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Research article

PECULIARITIES AND RISKS OF MYOPIA IN CHILDREN ATTENDING COMPREHENSIVE SCHOOLS WITH DIFFERENT EDUCATIONAL PROGRAMS

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The contemporary educational process involves growing diversity and complexity of educational programs and intensity of educational loads. All this, in its turn, affects schoolchildren's health. Diseases of the eye and adnexa occupy the leading place among pathologies that are caused by unfavorable educational conditions. Prevalence of such diseases grows steadily over the whole period of getting secondary education.

The aim of this study was to examine peculiarities and assess risks of myopia in children attending comprehensive schools with different educational programs.

Overall, we examined 804 children from the 1st to 11th grade. The test group was made of 312 children who attended comprehensive schools with profound studies of some subjects. The reference group included 492 children who attended ordinary comprehensive schools. Both groups were identical as regards sex and age (p = 0.203–0.479). The study involved handing out questionnaires; estimating whether the organization of the educational processes conformed to the sanitary legislation of the Russian Federation. The research data were analyzed with conventional statistical methods, ROC-analysis, and logistic modeling.

We established several leading risk factors that caused myopia in students of comprehensive schools with profound studies of some subjects. They included 5.4–19.2 % higher educational loads; 1.4 times longer periods of PC use during classes; 1.5 times longer periods of work with digital technologies. The children from the test group tended to have myopia, including moderate and high one, 1.3–2.4 times more frequently; the disease occurred at a younger age; risks of the disease were typically higher in such schools (OR = 1.48–2.5). Causation of myopia by factors related to the educational process and digital initiation equaled R^2 = 0.52–0.77. Use of ROC-curves identified cut-off points that showed how long it took myopia to develop under the specific educational conditions in comprehensive schools with profound studies of some subjects (the 5th grade) and in ordinary comprehensive schools (the 7th grade).

ROC-analysis data indicate it is necessary to apply a differentiated approach to organizing preventive activities for children who attend comprehensive schools with different educational programs.

Keywords: *myopia, refractive disorders, accommodative dysfunctions, students, schools with different educational programs, educational process, relative risk, ROC-analysis, cut-off point.*

According to Rosstat data, diseases of the eye and adnexa account for approximately 5–6.0 % of the total incidence among both children aged 0–14 years and adolescents aged 15–17 years. Among them, the leading place belongs to refractive disorders and accommodative dysfunctions; no descending trends have been registered for the incidence of these diseases starting from 2005[1] [1]. According to the WHO data, approximately 370 million children and adolescents worldwide may have myopia [2]. Experts pay special attention to

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[1] Zdravookhranenie v Rossii. 2021: Statisticheskii sbornik [Healthcare in Russia. 2021: Statistical data collection]. *Rosstat.* Moscow, Federal State Statistics Service, 2021, 171 p. Available at: https://rosstat.gov.ru/folder/210/document/13218 (April 18, 2023) (in Russian).

the fact that the number of myopia cases identified during medical examinations at school is higher than the incidence of myopia identified after an actual application for medical aid. The former number reaches 30 % and some researchers predict a further growth in the incidence of myopia [1–3].

Results reported in accomplished longitudinal studies indicate a statistically significant growth in both functional and chronic diseases of the eyes over 11 years of studying at school; this growth reaches +106.8 and +1445.5 % accordingly [4, 5].

In the Russian Federation, the state is obliged to take on basic responsibilities for providing such learning conditions that do not pose any health hazard and exclude exposure to any harmful factors[2]. Some researchers have reported that negative effects produced by socioeconomic factors, the environment, and the organization of the educational process contribute to additional cases of diseases, including diseases of the eye and adnexa [1, 6, 7]. Irrational use of electronic devices by teachers in the learning process as well as children using smartphones or other electronic devices on their own and without any control is among leading risk factors making for the development of refractive disorders and accommodative dysfunctions [8–10].

At present, the procedure and terms of obligatory medical examinations of minors are stipulated in the Order by the RF Public Healthcare Ministry dated August 10, 2017 No. 514n "On the Procedure for conducting medical examinations of minors"[3]. The Order does not consider the contents and orientation of educational programs. According to some previous studies, prevalence of myopia tends to be higher among schoolchildren attending schools with profound studies of some subjects than among their counterparts who attend ordinary comprehensive schools [1].

The aim of this study was to examine peculiarities and assess risks of myopia in children attending comprehensive schools with different educational programs.

Materials and methods. Overall, we examined 804 children and adolescents from the 1^{st} – 11^{th} grades of comprehensive school. The test group was made of 312 students attending comprehensive schools with profound studies of some subjects (162 (51.9 %) boys and 150 (48.1 %) girls, their average age was 12.6 ± 2.9 years). The reference group included 492 students who attended ordinary comprehensive schools (235 (47.8 %) boys and 257 (52.2 %) girls, their average age was 12.3 ± 2.9 years). The groups were identical as regards sex and age (p = 0.203–0.479). The share of students from each grade was comparable in both groups and amounted to 8–11 %.

We relied on several criteria to include children and adolescents into the study: they attended either a comprehensive school with profound studies of some subjects or an ordinary comprehensive school; they did not have any acute communicable diseases; their parents or legal representatives provided a written consent to medical examinations.

The exclusion criteria were as follows: children attended a school with other types of educational programs; they had an acute communicable disease, including those affecting the eye; they suffered from a disease of the eye that did not involve refractive disorders or accommodative dysfunctions.

The study was accomplished within the scientific research task entitled 'Establishment of causes and conditions for the development of diseases in children associated with peculiarities of the contemporary educational process

[2] Ob osnovakh okhrany zdorov'ya grazhdan v Rossiiskoi Federatsii: Federal'nyi zakon ot 21 noyabrya 2011 g. № 323-FZ [On fundamentals of public health protection in the Russian Federation: the Federal Law issued on November 21, 2011 No. 323-FZ]. *GARANT: information and legal support*. Available at: https://base.garant.ru/12191967/#friends (April 21, 2023) (in Russian).

[3] O Poryadke provedeniya profilakticheskikh meditsinskikh osmotrov nesovershennoletnikh: Prikaz Ministerstva zdravookhraneniya RF ot 10 avgusta 2017 g. № 514n (s izmeneniyami i dopolneniyami) [On the Procedure for conducting medical examinations of minors: the Order by the RF Public Healthcare Ministry dated August 10, 2017 No. 514n (with alterations and supplements)]. *GARANT: information and legal support*. Available at: https://base.garant.ru/71748018/ (April 21, 2023) (in Russian).

and quality of the environment'. The study was accomplished during the period between April 01, 2020 and December 01, 2022.

We comparatively assessed whether the organization of the educational process conformed to the sanitary legislation of the Russian Federation[4].

The study involved handing out questionnaires to be filled in by the participants. The author's questionnaire was developed by experts from the Federal Scientific Center for Medical and Preventive Health Risk Management Technologies and tested in 2015–2022. The questionnaires were filled in by parents of primary school children or by adolescents themselves who attended middle or senior school. Among other aspects, the questionnaire contained questions aimed at describing how schoolchildren interacted with different types of electronic devices and extra educational loads beyond educational programs provided at school.

Complex ophthalmological examination included visometry with Sivtseva tables, shadow-tests, autorefractometry, ophthalmoscopy with a direct ophthalmoscope, color sensitivity study with Rabkin's polychromatic tables, identification of the near and far point of vision, accommodation volume and reserves, strabismus quantification as per the Hirshberg's test, and binocular vision identification with the Worth Four Light Test.

We calculated prevalence of refractive disorders and accommodative dysfunctions; separately, prevalence of accommodative dysfunctions; prevalence of myopia including moderate and high one (the ratio between the number of diseases cases identified during a medical examination and the total number of examined schoolchildren multiplied by 100, (%)).

The present study was approved by the local Ethics Committee of the Federal Scientific Center for Medical and Preventive Health Risk Management Technologies (the meeting report No. 2 dated March 01, 2018). It was accomplished in conformity with the ethical principles stated in the WMA Declaration of Helsinki and the RF National Standard GOST-R 52379-2005 Good Clinical Practice (ICH E6 GCP). Parents or legal representatives of all the examined children gave their written informed consent to medical intervention.

Statistical analysis. Data were statistically analyzed with Jamovi statistical application, SPSS, and Excel-based software packages. When analyzing questioning data, we determined statistical significance of differrence between variables identified in subsamples and intensity of correlations between variables using correlation coefficients eligible for a specific quantity of samples (Spearman's, coefficient, Cramer' V, or phi coefficient) with a corresponding scale for estimating intensity of a correlation. Prevalence of diseases of the eye among schoolchildren attending analyzed schools was compared using Pearson's chi-square (χ^2) for fourfold tables; we also calculated a relative risk (*OR*) with 95 % confidence interval (*CI*). The results of logistic modeling are given as the determination coefficient (R^2) that indicates a per cent of variability for the dependent variable, Fisher's test (*F*), the constant (b_0), the regression coefficient (b_1), and statistical significance of a model (*p*). We built a ROC-curve (receiver operating characteristic) for the value indicating a 'grade'. The area under the curve or AUC, together with the

[4] 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 ot 28 sentyabrya 2020 g. № 28; vved. v deistvie s 01.01.2021 g.) [SP 2.4.3648-20. Sanitary-epidemiological requirements to organizing education, leisure and health improvement of children and youth: Sanitary Rules (approved by the Order of the RF Chief Sanitary Inspector on September 28, 2020 No. 28; became valid on January 01, 2021)]. *GARANT: information and legal support*. Available at: https://www.garant.ru/products/ipo/prime/doc/74993644/ (April 11, 2023) (in Russian); 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 ot 28 yanvarya 2021 g. № 2; vved. v deistvie s 01.03.2021 g.) [SanPiN 1.2.3685-21. Hygienic standards and requirements to providing safety and (or) harmlessness of environmental factors for people: Sanitary Rules and Norms (approved by the Order of the RF Chief Sanitary Inspector on January 28, 2021 No. 2; became valid on March 01, 2021)]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/573500115 (April 11, 2023) (in Russian).

model quality, was estimated as per conventional procedures. We relied on the Youden index values ((Se+Sp)-1) where Se is model sensitivity and Sp is model specificity) to identify a cut-off point of a grade for the development of myopia. In case the Youden index values were equal for different grades, we took a value for which sensitivity was close to specificity as a cut-off point. Differences were considered statistically significant at $p \leq 0.05$.

Results and discussion. Our comparative assessment of the education process established that some violations were common for both types of the analyzed schools such as duration of long breaks, switching between easy and difficult subjects during a day and a week, and even distribution of educational loads throughout a week. Apart from these violations, we established that small breaks between lessons on average equaled 9.66 ± 3.12 minutes in schools with profound studies of some subjects. This violated the requirements fixed in the item 3.4.16 of the Sanitary Rules SP 2.4.3648-20 (not shorter than 10 minutes) and was shorter than in ordinary comprehensive schools where the small breaks lasted 10.31 ± 3.09 minutes ($p = 0.045$).

We comparatively analyzed educational loads in hours and established that they were 19.2 and 5.5 % higher than their maximum permissible amount in primary and middle grades accordingly in comprehensive schools with profound studies of some subjects. In senior school, the educational loads were 5.4 % higher than the permissible amount in such schools. Our timing examinations of how long electronic teaching aids (ETAs) were used during classes revealed that an interactive whiteboard (IWB) was used 1.3–2.2 times longer than permitted during some classes in comprehensive schools with profound studies of some subjects. Average duration of IWB use was 1.2–2.6 times longer than in ordinary comprehensive schools ($p < 0.0001$). Average total IWB use was also up to 2.5 times longer in schools with profound studies of some subjects than in ordinary comprehensive schools ($p < 0.0001$–0.011). Duration of PC use during a class and the total PC use a day was 1.4–1.5 times longer than permitted in comprehensive schools with profound studies of some subjects; these indicators were 1.5–1.6 and 2 times higher accordingly in such schools than in ordinary comprehensive schools ($p < 0.0001$).

We analyzed how many electronic devices schoolchildren used and the age of their first contacts with such devices. As a result, we established that a half of students attending the analyzed comprehensive schools (52.5 %) usually contacted two different devices. However, the number of students who used 3 or even more devices was 1.5 times higher in schools with profound studies of some subjects than in ordinary comprehensive schools (33.1 against 22.1 %, $p = 0.001$; Cramer's V is 0.20; $p = 0.011$). In comprehensive schools with profound studies of some subjects, the number of schoolchildren who first used a tablet when they were younger than 6 years was 3.3 times higher (44.0 against 13.2 % in the reference group, $p = 0.004$; Cramer's V is 0.31; $p = 0.019$).

Our assessment of extra-school educational loads revealed that 1.4–1.5 times more respondents in the test group attended institutions of additional education (85.6 against 60.3 % in the reference group; $p < 0.0001$; the phi coefficient is 0.29; $p < 0.0001$) and were given homework in them (46.3 % in the test group and 31.4 % in the reference one; $p < 0.0001$; the phi coefficient is 0.15; $p < 0.0001$). Twenty-five point two percent of the children who attended schools with profound studies of some subjects and 20.3 % of those who attended ordinary comprehensive schools spent more than 20 hours a week on attending additional classes and doing homework, both given at schools and by institutions of additional education.

Table 1 provides the results of the complex eyesight diagnostics accomplished by an ophthalmologist. Refractive disorders and accommodative dysfunctions were 1.4 times more frequent in the test group than in the reference one; myopia was 1.3 times more frequent and moderate or high myopia was 2.4 times more frequent in the test group with its

Table 1

Ophthalmological examination of children attending two different types of schools

Examination results	The test group, $n = 312$		The reference group, $n = 492$		χ^2	p	*OR* (*CI*)
	n	%	n	%			
Refractive disorders and accommodative dysfunctions	181	58	202	41.1	21.3	< 0.001	1.41 (1.23–1.63)
Accommodative dysfunctions	56	17.9	69	14	2.24	0.163	1.28 (0.93–1.78)
Myopia	125	40.1	133	27	14.3	< 0.001	1.48 (1.22–1.81)
Moderate or high myopia	50	15.3	32	6.5	17.9	< 0.001	2.5 (1.62–3.75)

Table 2

Parameters of logistic regression models ‘Factor – probability of a response’

Factor	Response	b_0	b_1	F	p	R^2
Violation of maximum permissible weekly educational loads	Myopia	-6.73	0.21	30.0	< 0.001	0.52
Violation of permitted duration of PC use during classes	Myopia	-0.94	0.41	156.0	< 0.001	0.56
The number of used electronic devices	Refractive disorders and accommodative dysfunctions	-0.47	0.16	151.1	< 0.001	0.77

relative risk reaching 1.28–2.5 ($p < 0.001$). We did not establish any statistically significant differences between the groups with respect to separate accommodative dysfunctions and risks of their occurrence ($p = 0.163$).

We built one-factor logistic regression models to describe the relationship between refractive disorders and accommodative dysfunctions, myopia included, and factors of the educational process and lifestyle. As a result, we established statistically significant effects produced on the dependent variables by such factors as high weekly educational loads, irrational ETAs use at school, and the number of used electronic devices ($R^2 = 0.52–0.77$; $p < 0.001$) (Table 2).

We established a direct correlation between time spent on additional education and doing homework and higher frequency of myopia (the Spearman’s coefficient is 0.21; $p = 0.001$).

Our further analysis revealed that the median age at which myopia was diagnosed in schoolchildren attending schools with profound studies of some subjects tended to decline and amounted to 12 (11; 14) years against 13 (12; 14) years for schoolchildren who attended ordinary comprehensive schools ($p = 0.089$). We did not detect any statistically significant differences as regards the age at which accommodative dysfunctions occurred (12 (10; 13) against 11 (10; 14) years, $p = 0.532$).

Given the detected trend, we applied ROC-analysis in order to identify the critical threshold of studying at school (grade) for myopia development in schoolchildren attending the analyzed schools using the cut-off point. Good prognostic capabilities and reliability of the applied method were estimated as per the area of the ROC-curve above the line of the ‘worthless’ classifier for the value ‘grade’ with respect to myopia development both in the schoolchildren who attended comprehensive schools with profound studies of some subjects (AUC = 0.700; $p < 0.001$) and those attending ordinary comprehensive schools (AUC = 0.702; $p < 0.001$) with different values of the cut-off according to the ROC-analysis matrix.

For the schoolchildren who attended comprehensive schools with profound studies of some subjects, the cut-off point of the period of education for myopia development corresponded to the 5th grade (the maximum Yuoden index value is 0.31; the model sensitivity is

Table 3

Parameters of the ROC-analysis for identifying the cut-off point of a period of education for myopia development in the schoolchildren attending the analyzed comprehensive schools

Grade	Schools with profound studies of some subjects			Ordinary comprehensive schools		
	Sensitivity, %	Specificity, %	Yuoden index	Sensitivity, %	Specificity, %	Yuoden index
1	100	0	0.00	100	0	0.00
2	100	5.7	0.06	100	5.4	0.05
3	100	11.4	0.11	100	13.0	0.13
4	96.5	28.9	0.25	98.4	21.1	0.19
5	**88.2**	**42.5**	**0.31**	91.9	33.5	0.25
6	82.4	47.4	0.30	79.7	46.5	0.26
7	67.1	60.1	0.27	**69.9**	**57.8**	**0.28**
8	54.1	74.1	0.28	59.4	67.3	0.27
9	44.7	77.6	0.22	53.7	73.0	0.27
10	29.4	86.8	0.16	44.7	83.2	0.28
11	15.3	90.4	0.06	13.0	93.5	0.07

88.2 % and the model specificity is 42.5 %); the cut-off point corresponded to the 7th grade for the schoolchildren attending ordinary comprehensive schools (the maximum Yuoden index value is 0.28; the model sensitivity is 69.9 % and the model specificity is 57.8 %) (Table 3).

The aim of this study was to examine peculiarities and assess risks of myopia in children attending comprehensive schools with different educational programs.

We comparatively analyzed the organization of the education process and assessed whether it conformed to the valid sanitary legislation. As a result, we established that schools with profound studies of some subjects tended to have substantially elevated educational loads and violated the hygienic standards more frequently when drawing up timetables and organizing classes with ETAs use ($p < 0.0001$–0.045). All this increases 'ophthalmological costs' of learning. Our research data are consistent with the results reported by D.A. Eisfeld with colleagues [11] who investigated influence exerted by risk-inducing factors of the educational process and the environment on somatic health of students attending schools of different types; by A.G. Setko with colleagues [12] who examined peculiarities of the neuro-psychic state and life quality of students who attended innovative schools; by V.R. Kuchma and others [13] who estimated the organization of the educational process in profile classes in colleges. Statistically significant differences were identified when we compared the number of electronic devices used by schoolchildren and the age at which they had their first contacts with such devices, as well as volumes of additional educational loads beyond school ($p < 0.0001$–0.004). Direct influence exerted by the number of additional education institutions attended by schoolchildren on their health was confirmed in the study by O.P. Gritsina with colleagues [14, 15]. Uncontrollable use of gadgets by children and adolescents is another topical issue since it can contribute to eye disorders regardless of a school they attend [16].

Given the elevated weekly educational loads, too long periods of ETAs use during classes, and the growing number of electronic devices ($R^2 = 0.52$–0.77) used by schoolchildren who attend comprehensive schools with profound studies of some subjects, prevalence of refractive disorders and accommodative dysfunctions identified in this study is substantially higher than it is stated in the official statistical reports[5] [1]. Our research results do not

[5] Zdravookhranenie v Rossii. 2021: Statisticheskii sbornik [Healthcare in Russia. 2021: Statistical data collection]. *Rosstat.* Moscow, Federal State Statistics Service, 2021, 171 p. Available at: https://rosstat.gov.ru/folder/210/document/13218 (April 18, 2023) (in Russian).

contradict those reported in other studies with their focus on exposure to harmful factors of the educational process and its effects on schoolchildren's eyes [1, 7, 17, 18].

We identified that myopia tended to develop at a younger age in schoolchildren who attend comprehensive schools with profound studies of some subjects; frequency of myopia was 1.3–2.4 times higher among them and moderate or high myopia were also identified more frequently; we established relative risks of the disease for them to be equal to 1.48–2.5; the different cut-off points showing the grade during which myopia started to develop in schoolchildren were established as per the ROC-curves with good quality of the created models (AUC = 0.700; $p < 0.001$; AUC = 0.702; $p < 0.001$). All this indicates the necessity to pay greater attention to timely diagnostics of eye problems and diseases in schoolchildren considering the peculiarities of the contemporary educational process [19, 20].

Conclusions:

1. When educational programs involve profound studies of some subjects, the educational process and some lifestyle aspects associated with it are characterized with a growth in educational loads by 5.4–19.2 % against the hygienic standards; violated requirements to duration of short breaks and ETAs use during classes (the indicators are usually 1.3–2.2 times higher than the corresponding hygienic standards, $p < 0.0001$), early start of digital activity and highly intensive use of electronic devices (the Cramer's V is 0.20–0.31, $p = 0.011–0.019$) as well as active involvement into additional education (the phi coefficient is 0.29, $p < 0.0001$).

2. Under exposure to leading risk factors (weekly educational loads being higher than their maximum permissible level, irrational ETAs use during classes, and the growing number of used electronic devices), their contributions being confirmed by logistic modeling results ($R^2 = 0.52–0.77$, $p < 0.001$), myopia, including moderate or high myopia, develops 1.3–2.4 times more frequently and at an younger age, and the relative risk of the diseases also grows by 1.5–2.5 times ($OR = 1.48–2.50$; $CI = 1.22–3.75$; $p < 0.001$).

3. The ROC-analysis data indicate the significance of myopia development in schoolchildren attending comprehensive schools with profound studies of some subjects already in the 5th grade whereas it develops significantly in schoolchildren who attend ordinary comprehensive schools only in the 7th grade. This should be considered when developing and implementing health protection technologies at schools of different types.

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