h per day, with nearly half of them spending ≥ 2 h per day[8]. A growth trend could be detected by analyzing studies in the same countries and regions pre vs. post the COVID-19 outbreak with average rates of school-aged children who spent ≥ 2 h per day on screens were 41.3% and 59.4% respectively before and after January 2020[8]. The most recent data (May 2024) from the American Academy of Child and Adolescent Psychiatry found that US children ages 8–12 have ST of 4–6 h per day, and teens spend up to 9 h daily[9].

Considering that children's goal-oriented behavior is driven by executive functions (EFs)[10], the importance of EFs has been addressed by a handful of previous investigations suggesting that ST might harm EFs in toddlerhood[11] and preschool children[12] and cause decreased attention in children[13,14], but overall, it appears that the available data in this field (specifically in preschool children) are rather scarce and necessitate further

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investigation. Executive functions are defined as goal-oriented behavior that consists of competencies such as goal setting, time management, project monitoring, and organizing and prioritizing materials, all of which are key for successful learning and are thus prerequisites for academic success[15,16]. Three components of EFs are working memory (WM) (also called updating), cognitive flexibility (CF) (also called shifting or switching) and inhibition (also called inhibitory control)[17]. Working memory relates to short-term maintenance and usage of task-pertinent information, whereas inhibition is characterized by intentional suppression of distracting stimuli to manage attention, behavior, thoughts, and emotions[18]. Cognitive flexibility pertains to adjusting the focus of attention in a rapid manner to switch perspectives and promptly adapt to new task-determined needs such as demands, rules, or priorities[18].

Given that EFs significantly predict academic achievement in children[19,20], it is highly important to cultivate the development of EFs at an early age. Two approaches that have been shown to successfully increase EFs in preschool children are physical activity (PA)[21,22] and cognitive training (CT)[23]. For this reason, some scholars have suggested that when used jointly, PA and CT can produce greater effects in enhancing EFs than when any of these approaches are applied alone[22]. Indeed, many studies have adopted this approach and detected a significant effect of cognitively enhanced PA on cognitive function in various populations[24–26]. Unfortunately, preschool children spend the majority of their waking hours in sedentary behavior (approximately 73%)[27], while almost half of their time in childcare is spent sitting (48.4%)[28]. Although there are exceptions, ST in preschool children can generally be described as a sedentary behavior, and recent studies indicate that there is a dose-response relationship relative to child development. Namely, compared to preschool children who had ≤ 1 h per day, children who had ST for several hours per day had an increased likelihood of reported behavioral problems, delayed achievement of developmental milestones and poorer vocabulary acquisition[29].

A current body of knowledge regarding ST and EFs in preschool children is in its infancy, and thus, there is a need to address this topic in depth to further understand the influence of ST on EFs in kindergarteners. Hence, our research sought to investigate the relationship between ST and EFs in preschool children. Based on the available literature, we hypothesized that the more ST children acquire on a weekly basis, the worse the EFs outcomes will be.

Methods

This cross-sectional study and its consent procedures were conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of the Faculty of Psychology at Lomonosov Moscow State University (Approval No: 2023/77). Methods employed in this study were in accordance with the universally accepted guidelines and regulations of scientific publishing. All mothers provided written informed consent for their children's participation in the study.

The sample consisted of 1016 (51% boys, 518 males and 498 females) preschool children aged 5–6 years (M = 70.8 months, SD = 4.5). Only healthy children who spoke Russian fluently and were without any physical or cognitive issues were included in the study. Within the included sample, 80% of the mothers had higher education, and 86% of the families had an average level of income related to the Russian Federation. All the children attended municipal kindergartens in Moscow and two other large cities, Sochi and Kazan (Table 1).

Cognitive flexibility was assessed via the Dimensional Change Card Sort (DCCS) for ages 5–7 years[30] which was previously adopted for Russian language and showed good validity and reliability[31]. Hereby, the children were required to sort a series of bivalent test cards (with pictures of red rabbits and blue boats): the first 6 cards according to the color of the card (the first phase) and the second phase—6 cards according to the shape (rabbit or boat). In the third phase, the children had to sort 12 cards according to the more complicated rule with the additional factor (if the card had a frame, then he or she had to sort it by color, and if there was no frame, then

Variables	Total sample
Age (months)	70.8 ± 4.5
Sex, male/female (n)	518/498
Cognitive flexibility	20.2 ± 2.8
Visual working memory	71.3 ± 20.4
Verbal working memory	18.6 ± 3.9
Inhibition	10.7 ± 3.2
Body persistence and inhibition	26.4 ± 3.9
Passive ST, weekday (min per day)	71.2 ± 51.4
Passive ST, weekend day (min per day)	127.4 ± 78.7
Total passive ST (min per week)	611.2 ± 382.3
Active ST, weekday (min per day)	26.7 ± 38.7
Active ST, weekend day (min per day)	50.9 ± 63.8
Total active ST (min per week)	235.3 ± 305.3
Total ST (min per week)	851.5 ± 606.8

Table 1. Sample, EFs, and ST parameters. Data are reported as mean ± SD unless otherwise indicated; *Efs* executive functions, *Min* minutes, *n* number, *ST* screen time.

he or she had to sort it by form). The children received a single point for each correctly sorted card (a maximum of 24 points).

Visual WM assessment was performed via the NEPSY-II subtest “Memory for Designs” for individuals aged 3–6 years[32] which was previously adopted for Russian language and showed good validity and reliability[31]. The stimuli included four pictures of a grid with four to eight colored designs on it (the first trial—4 designs, the second—6, the third—6, and the last one—8). The children were shown a picture for 10 s, after which the picture was removed from their view, after which they selected the designs from a set of cards and placed the cards in a grid in the same place as previously shown. For each trial, points are scored separately for four parameters: (1) the content score assesses the child’s ability to recall which designs were shown for each trial; (2) the spatial score assesses the child’s ability to recall where a design was shown for the trial; (3) the bonus score reflects the child’s ability to recall which designs were in which locations for that trial; and (4) the total score for each trial is the sum of the content, spatial and bonus scores. The final results of this subtest are the sum of each kind of score (the maximum for all trials is 120).

Verbal WM was tested through the NEPSY-II subtest “Sentence Repetition” for individuals aged 3–6 years[32]. The stimuli included 17 sentences of increasing complexity and length. The children read one sentence and were asked to recall it immediately after it was presented. There are the following types of errors: omitting a word, changing a word, adding a word, and changing a word order. Children received 0 points for 3 or more errors in one sentence, 1 point for 1 or 2 errors, and 2 points for correct repetition of the sentence (maximum 34 points). The procedure was stopped when the child received 0 points three times consecutively.

Inhibition was assessed via the NEPSY-II subtest “Inhibition” for ages 5–6 years[32]. The subtest consists of two blocks: a series of white and black figures (circles and squares) and a series of arrows with different directions (upward and downward). Two tasks were carried out with each series of pictures: the task of naming figures (in this case, a child has to name the figures that he or she saw as quickly as possible) and the task of inhibition (in this case, a child is supposed to say the opposite of what he or she saw; for example, if the child saw a square, he or she has to say “circle”, etc.). Three indicators in each task are recorded: (1) the number of self-corrected errors that occurred when the child provided an incorrect response but corrected it next; (2) the number of uncorrected errors that occurred when the child did not correct the mistakes; and (3) the completion time. Then, these three indicators are translated into a combined score using tables from the NEPSY-II manual (from 1 to 20 points).

Motor persistence and inhibition assessments of the “Statue” subtest of the NEPSY-II for individuals aged 3–6 years were used[32]. In this task, the children were asked to stand completely still like a statue (with the feet slightly apart, the left arm at the side and the right arm bent at the elbow so that it was perpendicular to the body with the right hand in a fist) with their eyes closed until a tester said “Time is up!”. The children needed to stand motionless for 75 s without being distracted by external sound stimuli. The tester makes special sound stimuli four times: at 10 s, the tester drops the pencil; at 20 s, he or she coughs; at 30 s, he or she knocks the table twice; and at 50 s, he or she says “Ho Hum”. There are three types of errors: body movements, eye opening, and vocalization. Only one error of each type can be counted for each 5-s interval. The child received 0 points for 2 or more errors during a 5-s interval, 1 point for 1 error, and 2 points for no errors (a maximum of 30 points).

To elaborate on the passive and active ST of children, an online questionnaire for mothers was used. In the first question on ST, mothers were asked to write the number of hours and/or minutes that the child usually spends watching cartoons and videos on an average weekday and weekend-day separately. In the second question, mothers were asked to write the number of hours and/or minutes that the child usually spends on the computer, tablet, smartphone, game console, not counting the time spent watching cartoons and videos on an average weekday and weekend-day separately. Then, the average weekly passive and active STs of the children were calculated. The questionnaire contained also questions about sociodemographic factors (place of residence, age and sex of the child) and questions about the family’s socioeconomic characteristics (income level, level of education of the mother).

The EFs assessments were carried out individually for each child and were divided into two 20-min sessions with a few days between each session. During the first session, the children performed subtests aimed at assessing CF and inhibition, while WM and motor persistence were assessed during the second session. Children were tested in a quiet room in their kindergarten (in the bedroom or in the psychologist’s office). The assessments were performed by specially trained testers, and the tasks were given to all the children in the same order and with the same instructions. During the assessment, the children were allowed to stop the procedure if, for some reason, they did not feel like continuing. The assessment took place for all children at the same time in the morning, between 8:00 am and 12:00 am.

At the same time, with the EFs assessment of the children, their mothers completed online questionnaires about the ST of their children. The mothers received a link to the questionnaire via email from the kindergarten or in a parent group chat on the messenger. In the group chat and by email, mothers received reminders to fill out the questionnaire. It took approximately 20 min for mothers to complete the online questionnaire.

Data concerning the EFs and ST parameters are expressed as the mean ± standard deviation (SD). The normality of the distribution was examined with the Kolmogorov–Smirnov test. Since the data were not normally distributed, the Spearman rank correlation coefficient (r) was calculated. The strength of association among variables was interpreted in line with literature recommendations as very weak (0.00–0.10), weak (0.11–0.39), moderate (0.40–0.69), strong (0.70–0.89), and very strong (0.90–1.00)[33]. To detect sex-based differences relating to ST variables, the Mann–Whitney test was used. All analyses were carried out using the statistical software SPSS version 29.0 (IBM Corp., Armonk, NY, USA). The relationship between EFs and ST was considered to be statistically significant if the p value was < 0.05.

	Males, n = 385		Females, n = 378			
	M	SD	M	SD	Mann–Whitney U	*p*
Passive ST, weekday	72.9	51.9	69.2	50.7	69,785	0.319
Passive ST, weekend day	129.1	80.7	125.2	76.4	71,369	0.688
Total passive ST	622.9	390.7	596.8	372.0	70,367	0.467
Active ST, weekday	28.2	37.8	25.1	39.5	60,844	**0.038**
Active ST, weekend day	54.4	59.1	47.3	68.2	59,049	**0.005**
Total active ST	250.0	287.8	219.7	322.0	58,247	**0.005**
Total ST	878.9	596.8	820.3	615.3	61,543	0.111

Table 2. Differences between males and females in ST. Significant values are in bold.

	Passive ST, weekday		Passive ST, weekend day		Total passive ST		Active ST, weekday		Active ST, weekend day		Total active ST		Total ST	
Variables	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
Cognitive flexibility	− 0.08	**0.03**	− 0.04	0.22	− 0.07	**0.04**	− 0.07	**0.04**	− 0.09	**0.01**	− 0.09	**0.02**	− 0.11	**0.01**
Visual working memory	− 0.06	0.09	0.02	0.62	− 0.04	0.34	− 0.04	0.25	0.03	0.43	0.00	0.95	− 0.02	0.55
Verbal working memory	− 0.13	**< 0.01**	− 0.10	**< 0.01**	− 0.14	**< 0.01**	− 0.13	**< 0.01**	− 0.11	**< 0.01**	− 0.13	**< 0.01**	− 0.17	**< 0.01**
Inhibition	− 0.08	**0.03**	− 0.00	0.95	− 0.05	0.14	− 0.06	0.12	− 0.03	0.52	− 0.04	0.31	− 0.06	0.13
Body persistence and inhibition	− 0.05	0.23	− 0.02	0.64	− 0.03	0.40	− 0.04	0.32	− 0.04	0.25	− 0.05	0.20	− 0.06	0.13

Table 3. Relationship between EFs and ST parameters for the total sample. Bolded values indicate a statistically significant relationship between variables. Efs: executive functions; min: minutes; *p*: probability; r: correlation coefficient; ST: screen time.

Results

Descriptive statistics on screen time, executive functions and demographics

The total passive ST and total active ST were 611.2 min and 235.3 min, respectively, while the average total ST per week was 851.5 min per child. Thus, on average, children spent two hours per day on screens. In all the children, active ST on weekend days was almost twice higher than on weekdays, which indicates that weekdays and weekends should be considered separately when analyzing. All the demographic, EFs, and ST data are summarized in Tables 1 and 2.

Sex differences in screen time

Active ST was significantly greater in male preschool children than in their female counterparts: active ST, weekday (U = 60,844, $p = 0.038$, M = 28.2 ± 37.8 in males, M = 25.1 ± 39.5 in females); active ST, weekend day (U = 59,049, $p = 0.005$, M = 54.4 ± 59.1 in males, M = 47.3 ± 68.2 in females); and total active ST (U = 58,247, $p = 0.005$, M = 250.0 ± in males, M = 219.7 ± 322.0 in females). On average, boys have 5 min more active ST per day than girls which may contribute to their different outcomes in EFs.

Association between screen time and executive functions

There were very weak inverse correlations between CF and following variables: passive ST, weekday ($r = -0.08$, $p = 0.03$), total passive ST ($r = -0.07$, $p = 0.04$), active ST, weekday ($r = -0.07$, $p = 0.04$), active ST, weekend day ($r = -0.09$, $p = 0.01$), total active ST ($r = -0.09$, $p = 0.02$), and total ST ($r = -0.11$, $p = 0.01$). Although no statistically significant relationships were revealed between visual WM and any of the parameters related to the ST, a tendency toward a significant inverse association was observed for passive ST on weekdays ($r = -0.06$, $p = 0.09$). There was a weak inverse correlation between verbal WM and all ST parameters: passive ST, weekday ($r = -0.13$, $p < 0.01$), passive ST, weekend day ($r = -0.1$, $p < 0.01$), total passive ST ($r = -0.14$, $p < 0.01$), active ST, weekday ($r = -0.13$, $p < 0.01$), active ST, weekend day ($r = -0.11$, $p < 0.01$), total active ST ($r = -0.13$, $p < 0.01$), and total ST ($r = -0.17$, $p < 0.01$). Greater inhibition was very weakly correlated with reduced passive ST over the weekend ($r = -0.08$, $p = 0.03$). There was no statistically significant relationship between inhibition and other ST parameters (Table 2). Additionally, there was no statistically significant relationship between body persistence and inhibition or any of the ST parameters (Table 3).

Association between screen time and executive functions in boys

For boys, increased CF was weakly correlated with decreased total active ST ($r = -0.11$, $p = 0.04$). A tendency toward statistically significant relationships was recorded for several variables, including active ST, weekday ($r = -0.07$, $p = 0.07$), active ST, weekend day ($r = -0.09$, $p = 0.08$), and total ST ($r = -0.10$, $p = 0.05$). Visual WM was weakly positively correlated with passive ST on weekend days ($r = 0.13$, $p = 0.02$) and active ST on weekend days ($r = 0.12$, $p = 0.02$), while a trend toward a significant association was found with total ST ($r = 0.10$, $p = 0.07$).

Variables		Passive ST, weekday		Passive ST, weekend day		Total passive ST		Active ST, weekday		Active ST, weekend day		Total active ST		Total ST	
		r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*	r	*p*
Cognitive flexibility	Males	−0.08	0.15	−0.05	0.32	−0.07	0.19	−0.09	0.07	−0.09	0.08	−0.11	**0.04**	−0.10	0.05
	Females	−0.09	0.10	−0.04	0.46	−0.09	0.10	−0.04	0.46	−0.76	0.16	−0.05	0.33	−0.10	0.06
Visual working memory	Males	0.04	0.45	0.13	**0.02**	0.08	0.11	−0.02	0.77	0.12	**0.02**	0.06	0.26	0.10	0.07
	Females	−0.15	**0.00**	−0.09	0.10	−0.15	**0.01**	−0.05	0.33	−0.04	0.49	−0.03	0.61	−0.13	**0.02**
Verbal working memory	Males	−0.17	**< 0.01**	−0.13	**0.01**	−0.17	**< 0.01**	−0.16	**< 0.01**	−0.09	0.11	−0.13	**0.01**	−0.20	**< 0.01**
	Females	−0.10	0.07	−0.07	0.21	−0.10	0.06	−0.07	0.18	−0.12	**0.02**	−0.11	0.05	−0.12	**0.02**
Inhibition	Males	−0.07	0.17	0.03	0.56	−0.03	0.54	−0.07	0.17	−0.01	0.91	−0.04	0.45	−0.03	0.57
	Females	−0.10	0.07	−0.03	0.54	−0.08	0.13	−0.05	0.38	−0.04	0.50	−0.03	0.56	−0.08	0.13
Body resistance and inhibition	Males	−0.06	0.30	0.02	0.67	−0.03	0.59	−0.07	0.21	−0.04	0.46	−0.07	0.22	−0.06	0.24
	Females	−0.02	0.76	−0.06	0.30	−0.02	0.67	0.01	0.93	−0.02	0.67	−0.01	0.80	−0.03	0.54

Table 4. Relationship between EFs and ST parameters of males and females. Significant values are in bold.

Verbal WM also weakly inversely correlated with all ST parameters except active ST, weekend day: passive ST, weekday ($r=-0.17$, $p<0.01$), passive ST, weekend day ($r=-0.13$, $p=0.01$), total passive ST ($r=-0.17$, $p<0.01$), active ST, weekday ($r=-0.16$, $p<0.01$), active ST, weekend day ($r=-0.09$, $p=0.11$), total active ST ($r=-0.13$, $p=0.01$), and total ST ($r=-0.20$, $p<0.01$). There was no statistically significant association between inhibition and any of the ST variables (Table 3). Additionally, there was no statistically significant association between body persistence and inhibition or any of the ST variables (Table 4).

Association between screen time and executive functions in girls

No significant relationship was noted between CF and ST parameters in girls; nevertheless, a tendency toward a statistically significant correlation was observed for the total ST ($r=-0.10$, $p=0.06$). Weekday visual WM was weakly inversely associated with passive ST ($r=-0.15$, $p=0.00$), total passive ST ($r=-0.15$, $p=0.01$), and total ST ($r=-0.13$, $p=0.02$). Verbal working memory was weakly inversely associated with active ST, weekend day ($r=-0.12$, $p=0.02$), and total ST ($r=-0.12$, $p=0.02$); a tendency toward a statistically significant correlation was observed for passive ST, weekday ($r=-0.1$, $p=0.07$), total passive ST ($r=-0.11$, $p=0.06$), and total active ST ($r=-0.11$, $p=0.05$); and there was no statistically significant correlation between verbal working memory and passive ST, weekend day, and active ST, weekday. There was no statistically significant relationship between inhibition and each ST variable or between body persistence and inhibition and each ST variable.

Discussion

The purpose of the current investigation was to determine the relationship between EFs and ST among preschool children from the Russian Federation. Consistent with our hypothesis, the EFs variables were negatively associated with the ST parameters. More specifically, increased CF was very weakly and verbal WM was weakly correlated with lower values of all ST variables, while inhibition was very weakly inversely associated with passive ST over the weekend. Moreover, regarding boys, the obtained results suggested that a weak positive relationship existed between visual WM and passive ST on weekend days, as well as between visual WM and active ST on weekend days. Furthermore, increased verbal WM was weakly associated with higher values of nearly every ST parameter. Additionally, visual WM was weakly negatively correlated with passive ST on weekdays, total passive ST, and total ST among girls. Finally, greater verbal WM was weakly inversely associated with active ST on weekend days, and total ST in girls. A recent meta-analysis on the effects of ST on EF in preschoolers showed no statistically significant association in the relation between overall time use and EF but urged to take into account other contextual-related and development-related factors to determine the overall effect of ST on EF in children[34]. Also, longitudinal studies showed that the effects of ST do not have to be immediate and can affect children's EFs several years after initial exposure[35]. Thus, it is important to go beyond total ST duration and content, consider type (active or passive), and context to get a better picture of the overall effect of ST on EFs and broader cognitive function[11]. Time spent away from device should be considered given that variables such as sleep[36–38], daily physical activity[39], diet[40] and general upbringing[41] can impact cognitive performance in children.

With respect to differences in EFs between sexes, functional neuroimaging studies have revealed sex differences in the neural networks underlying certain EFs tasks, suggesting that male and female adults engage in different strategies depending on task demands[42]. However, due to the rather significant methodological heterogeneity of neuroimaging studies and the engagement of multiple neural networks, a simple overarching statement with respect to sex differences in EFs has been precluded to date. However, objective assessment of EFs was related to greater self-rated health in males than in females, while better subjective perception of EFs was significantly associated with greater self-rated health scores in both male and female adults[43]. In adolescents (i.e., 13–16 years), subjective reporting has shown that females evaluate their attention more than males do, and they report higher levels of self-control and self-monitoring[44]. In children, emerging evidence indicates that, when preschool children were given an EF task and patterns of activation in the lateral prefrontal regions were measured by functional near-infrared spectroscopy, there were no behavioral differences between children of either sex, although girls showed stronger prefrontal activation than boys[45]. In addition, a large meta-analysis showed an advantage in inhibitory control in girls over boys (1–9 years old)[46]. However, some studies have shown that girls' ability to inhibit motor responses in the Go/No-go task was greater than that of boys but not in the verbal Shape School inhibition task[47], indicating that there are many nuances when analyzing and interpreting data related to EFs in children.

Our study showed that Russian preschool children spent approximately 2 h performing both active and passive ST per day. Similar trends have been observed in other parts of the world. Canadian preschoolers who spent more than one hour on screens per day showed developmental difficulties in cognitive development, physical health and wellbeing, social competence, emotional maturity, language and communication skills compared to children reporting up to one hour of screen time/day[48]. Comparable findings were detected in Chinese preschoolers, in which children who had an ST > 1 h tended to have more behavioral problems than those with an ST < 1 h per day[49]. Another study from Canada revealed that preschool children with more than 2 h of ST/day had a nearly 800% increased risk of meeting the criteria for attention-deficit/hyperactivity disorder[50]. In toddlers, even as little as 30 min of ST per day can result in a 2.3-fold increased risk of parent-reported expressive speech delay[51]. In New Zealand, the average time preschool children spend using screens is approximately 1.5 h per day at 2 years of age, which increases to two hours per day when children are about to turn four years of age[52]. The same study revealed that preschool children who spent more than one hour per day on screens at 2 years were more likely to be obese, have more illnesses and visits to their doctor, have lower physical motor skills, and may exhibit hyperactivity problems at 4.5 years of age. Similarly, another study showed that preschool children who spent time with children had more ST and parent-child closeness[53]. Indeed, increased child ST was associated with decreases in measures of parent-child talk that were particularly notable at 3 years of age[54].

However, ST is a broad term, and further research on the effects of ST on EFs necessitates a detailed description of the nature of ST, i.e., whether it is interactive, educational, passive, etc.[55,56]. This approach would allow us to disentangle the influence of a specific type of ST on certain aspects of EFs. The opposing argument here would be an increasing number of emerging studies indicating that educative exergaming, which is a form of ST, can actually be beneficial to the development of EFs in preschool children[25,26,57,58].

Currently, data on the effects of ST on various health parameters, including cognitive function, are much more abundant in children and adolescents, where increased ST is correlated with an increased risk for cardiometabolic risk factors, obesity, mental health, unhealthy dietary habits and eating disorders, and problems in development and child–parent relationships[59]. In addition, increased ST is associated with greater obesity/adiposity and greater depressive symptoms, higher energy intake, less healthy diet quality and poorer quality of life in children and adolescents[60].

The authors of the present study fully agree with the ST recommendations for preschoolers that are put forth by preeminent institutions around the world (Canadian Pediatric Society, American Academy of Pediatrics, World Health Organization, Mayo Clinic and others). For example, the American Academy of Pediatrics discourages media use, except for video chatting, by children younger than 18 months[61]. If digital media is introduced to children aged 18 to 24 months, high-quality content is preferred, and media use should be avoided. Furthermore, for children aged 2 to 5, ST should be limited to one hour a day of high-quality programming.

At first glance, the solution to the status quo with respect to ST and EFs in preschool children might be obvious: limit ST and employ daily PA and CT, tools that are known to increase EFs in various populations, including preschool children. However, contextual factors shaping both children's and caregivers' behavior (including ST use) need to be taken into account. First, parental ST might lead to increased ST levels in children[62], while the role of peers in ST should not be neglected[63]. Additionally, depending on the country of origin and the development of the region, safety and lack of equipment, i.e., playgrounds, might be issues. Some caregivers view the lack of play space and small classroom size as influential factors on preschoolers' sedentary behavior while concurrently stating that increasing play equipment might stimulate children to be more active[64]. Additionally, in certain cases, parents perceive a child's play as risky and tend to be overly worried about children being injured. This situation, coupled with parents' busy lifestyle, might contribute to parental ambivalence regarding how to engage their children in active play[65].

Despite potential barriers, the importance of PA in preschool children for the development of EFs and their overall health cannot be overestimated. Studies have indicated that the more time preschool children spend performing moderate-to-vigorous intensity PA and the greater their cardiorespiratory fitness is, the better their EFs outcomes are[66], even if increased PA levels are practiced for only 24 h[67,68]. Notably, interventions that aim to increase PA levels are simultaneously effective at reducing ST in preschool children[69].

The present study has limitations. First, our study is cross-sectional in nature; therefore, we could only detect a relationship between the main variables observed, namely, ST and EFs. Thus, due to the absence of a randomized controlled trial design, we could not determine causality between these two variables and tried to eliminate as many confounding factors as possible. Next, unlike EFs, which were assessed objectively in a natural setting to include kindergarteners, weekly ST was reported via questionnaires by mothers. As this input requires recall and is highly subjective and prone to social desirability, the obtained data on ST are subject to question.

One of the strengths of the current study was that we succeeded in recruiting a fairly large sample of preschool children from different ethnic, economic and social backgrounds. Furthermore, we had almost the same number of boys and girls in this study, thereby equally representing both sexes in our study. Finally, we used tools to assess EFs that are globally recognized as valid and reliable in the measurement of WM, CF and inhibition.

Future studies on ST should elaborate on how children spend time away from screens and use wearable devices[70] to investigate factors such as sleep (using sleep trackers), daily physical activity (using accelerometers) and diet (using dietary diaries that would be filled out by parents) all of which are known to influence EFs in children and adults. In addition, if possible, researchers should also elaborate on type and content of ST consumed by children. By taking into account multiple variables affecting EFs in children, we could distill more concisely on the exact effect of ST on EF in children.

Conclusion
Our findings indicate that Russian preschool children spend about 2 h in front of various types of screens per day. However, acquired data is based on the parental reporting and is therefore subject to criticism due to high likelihood of bias. Consistent with the message of renowned pediatrics institutions worldwide, we support current guidelines stating that screen time in preschool children should be restricted to ≤ 1 h per day of high-quality educational/interactive content. Preschool children should engage in daily physical activity and cognitive training to ensure proper development of executive functions and increase the likelihood of later academic success.

Data availability
The authors confirm that the data supporting the findings of this study are available within the study and its supplementary materials.

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Author contributions

E.C. collected the data; M.M., N.L. and E.C. analyzed the data; N.L., M.M. and E.C. wrote the main manuscript.

Y.Z. and P.D helped in preparing tables. P.D. and Y.Z. supervised the manuscript. All authors reviewed the manuscript.

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Declarations

Competing interests
The authors declare no conflicts of interest.

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