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Research article

ELECTRONIC DIGITAL DEVICES AND A RISK OF FUNCTIONAL DISORDERS OF THE VISUAL ANALYZER IN STUDENTS OF DIFFERENT AGE

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The aim of our study was to perform hygienic assessment of use of electronic digital devices and its relationship with likely disorders of the visual analyzer in students of different age.

Our research object is represented by students of different age (5^{th} grade (n = 55), 11^{th} grade (n = 67) and the 6^{th} year of HEI (n = 102)). This study focused on examining a relationship between disorders of the visual analyzer and use of electronic digital devices (EDDs) by students of different ages (5^{th} and 11th grades in school, 6^{th} year in HEI). We conducted social research by using a group indirect survey that relied on a specifically designed questionnaire consisting of 13 questions. Answers were collected by using Google Forms online platform.

Students were established to use a smartphone (99.6 % of the respondents) and / or laptop (83 %) in their everyday activities. We analyzed duration of an activity involving use of various devices and established that 95 % of the respondents did not adhere to the existing hygienic standards when using EDDs and spent more than 4 hours a day on using them. The regression analysis revealed an association between myopia development and simultaneous use of various EDDs (R^2 = 0.68; $p < 0.0001$). A contribution made to developing eyesight disorders by working with a laptop equaled 62 % whereas contributions made by watching TV and use of smart-watch equaled 19 % and 10 % respectively. Our assessment of a relative risk established that use of a laptop (PC) for more than 4 hours a day increased likelihood of myopia by 8.6 times (RR = 8.6; 95 % CI = 1.4–54.9, $p < 0.05$). Development of other functional disorders in school students was primarily associated with watching TV (85–89 %).

Therefore, our study findings provide more precise data on the established relationship between improper EDDs use and disorders of the visual analyzer in students of different age. They provide solid grounds for implementation of relevant prevention activities.

Keywords: *HEI students, school students, myopia, computer vision syndrome, electronic digital devices, electronic learning devices, relative risk.*

Protection and promotion of children's health is a priority target in the development of the healthcare and education in the Russian Federation. The modern digital environment produces considerable effects on children, adolescents, and youth as regards their learning activities, spare time, socialization, and lifestyle [1, 2]. Digitalization of education provides wide opportunities for using electronic educational resources, various simulators and emulators in order to master practical skills [3]. Development of digital skills in children facilitates development of the intellectual component in human potential thereby accelerating development of thinking, memory, attention, and imagination [4, 5]. On the one hand, electronic digital devices (EDDs) make education more effective; however, on the other hand, they are able to create unfavorable conditions, which, in their turn, are likely to

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induce various symptoms and health impairment in students [6, 7]. Students often use gadgets not only in learning activities but also in their spare time; they keep a wrong posture while doing it and do not have sufficient lighting. All this leads to such health disorders as accommodative excess, myopia of various degrees, computer vision syndrome, more rapid fatigue and, consequently, weaker resistance to stress [8–10]. Use of electronic devices is associated with such a civilization disease as dry eye syndrome, which is identified in 9–18 % of the population in developed countries. Over the last 30 years, the prevalence of this disease has grown by 4.5 times. Surveys conducted among medical students reveal dry eye syndrome of various intensity in 43.6 % of respondents [11, 12]. Uncontrolled digitalization will promote an annual growth in prevalence of myopia among school children and myopia progression by 0.5–2 diopters in 30 or higher % of them [13]. At present, a new term, 'epidemics of myopia', is being used in Russia [14]. Some British researchers report that a number of children who use smartphones and have their own electronic devices grows every year. Children aged between 8 and 11 years mostly use gaming gadgets whereas older children aged between 12 and 15 years prefer to use tablets and smartphones. Also, use of tablets by children aged between 5 and 15 has tripled by now against 2012 [15, 16].

The aim of our study was to perform hygienic assessment of use of electronic digital devices and its relationship with likely disorders of the visual analyzer in students of different age.

Materials and methods. Students of different age were selected as our research object. The sample included children who attended secondary schools (5^{th} grade (n = 55) and 11^{th} grade (n = 67)) and medical university undergraduates (6^{th} year, n = 102) (Table 1).

Table 1

Respondents of different age distributed as per sex

Age	Total, n = 224	
	male	female
5^{th} grade	16 (29 %)	39 (71 %)
11^{th} grade	9 (13.4 %)	58 (86.6 %)
6^{th} year university undergraduates	12 (11.8 %)	90 (88.2 %)

We conducted social research by using a group indirect survey that relied on a specifically designed questionnaire consisting of 13 questions. They described respondents' relations with electronic digital devices (EDDs): a gadget type, frequency of its use, duration of uninterrupted use; as well as occurring disorders of the visual analyzer: complaints of feeling unwell during and after EDD use and diagnosed myopia. Answers were collected by using Google Forms online platform.

The study was conducted in conformity with the ethical principles stated in the Declaration of Helsinki and the EU Directives (8/609EC). Prior to the study, all the participants were informed of its aims. An access to the online questionnaire was granted only after participants provided their informed voluntary consent.

We evaluated whether EDDs use conformed to the existing hygienic requirements relying on the Sanitary Rules SP 2.4.3648-20[1] and Sanitary Rules and Norms SanPiN 1.2.3685-21[2].

Research data were statistically analyzed by conventional methods of variation statis-

[1] SP 2.4.3648-20. Sanitarno-epidemiologicheskie trebovaniya k organizatsiyam vospitaniya i obucheniya, otdykha i ozdorovleniya detei i molodezhi; utv. postanovleniem Glavnogo gosudarstvennogo sanitarnogo vracha RF 28.09.2020 № 28 [Sanitary-epidemiological requirements to organizing education, leisure and health improvement of children and youth; approved by the Order of the RF Chief Sanitary Inspector on September 28, 2020 no. 28]. *Rospotrebnadzor*. Available at: https://www.rospotrebnadzor.ru/files/news/SP2.4.3648-20_deti.pdf (January 20, 2023) (in Russian).

[2] SanPiN 1.2.3685-21. Gigienicheskie normativy i trebovaniya k obespecheniyu bezopasnosti i (ili) bezvrednosti dlya cheloveka faktorov sredy obitaniya; utv. postanovleniem Glavnogo gosudarstvennogo sanitarnogo vracha RF 28.01.2021 № 2 [Hygienic standards and requirements to providing safety and (or) harmlessness of environmental factors for people; approved by the Order of the RF Chief Sanitary Inspector on January 28, 2021 no. 2]. *Rospotrebnadzor*. Available at: https://www.rospotrebnadzor.ru/files/news/GN_sreda%20_obitaniya_compressed.pdf (January 20, 2023) (in Russian).

tics in Microsoft Office 2010 and Statistica 6.0 applied software packages. We used the chi-square test to evaluate significance of difference in prevalence of health disorders. Relationships and combined effects of several EDDs were evaluated by using regression analysis with model significance identified as per the Fisher test and the determination coefficient (R^2). We calculated a relative risk (RR) and its 95 % confidence interval (95 % CI) to establish influence the priority EDDs had on prevalence of disorders of the visual analyzer. The significance level was taken as $p < 0.05$ for $RR > 1$ and the CI bottom limit > 1.

Results and discussion. The present study involved examining effects of the following EDDs: mobile electronic devices (MEDs) such as a smartphone or a smart watch; electronic learning devices (ELDs) such as a PC, laptop, or a tablet; other technical devices (TDs) such as a TV set or a gaming console [1].

Our study established that all the students used a smartphone in their everyday activity (99.6 % of the respondents). A laptop took the second place as per frequency of its use by the respondents (83 %). The total daily time of EDDs use is a significant indicator that describes its safety. It is noteworthy that duration of MEDs use (smartphone or smart watch) and TDs (gaming console) is not regulated by the existing regulatory documents; ELDs use (PC, laptop, or tablet), however, should not exceed 120 minutes a day for middle school children and 170 minutes a day for senior school children and HEI students. Actual findings that describe how the examined students were distributed depending on duration of using different technical devices, indicate that 95 % of the respondents do not adhere to the established hygienic standard when using ELDs and use them for more than 4 hours a day. The share of the respondents who use a smartphone for longer than 4 hours a day equals 79 %.

TV is watched and a smart watch is used daily by 39 and 25 % of the respondents respectively. Such devices as an e-book or a gaming console are used by the respondents much less frequently (8–9 %). However, if children and adolescents watch TV, use a smart watch or play games on a console, they spend not less than 4 hours a day on these activities.

Failure to adhere to safety rules when using electronic devices may be a risk factor able to cause functional disorders and chronic diseases of the eye [1]. Table 2 provides data on prevalence of some disorders of the visual analyzer in the students of different age included into the analyzed sample.

Myopia is obviously the most frequent disorder. The regression analysis established an association between myopia development and ELDs use (laptop or PC), watching TV, and use of a smart watch ($R^2 = 0.68$; $p < 0.0001$) (Table 3). A contribution made by laptop use to eyesight disorders was the highest and equaled 65 % whereas contributions made by watching TV and use of a smart watch equaled 19 % and 10 % respectively.

Table 2

Prevalence of functional disorders and chronic diseases of the eye in students of different age, %

Functional disorders and chronic diseases of the eye	Total $n = 224$		5th grade $n = 55$		11th grade $n = 67$		6th year $n = 102$	
	abs.	%	abs.	%	abs.	%	abs.	%
Myopia	171	76.3	35	63.6*	53	79.1	83	81.4*
Blurred vision	154	68.8	18	32.7$^{*\Delta}$	37	55.2$^{\bullet\Delta}$	99	97.1$^{*\bullet}$
Lacrimation	59	26.3	17	30.9*	26	38.8$^{\bullet}$	16	15.7$^{\bullet *}$
Photophobia	42	18.8	14	25.5	15	22.4	13	12.7
Excessive blinking	42	18.8	13	23.6	17	25.4	12	11.8

Note: significant differences ($p < 0.05$) between various age groups: $^{\Delta}$ is between the 5th grade and 11th grade; *, 5th grade and 6th year; $^{\bullet}$, 11th grade and 6th year

Table 3

Parameters of regression models describing relationships between prevalence of functional disorders and chronic diseases of the eye and long EDDs use in students of different age

EDD type	Response	b_1	Error	Fisher's test (F)	p	R^2
All age groups						
laptop	Myopia	0.919355	0.044370	429.3	<0.001	0.65
TV		0.386861	0.052450	54.4	<0.001	0.19
smart watch		0.313609	0.062841	24.9	<0.001	0.10
5th grade school students						
laptop	Myopia	0.972222	0.038405	640.8	<0.001	0.92
TV		0.571428	0.112725	25.7	<0.001	0.33
smart watch		0.476190	0.141107	11.4	0.0013	0.18
laptop	Blurred vision	0.5	0.116852	18.3	<0.001	0.26
TV		0.9	0.051657	303.5	<0.001	0.85
smart watch		0.880952	0.091497	92.7	<0.001	0.64
11th grade school students						
laptop	Myopia	0.854839	0.159942	28.6	<0.001	0.31
TV		0.4375	0.085132	26.4	<0.001	0.29
smart watch		0.264151	0.119629	4.9	0.03	0.07
laptop	Blurred vision	0.596774	0.222728	7.2	0.009	0.10
TV		0.9375	0.041540	509.3	<0.001	0.89
smart watch		0.566037	0.134482	17.7	<0.001	0.21
6th year university undergraduates						
laptop	Myopia	0.943181	0.062485	227.8	<0.001	0.69
TV		0.271428	0.079394	11.7	<0.001	0.11
smart watch		0.256756	0.083377	9.5	<0.001	0.09

We assessed a relative risk caused by eyesight disorders associated with unsafe ELDs use; as a result, we established that laptop (PC) use for more than 4 hours a day increased likelihood of myopia by 8.6 times (RR = 8.6; 95 % CI = 1.4–54.9, $p < 0.05$).

Next, we conducted a more profound examination of effects produced by ELDs, MEDs, and other TDs on students' health considering their age. Analysis of myopia prevalence revealed an overall ascending trend in it among HEI graduates against school students (Table 2). Prevalence of such functional disorders as blurred or double visions also grows in older students.

Myopia prevalence was shown to be associated with long laptop use (the 5th grade, $R^2 = 0.92$; $p < 0.0001$; the 11th grade, $R^2 = 0.31$; $p < 0.0001$; the 6th year, $R^2 = 0.69$; $p < 0.0001$) and watching TV (the 5th grade, $R^2 = 0.33$; $p < 0.0001$; the 11th grade, $R^2 = 0.29$; $p < 0.0001$; the 6th year, $R^2 = 0.11$; $p < 0.0001$) for all the examined age groups. A weaker association was established for use of a smart watch (the 5th grade, $R^2 = 0.18$; $p = 0.0014$; the 11th grade, $R^2 = 0.07$; $p = 0.03$; the 6th year, $R^2 = 0.09$; $p = 0.002$) (Table 3). It is noteworthy that long ELDs use involves more frequent myopia development than in the total sample and no significant differences have been identified between the analyzed age groups: 94.4 ± 3.8 % in the 5th grade, 85.5 ± 4.5 % in the 11th grade, 94.3 ± 2.5 % in the 6th year of HEI ($p > 0.05$).

Blurred vision as an eyesight disorder in school students was associated with watching TV (in the 5th grade, $R^2 = 0.85$; $p < 0.0001$; in the 11th grade, $R^2 = 0.89$; $p < 0.0001$), use of a smart watch (in the 5th grade, $R^2 = 0.64$; $p < 0.0001$; in the 11th grade, $R^2 = 0.21$; $p < 0.0001$), and laptop use (in the 5th grade, $R^2 = 0.26$; $p < 0.0001$; in the 11th grade, $R^2 = 0.10$; $p < 0.009$). Combined contributions made by these factors into the analyzed disorder equaled 88 and 89 % in the 5th and 11th

grade accordingly. Meanwhile, we did not establish any similar associations in HEI undergraduates; this may indicate that high prevalence of this disorder is caused by some other factors. Search for other factors established a trend of blurred vision being likely associated with use of smartphone (*RR* = 1.1; 95 % CI: 0.9–1.3).

Myopia prevalence varies between 19 and 42 % in developed countries and reaches 70 % in some eastern countries. According to A.A. Minnikhanova with colleagues, myopia prevalence is 6–8 % in junior school whereas it grows up to 25–30 % in senior school children [17]. A.M. Abdulina provides some evidence of a negative trend in school ontogenesis in her article 'The Impact of Computer on Eyesight'. Thus, only 2.4 % of children have myopia when they first come to school; by the 5th grade, the share reaches 19.7 %; by the 11th grade, myopia prevalence reaches 36.8 % and this level is quite similar to the European one [14]. At the same time, V.R. Kuchma and others [18] report in their research on children's population health that myopia of different severity is diagnosed in 62 % of school students by the end of school education. O.M. Filkina with colleagues established in their study that the number of children with myopia grew by 2.1 times over the period of school education (p = 0.0098) [19]. Myopia prevalence among school students in Perm was analyzed in dynamics; as a result, a growth in it equaled 2.3 times between the 1st and 5th grade when the share of school students with myopia reached 39 % [20]. Myopia development has its peculiarities due to implementation of different educational programs. In particular, myopia develops much earlier in students who attend school with profound studies of some subjects (*RR* = 1.48–2.50; 95 % CI = 1.22–3.75; p < 0.001) [21]. A complex medical examination of medical students in Orenburg detected myopia in 29.5 % of them and mild myopia was the most widely spread (53.8 %) [22]. Findings of the present study revealed a rather high prevalence of the disease: 63.6 % in the 5th grade, 79.1 % in the 11th grade and 81.4 % in HEI graduates. On the one hand, this might be due to respondents' tendency to overestimate their health disorders and to be too anxious about their health. On the other hand, we cannot exclude some errors caused by absence of complete official data.

Computer vision syndrome caused by long use of electronic devices combines symptoms of asthenopia and dry eye syndrome [23]. In the present study, the respondents mentioned blurred and double vision (68.8 %) and lacrimation (26.3 %). When conducting a survey among medical students, O.V. Ievleva found that approximately 62 % of the respondents complained of double vision, lacrimation, and lower visual working capacity after or during EDDs use [24]. However, any signs of computer vision syndrome were mentioned solely in 3.6 % of cases in the study by E.I. Shubochkina with colleagues [25]. These differences are likely to be associated with different duration of gadget use by students.

Duration of students' interaction with such devices was analyzed to find evidence of EDDs negative effects as a risk factor able to cause health disorders in them. Review and generalization of findings reported in published articles make it possible to conclude that children who rarely use gadgets have higher values of the health index [5]. Parental control of MEDs use decreases the risk of myopia development by more than 2 times [14]. Other authors report an association between myopia in school students and use of gadgets by them for longer than 6 hours a day (*RR* = 1.8; 95 % CI = 1.21–3.61, p < 0.05) [19]. Some studies by foreign authors confirm this association as well: R. Saxena with colleagues provide some data on growing risks of myopia when time spent on PC games exceeds 4 hours a week (*OR* = 8.1; 95 % CI = 4.05–16.2; p < 0.001) [26]. Examination of adolescents aged between 10 and 15 years revealed an association between myopia prevalence and EDDs use for more than 1 hour a day (p = 0.011) [27, 28]. An association between visual acuity disorders and failure to use EDDs safely is also well-known and is identified for several parameters of unsafe use (absence of necessary breaks, irrational working posture, insufficient

lighting, failure to do eye gymnastics, etc.) (*RR* = 3.07; 95 % CI = 1.88–5.03, $p < 0.05$) [1]. Our research results provide more precise data on the established relationship between improper EDDs use and disorders of the visual analyzer. In particular, we identified priority EDDs and established the relationship between their use and myopia prevalence in students of different age (5^{th} grades, 11^{th} grades, and 6^{th} year). ELDs (laptop and PC) were established to increase the risk of visual acuity disorders by 8.6 times in case they were used for longer than 4 hours a day. We also determined peculiarities of associations between ELDs and prevalence of functional disorders in schoolchildren and HEI students.

Limitations of the study. Since the sample does not cover cases when some MEDs, ELDs and TDs are used for a shorter period of time than two or four hours, it is not deemed possible to fully evaluate likelihood of functional disorders and chronic diseases of the eye associated with use of such devices. In addition, we should consider the fact that the examined sample was predominantly made of females and we can expect certain bias in the study findings towards overestimation given the well-known and evidenced sex-specific differences in myopia prevalence.

Conclusions:

1. Smartphone (99.6 %) and laptop (83 %) are priority digital devices used by the respondents. Simultaneously, students of the 5^{th} grade also watch TV and those of the 11^{th} grade tend to use gaming consoles.

2. Myopia prevalence equals 76.3 % on the whole among schoolchildren and students in the examined sample; prevalence of functional disorders is 141.1 %.

3. Daily MEDs, ELDs and TDs use causes visual acuity disorders. Contribution to myopia development made by laptop (PC) use equals 65 %; contributions made by watching TV and use of a smart watch equal 19 % and 10 % accordingly. The total contribution made by all the factors amounts to 68 %.

4. Use of ELDs (laptop or PC) that does not conform to the existing hygienic standards for its duration (longer than 4 hours) increases the risk of myopia by 8.6 times (*RR* = 8.6; 95 % CI: 1.4–54.9, $p < 0.05$).

5. Development of functional disorders (blurred or double vision, lacrimation) in schoolchildren is primarily associated with watching TV (85–89 %), use of a smart watch (21–64 %) and laptop (PC) use (10–26 %). Similar disorders are caused in HEI students by some other risk-inducing factors, including those not covered by the present study.

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