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DIGITAL OVERLOAD AND ITS IMPACT ON COGNITIVE FUNCTIONS OF SCHOOLCHILDREN

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Abstract: Digital technologies have become an integral part of the educational environment and daily life of modern schoolchildren. While digital tools offer new opportunities for learning and communication, excessive and uncontrolled use of digital devices has led to the phenomenon known as digital overload. This review examines digital overload as a growing public health and hygienic problem and analyzes its impact on cognitive functions of school-aged children. Particular attention is paid to attention, memory, executive functions, learning ability, and emotional regulation. The article discusses neurophysiological and psychosocial mechanisms underlying cognitive changes associated with prolonged screen exposure, multitasking, and digital stress. Current epidemiological data indicate a steady increase in screen time among schoolchildren, accompanied by negative trends in cognitive performance and academic outcomes. The relevance of digital overload is especially high for countries undergoing rapid digitalization of education systems. It is concluded that digital overload represents a significant risk factor for cognitive development, requiring preventive interventions within school hygiene and public health frameworks.

Keywords: digital overload, cognitive functions, schoolchildren, screen time, attention, memory, preventive medicine, school hygiene.

ЦИФРОВАЯ ПЕРЕГРУЗКА И ЕЁ ВЛИЯНИЕ НА КОГНИТИВНЫЕ ФУНКЦИИ ШКОЛЬНИКОВ

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Аннотация: Цифровые технологии стали неотъемлемой частью образовательной среды и повседневной жизни современных школьников. Хотя цифровые инструменты открывают новые возможности для обучения и общения, чрезмерное и неконтролируемое использование цифровых устройств привело к явлению, известному как цифровая перегрузка. В данном обзоре рассматривается цифровая перегрузка как растущая проблема общественного здравоохранения и гигиены, а также анализируется ее влияние на когнитивные функции детей школьного возраста. Особое внимание уделяется вниманию, памяти, исполнительным функциям, способности к обучению и

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эмоциональной регуляции. В статье обсуждаются нейрофизиологические и психосоциальные механизмы, лежащие в основе когнитивных изменений, связанных с длительным воздействием экранов, многозадачностью и цифровым стрессом. Современные эпидемиологические данные указывают на устойчивое увеличение времени, проводимого школьниками за экраном, сопровождающееся негативными тенденциями в когнитивных показателях и академических результатах. Актуальность цифровой перегрузки особенно высока для стран, переживающих быструю цифровизацию систем образования. Сделан вывод, что цифровая перегрузка представляет собой значительный фактор риска для когнитивного развития, требующий профилактических мероприятий в рамках школьной гигиены и общественного здравоохранения.

Ключевые слова: цифровая перегрузка, когнитивные функции, школьники, время, проводимое за экраном, внимание, память, профилактическая медицина, школьная гигиена

Relevance: In the twenty-first century, digital technologies have fundamentally transformed the educational process and everyday life of children and adolescents. Online learning platforms, smartphones, tablets, and social media are increasingly integrated into school curricula and leisure activities. According to international data, the average daily screen time of schoolchildren has increased by more than 70% over the past decade, reaching 6–8 hours per day in many countries [1]. While moderate and purposeful use of digital tools can enhance learning outcomes, excessive digital exposure has raised serious concerns regarding its impact on children's cognitive development and mental health.

The concept of digital overload refers to a state in which the intensity, duration, and fragmentation of digital information exceed the adaptive capacity of the developing brain. Unlike traditional learning environments, digital environments are characterized by constant notifications, multitasking, rapid information flow, and reduced opportunities for sustained attention. Neurodevelopmental research indicates that school age represents a critical period for the maturation of attention control, working memory, and executive functions [2]. Disruption of these processes by excessive screen exposure may have long-term consequences for cognitive performance and academic achievement.

Epidemiological studies suggest that excessive screen time is associated with reduced attention span, impaired memory consolidation, lower academic performance, and increased risk of emotional and behavioral disorders [3]. According to the World Health Organization, prolonged sedentary screen-based activities are among the key behavioral risk factors affecting child development and well-being [4]. These findings highlight the urgent need to consider digital overload as a significant public health issue rather than merely a behavioral or educational concern.

For countries undergoing rapid digitalization of educational systems, including Central Asian states, the relevance of digital overload is particularly high. The expansion of online education, limited regulation of screen exposure, and insufficient digital hygiene awareness among parents and teachers contribute to increased cognitive strain among schoolchildren. Traditional preventive medicine approaches, which focus primarily on physical health, must be expanded to include cognitive and neuropsychological dimensions of child health [5].

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Materials and methods: This review is based on an analysis of contemporary scientific literature addressing digital technology use, screen time, cognitive development, and child health. Relevant sources were identified through systematic searches of PubMed, Scopus, Web of Science, and Google Scholar, as well as reports from the World Health Organization, UNESCO, and pediatric and neurological associations.

Search terms included digital overload, screen time, cognitive functions, attention, memory, schoolchildren, and digital stress. Peer-reviewed articles, systematic reviews, meta-analyses, and large-scale observational studies published within the last 10–15 years were prioritized. Earlier foundational studies were included to provide neurodevelopmental context. Qualitative content analysis was applied to synthesize evidence on cognitive effects of digital exposure and preventive strategies relevant to school hygiene and public health [6,7].

Results and discussion: The digital environment of modern schoolchildren is characterized by early exposure to electronic devices, continuous connectivity, and simultaneous engagement with multiple digital platforms. Surveys indicate that more than 80% of children aged 8–12 years use smartphones daily, with a significant proportion engaging in multitasking during learning activities [8]. Educational digitalization, accelerated by the COVID-19 pandemic, has further increased screen exposure through online classes and homework assignments.

Unlike traditional educational materials, digital content often combines visual, auditory, and interactive elements, which increase cognitive load. Frequent task-switching and interruptions impair the brain's ability to maintain sustained attention and deep information processing. Cognitive load theory suggests that excessive external stimuli reduce working memory efficiency and learning capacity [9].

Attention is one of the most vulnerable cognitive functions affected by digital overload. Sustained attention, selective attention, and inhibitory control are essential for effective learning and academic performance. Studies demonstrate that excessive screen time is associated with a 20–30% reduction in sustained attention capacity among school-aged children [10].

Constant exposure to rapidly changing digital stimuli conditions the brain to expect immediate rewards, making it difficult to focus on monotonous or complex tasks. This phenomenon contributes to attentional instability and increased distractibility in classroom settings. Teachers increasingly report difficulties in maintaining students' concentration, which negatively affects learning outcomes.

Memory formation and consolidation are also significantly influenced by digital overload. Working memory, which supports problem-solving and comprehension, is particularly sensitive to cognitive fragmentation. Experimental studies indicate that multitasking during learning reduces information retention by up to 40% compared to single-task learning [11].

Moreover, excessive screen exposure before sleep interferes with circadian rhythms and sleep quality, which are essential for memory consolidation. Blue light emitted by digital devices suppresses melatonin secretion, leading to delayed sleep onset and reduced sleep duration. Chronic sleep deprivation in schoolchildren is associated with impaired memory, reduced academic performance, and emotional dysregulation [12].

Executive functions, including planning, cognitive flexibility, and self-regulation, undergo active development during school age. Digital overload negatively affects these functions by promoting impulsivity and reducing tolerance for delayed gratification. Neuroimaging studies suggest that excessive digital stimulation may alter neural pathways involved in executive control, although long-term effects require further investigation [13].

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Children exposed to high levels of digital multitasking demonstrate poorer performance in tasks requiring cognitive flexibility and problem-solving. These deficits may translate into difficulties with complex academic tasks and adaptive behavior in real-life situations.

Emotional regulation is closely interconnected with cognitive development and academic functioning in school-aged children. Digital overload exerts a substantial influence on emotional processes by increasing cognitive strain, disrupting reward mechanisms, and reducing opportunities for emotional self-regulation. Excessive exposure to digital stimuli, particularly fast-paced and emotionally charged content, contributes to heightened emotional reactivity and reduced tolerance for frustration.

Research indicates that children with high daily screen time demonstrate increased irritability, mood instability, and difficulties in emotional control compared to peers with moderate digital exposure [14]. Continuous stimulation of dopaminergic reward pathways through digital interactions, such as social media notifications and gaming rewards, conditions the brain to seek immediate gratification. As a result, children may experience decreased motivation for tasks requiring sustained effort, including academic activities.

From a neurodevelopmental perspective, emotional regulation skills are still forming during school age. Disruption of these processes by digital overload may have long-term consequences, increasing the risk of emotional dysregulation, behavioral problems, and reduced academic engagement. These findings emphasize the need to consider emotional health as an integral component of cognitive well-being in the context of digital hygiene.

Digital overload is increasingly associated with digital stress, a condition characterized by cognitive fatigue, emotional tension, and reduced psychological well-being. Schoolchildren exposed to prolonged screen time, online multitasking, and constant connectivity are at higher risk of stress-related symptoms, including anxiety, restlessness, and sleep disturbances.

Epidemiological studies suggest that children who spend more than 5–6 hours per day on digital devices have a 1.5–2 times higher risk of anxiety and depressive symptoms compared to those with limited screen exposure [15]. Academic pressure combined with digital learning environments further amplifies stress levels, particularly during periods of remote education.

The relationship between digital overload and mental health is bidirectional. While excessive digital use may contribute to anxiety and stress, children experiencing psychological distress may also turn to digital devices as a coping mechanism, creating a self-reinforcing cycle. Preventive strategies must therefore address both digital behavior and underlying psychosocial factors to effectively mitigate mental health risks.

Academic performance is a key indicator of cognitive functioning in schoolchildren and is significantly influenced by digital exposure patterns. While educational technologies can support learning when used appropriately, excessive and unstructured digital use is associated with lower academic achievement.

Large-scale studies demonstrate a negative correlation between excessive screen time and academic performance, particularly in reading comprehension, mathematical reasoning, and problem-solving skills [16]. Children who engage in frequent multitasking during homework exhibit reduced task completion rates and lower grades. The constant interruption of cognitive processes undermines deep learning and knowledge integration.

Digital overload also affects motivation and learning attitudes. Reduced attention span and increased cognitive fatigue decrease engagement with traditional learning materials. Teachers report increased classroom distractions and difficulties in maintaining students' focus, highlighting the need for balanced digital integration in educational settings.

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Sleep plays a critical role in cognitive development, memory consolidation, and emotional regulation. Digital overload significantly disrupts sleep patterns among schoolchildren, primarily due to evening screen exposure. Blue light emitted by digital devices suppresses melatonin production, delaying sleep onset and reducing sleep quality.

Studies indicate that children who use digital devices before bedtime experience a reduction in sleep duration by 30–60 minutes per night on average [17]. Chronic sleep deprivation is associated with impaired attention, memory deficits, increased impulsivity, and emotional instability. These effects compound the cognitive consequences of digital overload and contribute to declining academic performance.

From a preventive medicine perspective, sleep hygiene represents a crucial intervention point. Limiting screen exposure in the evening hours and promoting regular sleep routines can significantly mitigate the negative cognitive effects of digital overload.

The concept of digital hygiene has emerged as a preventive framework aimed at minimizing health risks associated with digital device use. Hygienic standards encompass recommendations related to screen time duration, ergonomics, visual health, and scheduling of digital activities.

International guidelines suggest limiting recreational screen time for school-aged children to no more than 2 hours per day, excluding educational use [18]. Regular breaks, appropriate lighting, correct posture, and adequate viewing distance are essential components of digital hygiene. Failure to adhere to these standards contributes not only to cognitive strain but also to visual fatigue, musculoskeletal disorders, and overall health decline.

In many educational systems, digital hygiene standards are insufficiently regulated or inconsistently applied. Teachers and parents often lack adequate training to manage digital exposure effectively. Integrating digital hygiene education into school health programs is therefore a critical preventive measure.

From a public health standpoint, digital overload represents a growing risk factor for child health that extends beyond individual behavior. Population-level increases in screen time have the potential to affect cognitive development trends and educational outcomes at a societal level.

Preventive medicine must therefore address digital overload through policy development, health education, and surveillance. Monitoring screen time patterns, cognitive indicators, and mental health outcomes among schoolchildren can inform targeted interventions. Public health campaigns promoting balanced digital use and awareness of cognitive risks are essential components of a comprehensive prevention strategy [20].

Effective prevention of digital overload requires a comprehensive, multi-level approach that addresses individual behavior, family environment, school policies, and public health regulation. From the perspective of preventive medicine and school hygiene, the primary goal is not the elimination of digital technologies, but the optimization of their use in accordance with the developmental needs of children.

One of the most effective preventive strategies is the regulation of screen time. Evidence-based recommendations emphasize the importance of age-appropriate limits on digital device use, particularly during early and middle school years. Studies indicate that reducing daily screen time to recommended levels is associated with significant improvements in attention, working memory, and academic performance within 6–12 months [21]. Structured schedules that alternate digital and non-digital activities help prevent cognitive fatigue and support sustained concentration.

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Another key strategy involves promoting single-task learning and reducing digital multitasking. Educational research demonstrates that minimizing multitasking during learning activities improves information retention, problem-solving ability, and conceptual understanding [19]. Schools should therefore encourage focused engagement with learning materials and limit unnecessary digital interruptions during lessons.

Parents play a decisive role in shaping children's digital habits and cognitive health. Parental modeling of healthy digital behavior strongly influences children's screen use patterns. Studies show that children whose parents set clear rules regarding screen time and device use demonstrate better self-regulation and lower levels of digital stress [21].

Home-based preventive measures include establishing screen-free zones and times, particularly during meals and before bedtime. Limiting evening screen exposure is especially important for protecting sleep quality and cognitive recovery. Parental involvement in children's digital activities, such as co-viewing educational content and discussing online experiences, enhances critical thinking and emotional regulation.

Educational programs aimed at improving parental awareness of digital overload risks are essential components of public health prevention. Parents often underestimate the cognitive impact of prolonged digital exposure, highlighting the need for targeted health education initiatives.

Teachers and schools are central actors in preventing digital overload and protecting cognitive health. Educational institutions must adopt balanced approaches to digital learning that prioritize cognitive development over technological novelty. Structured integration of digital tools, combined with traditional teaching methods, supports learning while minimizing cognitive strain.

Teacher training in digital hygiene and cognitive health is essential. Educators equipped with knowledge about digital overload can design lessons that optimize cognitive load and promote sustained attention. Classroom strategies such as scheduled breaks, active learning, and offline activities have been shown to improve attention and reduce cognitive fatigue among students [20].

School-based screening programs for attention difficulties, sleep problems, and digital stress can facilitate early identification of at-risk children. Collaboration between teachers, school psychologists, and healthcare professionals enhances the effectiveness of preventive interventions.

Healthcare professionals, particularly pediatricians, preventive medicine specialists, and school health physicians, play a critical role in addressing digital overload as a public health issue. Routine health assessments should include evaluation of screen time habits, sleep patterns, and cognitive functioning.

Counseling on digital hygiene should become a standard component of preventive healthcare for children and adolescents. Evidence suggests that brief counseling interventions delivered during routine medical visits can lead to meaningful reductions in screen time and improvements in sleep and attention [18].

Healthcare professionals also serve as trusted sources of information for parents and educators. Their involvement in community education programs strengthens public awareness and supports evidence-based prevention strategies.

At the population level, digital overload requires coordinated public health policies and regulatory frameworks. National guidelines on screen time, digital education standards, and school hygiene regulations provide a foundation for consistent preventive practices. Countries

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that have implemented national digital health policies report improved awareness and reduced variability in digital exposure among children [6].

Public health surveillance systems should include indicators related to digital behavior, cognitive development, and mental health. Monitoring trends in screen time and associated health outcomes enables timely intervention and policy adjustment. Media campaigns promoting balanced digital use and cognitive well-being further reinforce preventive messages.

The long-term implications of digital overload extend beyond immediate academic performance. Cognitive functions developed during school age form the foundation for lifelong learning, professional competence, and mental health. Persistent impairment of attention, memory, and executive functions may limit educational and occupational opportunities in adulthood.

Preventive interventions implemented during childhood have the potential to produce long-lasting benefits. Longitudinal studies suggest that early regulation of digital exposure is associated with improved cognitive outcomes and reduced risk of mental health disorders later in life [7]. These findings underscore the importance of early and sustained prevention efforts.

Conclusions: Digital overload represents a significant and growing challenge for child health, cognitive development, and educational outcomes in the digital era. This review demonstrates that excessive and unregulated digital exposure negatively affects key cognitive functions of schoolchildren, including attention, memory, executive control, and emotional regulation. These effects are mediated through increased cognitive load, disrupted sleep, emotional stress, and reduced opportunities for sustained learning.

From a preventive medicine and school hygiene perspective, digital overload should be recognized as an important behavioral and environmental risk factor. Traditional health promotion approaches must be expanded to include cognitive and neuropsychological dimensions of child health. Evidence discussed in this review highlights that balanced digital use, adherence to digital hygiene standards, and early preventive interventions can significantly mitigate the negative cognitive effects of digital overload.

The successful prevention of digital overload requires coordinated action by parents, teachers, healthcare professionals, and public health authorities. Educational institutions must implement structured digital learning strategies, families should foster healthy digital habits, and healthcare systems must integrate digital behavior assessment into routine preventive care.

In conclusion, addressing digital overload is essential for safeguarding cognitive development and academic potential of schoolchildren. Preventive strategies grounded in scientific evidence and public health principles can enhance cognitive resilience, improve educational outcomes, and support the healthy development of future generations in an increasingly digital world.

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