REVISTA NEUROCIÊNCIAS

Consequences of Early Exposure to Electronic Devices on Neurodevelopmental Outcomes in Early Childhood

Consequências da exposição precoce a dispositivos eletrônicos nos resultados do neurodesenvolvimento na primeira infância

Consecuencias de la exposición temprana a dispositivos electrónicos sobre los resultados del desarrollo neurológico en la primera infancia

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Resumo

Introdução. A ampla integração da internet e dos dispositivos digitais no Brasil estimulou extensas pesquisas sobre a correlação entre o crescimento tecnológico e resultados adversos no desenvolvimento neurológico devido ao aumento do tempo de tela na primeira infância. Vários estudos demonstraram consistentemente o impacto negativo do uso prolongado de telas no neurodesenvolvimento infantil. **Método.** Revisão sistemática, seguindo as diretrizes PRISMA, explora a relação entre o tempo de tela e os distúrbios do neurodesenvolvimento em crianças de até 6 anos de idade. A busca, abrangendo uma década na Bireme, Scielo e PubMed. **Resultados**. 110 artigos, sendo 16 selecionados para análise, incluindo estudos transversais, coorte, ensaio clínico randomizado e meta-análise. Uma percentagem significativa de crianças, especialmente entre os 2 e os 4 anos, passa muito tempo em frente a telas, com potenciais disparidades socioeconómicas a influenciar a utilização. O tempo excessivo de tela está associado a marcos de desenvolvimento, incluindo os domínios cognitivo, psicossocial, motor, emocional e de linguagem, principalmente ligados a atrasos de linguagem. **Conclusão.** A revisão ressalta as implicações críticas do tempo excessivo de tela no desenvolvimento

neuropsicomotor e cognitivo. Salienta a necessidade de gerir cuidadosamente o tempo de ecrã, considerando a idade da exposição inicial e a duração total. As descobertas destacam o papel fundamental dos pais, cuidadores e educadores na manutenção de um equilíbrio saudável entre o tempo de tela e as atividades que promovem o desenvolvimento geral da criança, defendendo uma abordagem cautelosa ao uso de dispositivos eletrônicos durante esta fase crucial da infância.
Unitermos. Telas; celular; dispositivos eletronicos; primeira infancia

Abstract

Introduction. The widespread integration of the internet and digital devices in Brazil has spurred extensive research on the correlation between technological growth and adverse neurodevelopmental outcomes due to increased screen time in early childhood. Several studies have consistently demonstrated the negative impact of prolonged screen use on childhood neurodevelopment. **Method.** Systematic review, following PRISMA guidelines, explores the relationship between screen time and neurodevelopmental disorders in children up to 6 years old. The search, covering a decade on Bireme, Scielo, and PubMed. **Results.** 110 articles, with 16 selected for analysis, including cross-sectional study, cohort, randomized controlled trial, and a meta-analysis. Results indicate a significant percentage of children, especially aged 2 to 4, engage in extensive screen time, with potential socio-economic disparities influencing usage. **Conclusion.** Excessive screen time is associated with developmental milestones, including cognitive, psychosocial, motor, emotional, and language domains, notably linking to language delays. The review underscores the critical implications of excessive screen time on neuropsychomotor and cognitive development. It stresses the need to carefully manage screen time, considering the age of initial exposure and total duration. The findings highlight the pivotal roles of parents, caregivers, and educators in maintaining a healthy balance between screen time and activities that promote overall child development, advocating for a cautious approach to electronic device use during this crucial childhood phase.
Keywords. Screens; cell phones; electronic devices; early childhood

Resumen

Introducción. La integración generalizada de Internet y los dispositivos digitales en Brasil ha estimulado una extensa investigación sobre la correlación entre el crecimiento tecnológico y los resultados adversos del desarrollo neurológico debido al mayor tiempo frente a la pantalla en la primera infancia. Varios estudios han demostrado consistentemente el impacto negativo del uso prolongado de pantallas en el desarrollo neurológico infantil. **Método.** Revisión sistemática, siguiendo las pautas PRISMA, explora la relación entre el tiempo frente a una pantalla y los trastornos del neurodesarrollo en niños de hasta 6 años. La búsqueda, que abarcó una década en Bireme, Scielo y PubMed. **Resultados**. 110 artículos, de los cuales 16 se seleccionaron para el análisis, incluidos estudios transversales, cohortes, ensayo controlado aleatorio y metanálisis. Los resultados indican que un porcentaje significativo de niños, especialmente de 2 a 4 años, pasan mucho tiempo frente a una pantalla, y las posibles disparidades socioeconómicas influyen en su uso. **Conclusión**. El tiempo excesivo frente a una pantalla se asocia con hitos del desarrollo, incluidos los dominios cognitivo, psicosocial, motor, emocional y del lenguaje, y se vincula notablemente con retrasos en el lenguaje. La revisión subraya las implicaciones críticas del tiempo excesivo frente a una pantalla en el desarrollo neuropsicomotor y cognitivo. Destaca la necesidad de gestionar cuidadosamente el tiempo frente a la pantalla, teniendo en cuenta la edad de exposición inicial y la duración total. Los hallazgos resaltan el papel fundamental de los padres, cuidadores y educadores a la hora de mantener un equilibrio saludable entre el tiempo frente a la pantalla y las actividades que promueven el desarrollo infantil general, y abogan por un enfoque cauteloso en el uso de dispositivos electrónicos durante esta fase crucial de la infancia.
Palabras clave. Pantallas; celulares; dispositivos electrónicos; primera infancia

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INTRODUCTION

Since the second decade of the 21st century, with the creation, optimization, and implementation of the internet and digital devices in all social classes in Brazil, research has been developed to clarify the relationship between this technological growth and negative alterations in neurodevelopmental outcomes due to the increase in screen time during early childhood. It is increasingly evident that prolonged screen use during childhood directly and negatively affects neurodevelopmental outcomes[1-3].

Among children aged 2 to 4 years, 67.2% spend more than 69.2 minutes per day in front of tablets and smartphones[4,5]. There is not a significant difference in screen time between the two sexes. However, when we relate the socioeconomic class of these children to this time, 34.2% of the children with screen time less than 2 hours/day were from classes A, B, and C[1]. Already when the screen time was greater than 2 hours/day, children from these social classes represented 58% of the total studied. This article evaluates the implications of excessive screen use on neurodevelopmental outcomes in early childhood.

METHOD

This is a systematic literature review that follows the methodological guidelines stipulated by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The indexed databases used were Bireme, Scielo, and PubMed with the descriptors: "Screen Time" AND "Child"

AND "Neurodevelopmental Disorders". The search was conducted for articles published in a period of 10 years. The inclusion criteria were meta-analysis, case series, clinical trial, randomized controlled trial, and randomized study, we recommend pediatric patients up to 6 years of age and articles related to neurodevelopmental outcomes, neurocognitive alterations altered using screens (tablet, cell phones, and televisions). In the evaluation, we excluded duplicate abstracts, duplicate articles, literature reviews, and articles that described adults as the key in the study and patients with intellectual disability.

RESULTS

A total of 110 articles were found, of which three were from the Scielo platform, 10 from PubMed, and 97 from Bireme. After being analyzed using the inclusion and exclusion criteria, the following remained: one Scielo, two PubMed, and 13 Bireme (Figure 1).

Sixteen articles were selected, of which 11 are cross-sectional studies, three are cohort studies, one is a randomized controlled trial, and one is a meta-analysis. The results obtained evaluated the average screen time and its consequences on different milestones of child development, such as cognitive, psychosocial, motor, emotional, and language development. Most of the selected articles evaluated children in early childhood (0 to 6 years of age), with one of them analyzing children from 4 to 8 years of age (Table 1).

Figure 1. Study selection PRISMA flow diagram.

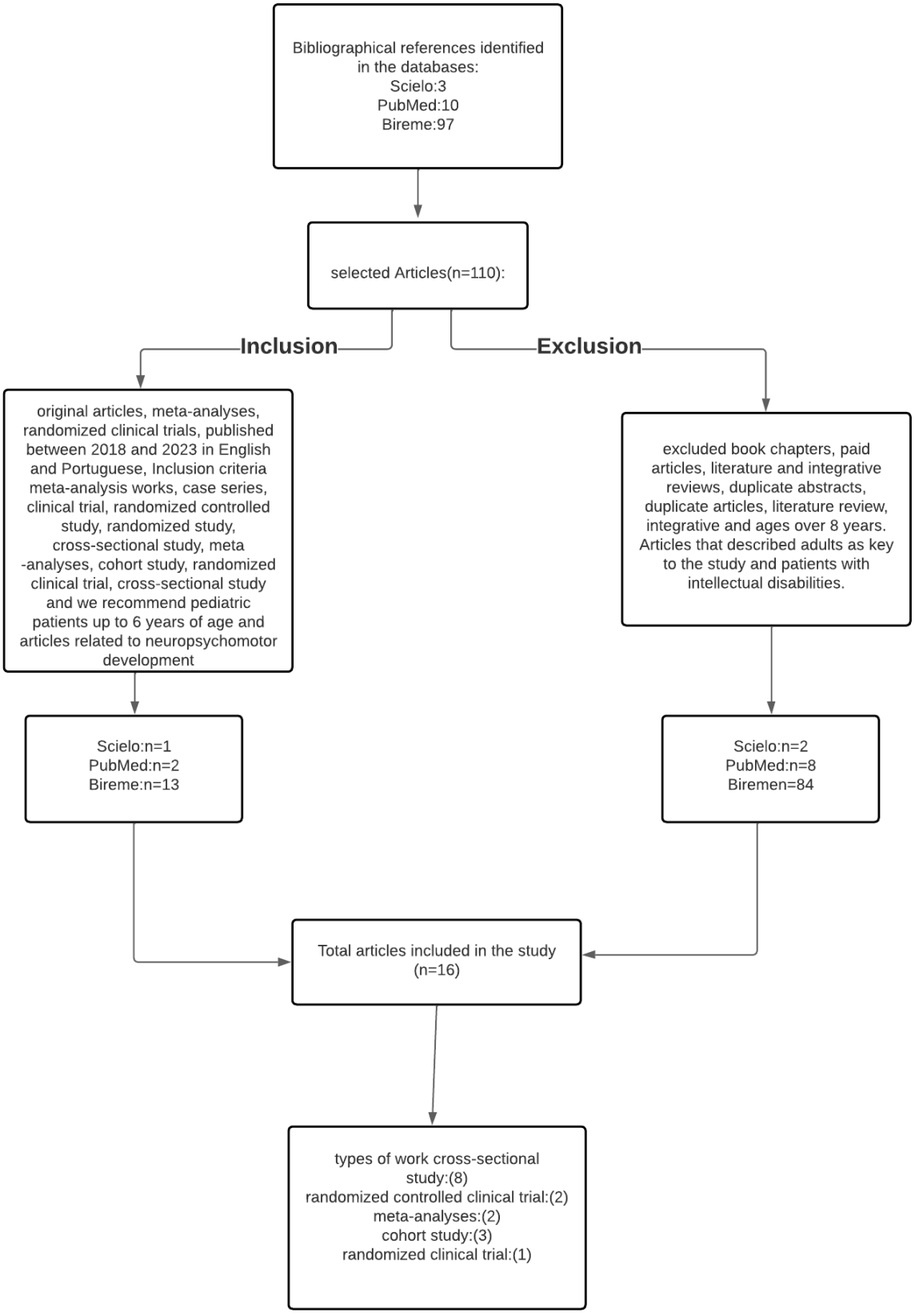

Table 1. Main findings of consequences of early exposure to electronic devices on neurodevelopmental outcomes in early childhood.

Author	Study type	Result
Nobre *et al*. 2021[4]	Cross-sectional, descriptive, and exploratory study	63% of children had screen time of more than two hours/day, with television being the main culprit. Children with more family resources that promote proximal processes (availability of toys and learning materials), higher socioeconomic status, and greater language proficiency were more likely to have more screen time.
Madigan *et al*. 2020[3]	Systematic review and meta-analysis	More screen time was related to lower language skills; Better quality of screen use (educational programs) and later onset of screen contact were related to higher language skills.
Tamana *et al*. 2019[1]	Cohort study	Compared to children with less than 30 minutes/day of screen time, those who watched more than two hours/day were five times more likely to report clinically significant externalizing problems and had 5.9 times more likely to report inattention problems. Children with more than 2 hours of screen time/day had a 7.7 times higher risk of meeting the criteria for ADHD. There was no significant association between screen time and aggressive behaviors.
Gastaud *et al*. 2023[6]	Cross-sectional study	58% of children had 1 hour or more of screen time per day. Cognitive development was lower in children exposed to more than 2 hours of screen time per day.
Chaibal *et al*. 2022[7]	Cross-sectional study	Children's exposure to smartphones and tablets was negatively associated with gross motor development. Additionally, there was a positive correlation between children's screen time and screen time of mothers and family members.
Zhao *et al*. 2022[2]	Cohort study	Children who had a progressive increase in screen time from 6 to 72 months of age had lower scores on the Full-Scale Intelligence Quotient and General Ability Index compared to children who had a smaller and stable screen time from 6 to 72 months. Children with high screen exposure from 6 months had lower scores on the Full-Scale Intelligence Quotient and Cognitive Proficiency Index, as well as a higher total difficulty score.

Table 1 (cont.). Main findings of consequences of early exposure to electronic devices on neurodevelopmental outcomes in early childhood.

Author	Study type	Result
Kerai *et al*. 2022[8]	Cross-sectional study	Children with more than 1 hour of daily screen time were more likely to be vulnerable in all developmental domains (physical health and well-being, social competence, emotional maturity, cognitive and language development, and communication skills) compared to children with up to 1 hour of daily screen time. The interaction between income and screen time did not reveal an effect on developmental health.
Moon *et al*. 2019[9]	Cross-sectional study	The frequency of smart device use was positively correlated with fine motor skills development in 3-year-old children. The adequate level of smart device use was also positively correlated with social development. However, smart device use time was significantly negatively correlated with expressive language months.
Madigan *et al*. 2019[10]	Randomized controlled trial	Higher levels of screen time at 24 and 36 months were significantly associated with poorer performance on developmental screening tests at 36 months and 60 months, respectively.
Van den *et al*. 2019[11]	Cross-sectional study	The prevalence of expressive speech delay reported by parents was 6.6%, and the prevalence of other communication delays reported by parents was 8.8%. For children who used a mobile device, each additional 30 minutes of daily mobile device use was associated with higher odds of expressive speech delay reported by parents. No association was observed between mobile device use and other communication delays reported by parents.
McNeil *et al*. 2019[12]	Cross-sectional study	Higher levels of screen time watching programs
Skalickál *et al.* 2019[13]	Cross-sectional study	More screen time at 4 years predicted lower levels of emotional understanding at 6 years. In addition, television in the children's room at age 6 predicted lower levels of emotional understanding at age 8. Gender was moderate, with stronger effects of watching television observed among girls, but no significant effect was detected among boys. In contrast, the games predicted a lower level of emotional understanding in boys, not girls.

Table 1 (cont.). Main findings of consequences of early exposure to electronic devices on neurodevelopmental outcomes in early childhood.

Author	Study type	Result
Guedes *et al*. 2020[5]	Cross-sectional study	The prevalence of the use of interactive media was 67.2%, with an average time of use of 69.2 minutes per day. The most performed activities were watching videos (55%), listening to music (33%), and playing games (28%). Most parents reported allowing the use of media to stimulate the development of their child (58.4%), accompanying him during use (75.2%), and limiting time with the media (86.4%).
Varadarajan *et al*. 2021[14]	Cross-sectional study	The average screen time (TT) was 2.39 hours/day and the prevalence of excessive TT was 73%. Excessive TT was significantly associated with mothers' TT, screen use at bedtime, birth order (in children < 2 years) and school attendance (in children ≥ 2 years). Increased TT was significantly associated with developmental delay, in particular, in the domains of language acquisition and communication. In children aged ≥ 2 years, delay in ≥ 3 domains was associated with TT, as was language delay. In children < 2 years, delay in ≥ 2 domains was associated with TT, as well as language delay A very high prevalence of excessive TT was identified, with a significant association with developmental delay in children. There is an urgent need to include education about the limits of TT at the primary healthcare level.
Rocha *et al*. 2021[15]	Cross-sectional study	A total of 3,155 children aged 0-60 months had screen time exposure assessed and 69% percent were identified as exposed to excessive screen time. This percentage of excessive screen time increased with the age of the child, from 41.7% for children from 0 to 12 months to 85.2% for children from 49 to 60 months. Each additional hour of screen time was associated with lower child communication, problem-solving, and personal-social domain scores.
McArthur *et al.* 2022[16]	Cohort study	Compared to 1 h/day, children who used screens for 2h had an increased probability of reporting behavioral problems, delay in meeting developmental milestones, and worse vocabulary acquisition.

DISCUSSION

Early childhood is the period from birth to 6 years of age, and this period is of great importance for neuropsychomotor development. About 75% of children in

this age group are using electronic devices (smartphones, tablets, and television) in an abusive manner. In the United States, 42% of children under 2 years of age use tablets, and 37% use smartphones. Over the years, it has been noted that excessive screen time modifies the neurodevelopment of children, leading authors to conduct studies to assess factors such as language, social interaction, motor development, and psychology.

In this sense, Guedes 2020 conducted a cross-sectional study with 244 parents and/or guardians of children enrolled in daycare centers with an average screen time of 69.2 minutes, which from questionnaires showed low school performance in around 51.2% after this period of use. In addition, they observed that children of low socioeconomic status use more social media[5]. The questionnaire had a key question that was "What was the reason for exposing the children to screen use?" and the answers were: 1- to distract the children in public (n=25; 15.3%); 2- to distract them at home (n=83; 50.9%); and 3- to stimulate development (n=97; 59.5%), remembering that electronic devices are generally small and easy to handle, often connected to the internet, such as smartphones, tablets, televisions, and computers, to attract even more the attention of children as well as bring interactive content and visual attraction, with colors.

Analyzing 117 children aged 3 to 5 years old, Moon 2019[9] developed a questionnaire like the aforementioned author, but here the author conducts a study where he

questions the parents and applies a final study on the children, the parents answered questions related to the use of smart devices, while their children underwent a developmental screening test and a receptive-expressive language scale. The questions addressed the frequency of use of intelligent devices, the time dedicated to them, the adequate level of use, and the levels of development. The results of the two questionnaires revealed a positive correlation with motor skills development (Spearman correlation rs=0.426), a negative correlation with expressive language (rs=-0.481), and a positive correlation with social development (rs=0.474), the association between the variables proportional to each other if one skill grows the other decreases.

Concerning the frequency of use of electronic devices, about 67.5% used between one to four times a week, 23.9% more than five times a week and 8.6% did not use. On the use time of electronic devices, 60.7-70.1% of children used for one hour a day, 86.3-95.7% used more than two hours a day, while less than 1 to 2% used for more than three hours a day. The study also concludes through these results that there is a delay in language development, there was no significant correlation between the use of intelligent devices, correlated positively with the social domain, however fine motor skills were more elaborated. Similar to what the Brazilian Pediatric Society recommends at most 1 hour per week of screen use for children over 2 to 5 months, with supervision, with specific stimuli such as educational

material, and other ages advise not to expose children to any type of screen and always maintain the stimulus to social interaction and creativity[17].

Zhao 2022[2] conducted a cohort study with 152 children from China between 6 months and 6 years of age using screens. The cognitive assessment of these children was assessed by the Wechsler Intelligence Scale for Children, 4th edition, this scale assesses the intellectual ability functions and the problem-solving process in children between 06 years and 0 months to 16 years and 11 months. The authors applied this scale to children who completed 72 months and related the excessive screen use in the early years to poor cognitive and socioemotional development, from the answers given on the scale.

Kerai 2022[8] conducted a study with preschoolers in Canada in which they observed and analyzed children using more than one hour of screens daily, through the application of a questionnaire where parents answered about the time and frequency of the use of screens. It was evidenced that impairment of the five developmental health domains (physical health and well-being, social competence, cognitive and language development, and communication skills) observed that children who used one more hour of screen per day, compared to children who used only 1 hour per day screen time. It is known that such skills are essential for the initiation of social interaction of these children, if impaired there may be children with psychological disorders.

In southern India, Varadarajan 2021[14], conducted a study with a sample number of 718 children under 5 years of age without cognitive or intellectual disabilities from rural and urban areas and described that the overall average use of smartphones and televisions was 2.39 hours per day. Of the total sample, 72.8% had similar screen time (TT) (weekdays and weekends), 24.2% had increased TT on weekends and only 2.7% decreased TT during the weekend. The authors also described that about 21.6% of children have access to electronics in their rooms. In child development, there were results such as delay in gross motor development (1.5%) and fine motor (2.1%), activities of daily living (3.6%), expressive language (11.8%), receptive language (6.2%), social interaction (4.6%) and emotional development (3.6%). These data demonstrate an association of use and TT as crucial factors in the delay of child development.

In Brazil, Rocha 2021[15] conducted a study in the state of Ceará with 3155 children from 0 to 5 years of age from maternal reports. It was observed that 69% had an excessive time of use of screens, (in addition to 1h/day), there was an increase in the percentage of use of screens with the increase in age, 41.7% for children from 0 to 12 months and 85.2% for children from 49 to 60 months of age.

In a study with parents and guardians of children in kindergartens in the interior of Brazil, children were distributed into 3 groups according to the use of social media, being a group that does not use them, a group that

uses up to 45 minutes a day and a third group that uses more than 45 minutes a day. Through the application of a questionnaire for parents, it was found that children in the first group from 24 to 35 months of age had an average time of use of 70.8 minutes/day, children in the second group from 36 to 47 months had an average5 minutes/day and the third 0% did not use screens[5].

There is also the contribution of Nobre 2021[4] who conducted a cross-sectional study with 180 children from 24 to 42 months without congenital and acquired diseases that affect psychomotor development, in which they were divided into two groups according to the time of use of screens. In group 1 were children with less than 2 hours/day and in group 2 children with screen exposure equal to or greater than 2 hours/day. Of these children, 63.3% were exposed to more than 2 hours/day of screen, with the recommendation of the Brazilian Society of Pediatrics being at most 1 hour/day. They also reported that 94.5% of children were exposed to screens mainly on television (61%), followed by portable interactive media, smartphones (41%), and tablets (22%). They also discuss the relationship between television use and language delay, impaired social interaction, and sedentary lifestyle, but positively relate the use of these devices with cognitive, linguistic, and fine motor child development.

Chaibal 2022[7] conducted a study with 85 healthy children with a mean age of 4.05±0.91 years who started the use of electronic devices at 2.77±1.04 years, in most

cases the objective of recreational use with exposure to screens to watch cartoons. After that, child development was evaluated using the Denver II Developmental Screening Test, which includes gross motor development, language, fine-adaptive motor, and personal-social developments. It was evidenced that 32.94% of the participants were classified with alterations in fine-adaptive motor development, 11.76% in personal-social development, 9.42% in language, and 2.35% in motor-grosso. In addition to this analysis, the details of the use of smartphones and tablets in the following seven days were evaluated and it was observed that the average time of use of smartphones and tablets was 82.78±62.82 min/day, with the longest time in children between 2 and 3 years. The main conclusion of this study was the highly significant impact of the duration of use of the smartphone and tablet by a child and its gross motor development. However, the results did not show a significant correlation between the duration of the use of electronics and the fine-adaptive motor, personal-social, and language developments. The time of use of these devices by children showed a positive and significant correlation with the time spent on smartphones and tablets by mothers and legal guardians, which highlights the importance of the attitudes of parents or guardians in child behavior. The father's medical history and family income showed significant interference with child development. Thus, caregivers should be aware of the exposure time of their children to smartphones and tablets to prevent developmental changes.

In a Brazilian cross-sectional study with 470 children, Gastaud 2023[6] analyzed cognitive development through the Bayley Scale of Child Development - Third Edition (BSID-III) scale is the gold standard for assessing child development and is applied to measure developmental milestones, this is a means of screening to detect delays through age-specific milestones[18]. The questionnaire was completed by the primary caregiver. The results showed that from the total, 58.8% of the children had 1 hour of screen time per day and that children 18 months who were exposed to digital media for 2 hours or more per day had lower scores on cognitive development compared to babies who had an exposure of less than 2 hours. In addition, cognitive development was lower in children whose mothers had lower levels of schooling, in boys, and in children exposed to 2 hours or more of screen time/day.

A study analysis regarding the influence of the use of screens on the attention of preschool children, examined data from the Canadian Study of Longitudinal Healthy Infant Development and realized that electronic devices were available to more than 95% of children[1]. Being a total of 2,322 children for 2,427 smartphones. In addition, it was evidenced in the study that, compared to children with less than 30 minutes/day screen time, those who watched more than two hours/day were 5.9 times more likely to report clinically significant inattention problems (95% IC: 1.6, 21.5; p=0.01). The association between screen time and behavioral changes was higher than any other risk factor.

Therefore, the authors reinforced the importance of parental control concerning the use of screens, especially in preschool age, since it can be a critical period for child development.

According to the meta-analysis of Madigan 2020[3], there is an association between screen time and the development of children's language, with a focus on 3 components: quantity, quality, and age of screen exposure. The authors also evaluated the time of linguistic development, which is the main marker of neurodevelopmental delay risk. Language has influences of psychosocial, neurobiological, and extrinsic factors, and the latter can be modified to optimize learning through stimuli, being through social interactions and interactive games. The amount of time spent on screens was analyzed by the program Comprehensive Meta-Analysis Software, version 3.0 (BioStat), and questionnaire Ages and Stages, Third Edition which evidenced that screen time was associated with lower child linguistic ability. The inclusion criteria of the study are pregnant women, age 18 years or older, ability to communicate in English, gestational age less than 24 weeks, and receive local prenatal care, from the pregnancies up to when their children were 4, 12, 24, 36 and 60 months of age. When the children had the months already described above, mothers answered the Questionnaire of Ages and Stages, Third Edition (ASQ-3), which is an early childhood development assessment instrument used by pediatricians. Through questions to parents, we evaluate the five domains: communication, gross motor skills, fine motor skills,

problem-solving, and personal-social, of infants. The highest scores indicate better development. They arrived at the result that the use of television has an association with language change. Within this same evaluation, they found that the later the children had contact with screens more developed their language. Thus, demonstrating that the later the child's contact with the screens the better his neurological development.

CONCLUSION

A comprehensive analysis of the aforementioned criteria reveals that excessive screen time in early childhood is associated with substantial implications for neuropsychomotor and cognitive development. These studies indicate that a significant number of children are being exposed to excessive screen time, primarily through smartphones, tablets, and televisions. This exposure is substantially related to negative outcomes, such as language delays, motor development impairment, cognitive development impacts, attention problems, and social and emotional disturbances.

The evidence also indicates that the timing of a child's first exposure to screens and the amount of exposure time play crucial roles in their effects. Therefore, delaying the onset of contact with electronic devices and limiting exposure time becomes a possibly beneficial alternative for child development. In this way, it is evident that parents, caregivers, and educators have a fundamental role in

managing children's screen time and should be aware of the implications of excessive screen time. It is essential to promote a healthy balance between screen time and other activities that stimulate child development. The results of these studies highlight the importance of a cautious and balanced approach to the use of electronic devices in early childhood, to ensure healthy and appropriate development for children during this crucial phase of their lives.

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