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Research article

SUBSTANTIATING OPTIMAL PARAMETERS OF RISK FACTORS EXISTING IN THE EDUCATIONAL ENVIRONMENT FOR SCHOOLCHILDREN AS PER INDICATORS OF PHYSICAL, MENTAL AND SOMATIC HEALTH

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Schoolchildren are simultaneously exposed to several risk factors associated with the educational process, nutrition in school, ambient air quality, water quality, socioeconomic conditions etc. Their intensity and combinations largely determine indicators of children's physical, somatic and mental health. Our research goal was to quantify influence exerted by a set of risk factors existing in the educational environment on key indicators of schoolchildren's health. We examined 661 children who attended four secondary education institutions of different types. The educational processes in each institution were estimated to check their conformity with sanitary-epidemiological requirements and hygienic standards. Psychological testing included tests aimed at assessing attention, cognitive functions, memory and stress. Laboratory tests involved using liquid and gas chromatography and spectrophotometry. Nutrition provided by schools was estimated to check whether it conformed to the standards stipulated in the Sanitary Rules and Norms SanPiN 2.3/2.4.3590-20. Socioeconomic factors influencing the examined children were assessed as per results produced by a social survey. All the data were statistically analyzed with conventional statistical procedures and mathematical analysis. Influence exerted by risk factors on body composition, incidence and results of psychological testing was assessed by using single-factor logistic regression modeling of "dose – likelihood of a response (effect)" relationships. Significance of the created models was estimated as per Fischer's test.

We established parameters of risk factors that would ensure absence of any negative effects on schoolchildren's health under simultaneous exposure. The article provides the results produced by comparative analysis of the educational environment in different types of schools and its conformity with established optimal parameters as well as existing standards. We have also developed certain recommendations on how to create a health-preserving environment for a contemporary schoolchild, both in school and beyond classes.

Keywords: *children's population, factors of the educational process, blood contamination, socio-economic state, nutrition, body composition, incidence structure, psychological testing.*

Modern educational programs that are implemented in secondary schools produce certain harmful effects on schoolchildren who have to study under combined exposure to several risk factors. These risk factors occur within a school environment due to peculiarities of educational processes. Among such peculiarities, we can mention intensified intellectual loads, a growing number of lessons per day or per week, greater digitalization of educational processes that is usually combined with limited physical activity of children. In addition, meals provided at school do not conform to the health standards and a school environment can often fail to meet the requirements fixed in the sanitary legislation. All this impairs adaptation capabilities of a child's growing body and induces somatic pathologies in schoolchildren[1] [1–4].

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[1] Obshchaya zabolevaemost' detskogo naseleniya v Rossii (0–14 let) v 2019 godu: statisticheskie materialy. Chasti V, VI. [Overall morbidity among children in Russia (aged 0–14 years) in 2019: statistical data collections. Parts V, VI]. Moscow, Russian Research Institute of Health of the RF Public Healthcare Ministry, 2020, 144 p. (in Russian).

Analysis of results produced by dynamic periodical examinations of schoolchildren indicates that chronic pathologies are becoming more and more frequent among them as they grow older and move to the next level in school education. Growing prevalence has been detected for chronic pathologies of the digestive organs, endocrine, nervous and cardiovascular system; besides, anxiety is established to be also growing in older schoolchildren against their younger counterparts [5–9]. According to some authors, a number of morphofunctional disorders per one schoolchild as well as the polymorbidity index of chronic diseases have grown by 1.6–2.4 times over the last 30 years [10, 11].

Contemporary secondary education relies, among other things, on creating specialized schools (gymnasiums, lyceums, schools with advanced studies of various subjects, and military schools). These specialized schools strive to make education they provide more effective; to do that, they develop a wide range of educational programs and technologies [12–14]. At present, several basic risk factors produce negative effects on schoolchildren's health within the contemporary innovative educational process. They are educational loads exceeding the levels established by the hygienic standards; violated rules for safe use of modern technical teaching aids; combined mandatory and optional education without considering simultaneous loads on a student; excessive emotional overloads [3, 15]. If we analyze how educational processes are organized in different specialized schools, we can clearly see that schoolchildren who attend them have to face much more significant educational loads against their counterparts from ordinary secondary schools. This allows us to include schoolchildren from specialized schools into a risk group prone to development of school-induced pathologies [16].

Nutrition is a most significant factor influencing health of a growing body. According to some authors, diseases that result from improper nutrition can become apparent not only in childhood but also at later stages in ontogenesis [17]. The results produced by examining actual meals provided to schoolchildren in urban schools have revealed that more than a half of them do not get enough animal food products (milk, sour milk products, butter, eggs, meat or fish), vegetables and fruit. Potatoes are the most widely spread food for 60.0 % of children; 40.0 % of schoolchildren are given macaroni and cereals in excessive quantities and 60.0 % get more confectionary than they should [18, 19]. Given that, it becomes more and more significant to provide schoolchildren with qualitative meals at school. To be more exact, these meals should conform to children's age-specific physiological needs as per contents of macro- and micronutrients in them as well as their total caloric contents [20–25].

Since any educational institution is included into an ecosystem of a city or a rural settlement, a significant contribution made on children's health belongs to chemical environmental factors detected inside school premises, in ambient air and consumed water. Several studies have detected that contents of formaldehyde, phenol, styrene, ethylbenzene and benzene in air inside secondary schools exceed the hygienic standards; children who attend these schools have these chemicals in their biological media in concentrations being up to 3 times higher than maximum permissible levels [26]. Chronic inhalation and oral introduction of technogenic chemical pollutants creates persistent chemical contamination of schoolchildren's biological media with overall resorptive and organotropic negative effects developing in future [8, 27–29].

Although children spend a significant part of their time at school, we cannot underestimate a role played by socioeconomic factors existing in a child's family as well as by a child's activities beyond classes [30–32]. V.R. Kuchma with colleagues established that 59.8 % of schoolgirls and 43.1 % of schoolboys did not have enough physical activity to meet the requirements fixed for their age by the World Health Organization. Thirty percent of schoolchildren did physical exercises only during their physical training lessons and 57.6 % of schoolchildren spent less than 2 hours a day outdoors [33]. At the same time, a rapidly developing contemporary information-interactive space is engaging more and more children to be its active users. According to the data provided by the Foundation for Internet Development, on average 91.0 % of Russian children who are aged 10–17 years use the Internet and more than 90.0 % have their own mobile phones [33].

At present, not enough attention has been paid to influence exerted by a set of factors related to the educational process (how this process is organized, meals provided at school, a school environment) on schoolchildren's health and there are no sufficient data on so called "no-effect" safe levels of risk factors related to the educational process. At present, a vital task the hygiene as a science has to tackle is to establish peculiarities of effects produced by the educational process on health of children attending different types of secondary schools.

Our research goal was to substantiate optimal parameters of risk factors that would not produce any negative effects on physical, somatic and mental health of children attending secondary schools.

Materials and methods. Our task was to examine peculiarities of influence exerted by the educational process (how this process is organized, meals provided at school, sanitary-hygienic indicators of an outer and intra-school environment) on schoolchildren's health. To do that, we performed a clinical-functional and laboratory examination of 661 children who attended five different schools where the educational process was organized in four different ways. The first type was a secondary school with an additional educational program with more profound studies of natural sciences (physics and mathematics). The second type was a secondary school with an additional educational program that focused on general development (more profound studies of humanitarian sciences). The third type was a secondary school with an additional educational program focusing on sports and physical training (more profound military training). The fourth type was a secondary school without any additional educational program; it was located in a regional center and children who attended it were from families with a higher socioeconomic status. The fifth type was also a secondary school without any additional programs but it was located in a smaller town and children attending it were from families with a lower socioeconomic status. Overall, we examined 282 junior schoolchildren, 224 middle schoolchildren and 155 teenagers from senior school.

Indicators related to the educational process were assessed by analyzing their conformity with the sanitary-epidemiological requirements and hygienic standards established by the existing legislation[2]. Intensity of the educational process was examined in accordance with the recommendations created by the Russian Society for Development of School and University Medicine and Health[3].

Nutrition at school was estimated by analyzing daily menus and calculating a chemical structure of a typical meal (proteins, fats, carbohydrates, vitamins B1, B2, C, A, minerals Ca, P, Mg, Fe), energy value and ratios of basic nutrients in it. The results were then compared with the requirements fixed in the Sanitary Rules SanPiN 2.3/2.4.3590-20[4]. We analyzed data on schoolchildren's weekly ration and compara-

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[2] 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 28.09.2020 № 28; vvedeny v deistvie 01.01.2021) [Sanitary Rules SP 2.4.3648-20. Sanitary-epidemiological requirements to organizing education, leisure and health improvement of children and youth (approved by the Order of the RF Chief Sanitary Inspector dated September 28, 2020 No. 28; became valid on January 01, 2021)]. *Rospotrebnadzor*. Available at: https://www.rospotrebnadzor.ru/files/news/SP2.4.3648-20_deti.pdf (March 05, 2022) (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 goda № 2; vvedeny v deistvie 01.03.2021) [Sanitary Rules and Standards SanPiN 1.2.3685-21. 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 dated 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 (March 05, 2022) (in Russian).

[3] Rukovodstvo po gigiene detei i podrostkov, meditsinskomu obespecheniyu obuchayushchikhsya v obrazovatel'nykh organizatsiyakh. Model' organizatsii, federal'nye rekomendatsii okazaniya meditsinskoi pomoshchi obuchayushchimsya [The guide on children and adolescents hygiene, medical support provided for students and schoolchildren. Organizational model and federal recommendations on how to provide healthcare for students and schoolchildren]. In: V.R. Kuchma, Corresponding Member of the RAS ed. Moscow, Scientific Center of Children's Health of the RF Public Healthcare Ministry, 2016, 610 p. (in Russian).

[4] SanPiN 2.3/2.4.3590-20. Sanitarno-epidemiologicheskie trebovaniya k organizatsii obshchestvennogo pitaniya naseleniya (utv. postanovleniem Glavnogo gosudarstvennogo sanitarnogo vracha RF ot 27 oktyabrya 2020 g. № 32; vvedeny v deistvie 27.10.2020) [Sanitary Rules and Standards SanPiN 2.3/2.4.3590-20. Sanitary-epidemiological requirements to organizing catering provided for population (approved by the Order of the RF Chief Sanitary Inspector dated October 27, 2020 No. 32; became valid on October 27, 2020)]. *KonsultantPlus*. Available at: http://www.consultant.ru/document/cons_doc_LAW_367564/47eed3976d21a946bdffdc2bd5b9535a2f8930c3/ (February 08, 2022) (in Russian).

tively assessed whether an actual average daily ration provided to them conformed to the ration recommended by the SanPiN 2.3/2.4.3590-20[4].

We performed hygienic assessment of ambient air quality on the territories where the analyzed schools were located, quality of air inside school premises and quality of drinking water provided in these schools. The assessment was based on the results produced by field observations. Ambient air samples and air samples inside school premises were taken according to the State Standards GOST 17.2.3.01-86[5] and GOST R ISO 16000-1-2007[6]. Tap water samples were taken at nutrition units at schools in accordance with the State Standard GOST 31862-2012[7]. Hygienic assessment of drinking water quality was performed in conformity with the hygienic standard HS 2.2.5.1315-03[8]. Laboratory tests aimed at assessing ambient air quality, air quality inside school premises and drinking water quality involved using unified conventional procedures including high-performance liquid chromatography (formaldehyde), gas chromatography (aromatic hydrocarbons, chloroform), spectrophotometry (phenol) and mass-spectrometry (lead, manganese, chromium, and nickel). The tests were performed in accordance with the valid regulatory and methodical documents: MUK 4.1.1045-01, MUK 4.1.662–97, RD 52.04.186- 89, RD 52.04.186–89, PND F 14.1:2:3.171-00[9].

Biomedical examinations were accomplished in full conformity with the ethical principles stated in the Declaration of Helsinki (1975) and the RF National Standard GOST R 52379–2005

[5] State Standard GOST 17.2.3.01-86. Nature protection. Atmosphere. Air quality control regulations for populated areas (introduced by the Order of the USSR State Committee on Standards on November 10, 1986 No. 3395; became valid on January 01, 1987). *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200012789 (February 08, 2022) (in Russian).

[6] GOST R ISO 16000-1-2007. Indoor air. Part 1. Sampling. General (approved and introduced by the Order of the Federal Agency on Technical Regulation and Metrology on March 15, 2007 No.30-st). *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200049806/titles (February 08, 2022) (in Russian).

[7] GOST 31862-2012. Voda pit'evaya. Otbor prob (Primenenie v kachestve natsional'nogo standarta RF prekrashcheno) [Drinking water. Sampling (no longer applied as the RF National Standard)]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200097517/titles/7D60K4 (September 19, 2021) (in Russian).

[8] HS 2.1.5.1315-03. Predel'no dopustimye kontsentratsii (PDK) khimicheskikh veshchestv v vode vodnykh ob"ektov khozyaistvenno-pit'evogo i kul'turno-bytovogo vodopol'zovaniya (utv. Glavnym gosudarstvennym sanitarnym vrachom RF, Pervym zamestitelem Ministra zdravookhraneniya RF G.G. Onishchenko 27.04.2003 (utratilo silu s 1 marta 2021 goda na osnovanii postanovleniya Glavnogo gosudarstvennogo sanitarnogo vracha RF ot 28 yanvarya 2021 goda № 2)) [Maximum permissible concentrations (MPC) of chemicals in water taken from water objects of drinking wand communal water supply (approved by G.G. Onishchnko, the RF Chief Sanitary Inspector and the First Deputy to the RF Public Healthcare Minister on April 27, 2003 (no longer valid since March 01, 2021 according to the Order by the RF Chief Sanitary Inspector dated January 28, 2021 No. 2))]. *KODEKS: electronic fund for legal and reference documentation.* Available at: https://docs.cntd.ru/document/901862249 (February 16, 2021) (in Russian).

[9] MUK 4.1.1045-01. Metody kontrolya. Khimicheskie faktory. VEZhKh opredelenie formal'degida i predel'nykh al'degidov (C_2–C_{10}) v vozdukhe (utv. Glavnym gosudarstvennym sanitarnym vrachom RF, Pervym zamestitelem Ministra zdravookhraneniya RF G.G. Onishchenko 5 iyunya 2001 g.; data vvedeniya 1 oktyabrya 2001 g.) [Control procedures. Chemical factors. HPLC applied to determine formaldehyde and saturated aldehydess (C_2–C_{10}) in ambient air (approved by G.G. Onishchenko, the RF Chief Sanitary Inspector and the First Deputy to the RF Public Healthcare Minister on June 5 2001; became valid on October 1, 2001)]. *MEGANORM: regulatory documents.* Available at: https://meganorm.ru/Data2/1/4294814/4294814986.pdf (February 16, 2021) (in Russian); MUK 4.1.662-97. Metody kontrolya. Khimicheskie faktory. Metodicheskie ukazaniya po opredeleniyu massovoi kontsentratsii stirola v atmosfernom vozdukhe metodom gazovoi khromatografii (utv. Pervym zamestitelem Predsedatelya Goskomsanepidnadzora Rossii, zamestitelem Glavnogo gosudarstvennogo sanitarnogo vracha RF 31.10.1996) [Control procedures. Chemical factors. Methodical guidelines on determining mass concentrations of styrene in ambient air with gas chromatography (approved by the First Deputy to the Head of the Russian State Sanitary Epidemiological Surveillance, deputy to the RF Chief Sanitary Inspector on October 31, 1996)]. *MEGANORM: regulatory documents.* Available at: https://meganorm.ru/Index2/1/4293814/4293814194.htm (February 16, 2021) (in Russian); RD 52.04.186-89. Rukovodstvo po kontrolyu zagryazneniya atmosfery (Chasti II, III. Prilozheniya k chasti I) (otmenen v chasti) [Guide on control over ambient air pollution (Parts II and III. Supplements to Part I) (Part I is no longer valid)]. *KODEKS: electronic fund for legal and reference documentation.* Available at: https://docs.cntd.ru/document/1200037440/titles (February 16, 2021) (in Russian); PND F 14.1:2:3.171-00. Kolichestvennyi khimicheskii analiz vod. Metodika vypolneniya izmerenii massovoi kontsentratsii khloristogo metila, vinilkhlorida, vinilidenkhlorida, metilenkhlorida, khloroforma, chetyrekhkhloristogo ugleroda, 1,2-dikhloretana, benzola, trikhloretilena, 1.1.2-trikhloretana, toluola, orto-ksilola, summarnogo soderzhaniya, meta- i paraksilolov v stochnykh, prirodnykh poverkhnostnykh i podzemnykh vodakh gazokhromatograficheskim metodom (utv. direktorom FGU «Tsentr ekologicheskogo kontrolya i analiza» G.M. Tsvetkovym 6 avgusta 2002 g.) [Quantitative chemical analysis of waters. The procedure for measuring mass concentrations of methyl chloride, vynil chloride, vynilene chloride, methylene chloride, chloroform, carbon tetrachloride, 1,2-dichloroethane, benzene, trichloroethylene, 1.1.2-trichloroethane, toluene, orto-xylene, total contents, meta- and paraxylenes in sewage, natural surface and underground waters with gas chromatography (approved by G.M. Tsvetkov, Director of the Center for Ecological Control and Analysis on August 6, 2002)]. *MEGANORM: regulatory documents.* Available at: https://meganorm.ru/Data2/1/4293739/4293739708.htm (February 16, 2021) (in Russian).

"Good Clinical Practice" (ICH E6 GCP)[10]. Legal representatives of all the examined children gave their written informative voluntary consent to children's participation in the research in conformity with the federal legislation.

Socioeconomic risk factors were assessed by analyzing results of a social survey. The survey was accomplished by handing out questionnaires and concentrated on examining a child's family, parents' education, whether parents had a full-time or a part-time job or were unemployed, income per one family member, living conditions, whether a child had his or her own room etc. The social survey also involved analyzing how children spent their free time (time spent outdoors on walking or doing sports, on using gadgets or watching TV, on some creative activities or going to sport clubs). Attention was paid to optional education in case of having any (studies with a tutor, going to optional education institutions) and to breaks between different types of educational activities, time spent on doing homework etc. Children's physical activity was estimated by analyzing how regularly they did sports and how much time they spent outdoors either playing or doing exercises, how frequently they walked on foot for longer than 20 minutes etc.

All the participating children were examined by a pediatrician, allergologist, neurologist, gastroenterologist, ENT doctor and a cardiologist. Children's physical development and their somatic health were assessed by accomplishing anthropometric studies, BIA, ECG, heart rate variability examination, US of the abdominal cavity organs, conventional general clinical, biochemical and immunological analyses. Psychological testing was performed by using Vienna Test system for computerized psychological assessments and "NS-Psychotest" software for psychophysiological testing. The tests involved assessing a time needed to react to a stimulus, motor function velocity, attention level (RT-test), cognitive functions (STROOP-test), visual-spatial short-term working memory (CORSI-test), and a psychological stress level (Luscher test).

A complete clinical diagnosis was put for each child based on the results produced by the aforementioned clinical-functional and laboratory examinations.

Concentrations of technogenic chemicals (formaldehyde, phenol, ethylbenzene, benzene, toluene, chloroform, lead, nickel, chromium and manganese) were determined in children's blood as per conventional procedures in accordance with the valid regulatory and methodical documents MUK 4.1.2111-06; MUK 4.1.2115-06; MUK 4.1.765-99; MUK 4.1.2108-06; MUK 4.1.3230-14; MUK 4.1.3161-14[11]. The examina-

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[10] GOST R 52379-2005. Good Clinical Practice (GCP) (approved by the Order of the Federal Agency Technical Regulation and Metrology on September 27, 2005 No. 232-st). *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200041147/titles (March 18, 2021) (in Russian).

[11] Opredelenie vrednykh veshchestv v biologicheskikh sredakh: sbornik metodicheskikh ukazanii MUK 4.1.2102–4.1.2116-06 (utv. i vved. v deistvie Rukovoditelem Rospotrebnadzora, Glavnym gosudarstvennym sanitarnym vrachom RF 9 avgusta 2006 g.) [Determination of harmful chemicals in biological media: the collection of methodical guidelines MUK 4.1.2102–4.1.2116-06 (approved and introduced by G.G. Onishchenko, the Head of Rospotrebnadzor, the RF Chief Sanitary Inspector on August 09, 2006)]. Moscow, The Federal Center for Hygiene and Epidemiology of Rospotrebnadzor, 2008, 183 p. (in Russian); MUK 4.1.765-99. Gazokhromatograficheskii metod kolichestvennogo opredeleniya aromaticheskikh (benzol, toluol, etilbenzol, o-, m-, p-ksilol) uglevodorodov v biosredakh (krov') (utv. Glavnym gosudarstvennym sanitarnym vrachom RF G.G. Onishchenko 6 iyulya 1999 g.) [Gas chromatography applied to quantify aromatic (benzene, toluene, ethylbenzene, o-, m-, p-xylene) hydrocarbons in biological media (blood) (approved by G.G. Onishchenko, RF Chief Sanitary Inspector on July 06, 1999)]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200039012/titles (March 15, 2021) (in Russian); MUK 4.1.2108-06. Opredelenie massovoi kontsentratsii fenola v biosredakh (krov') gazokhromatograficheskim metodom / utv. Rukovoditelem Rospotrebnadzora, Glavnym gosudarstvennym sanitarnym vrachom RF G.G. Onishchenko 9 avgusta 2006 g. [Determination of mass concentration of phenol in biological media (blood) with gas chromatography (approved by G.G. Onishchenko, the Head of Rospotrebnadzor, the RF Chief Sanitary Inspector on August 09, 2006)]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200065240 (March 15, 2021) (in Russian); MUK 4.1.3230-14. Izmerenie massovykh kontsentratsii khimicheskikh elementov v biosredakh (krov', mocha) metodom mass-spektrometrii s induktivno svyazannoi plazmoi (utv. Rukovoditelem Rospotrebnadzora, Glavnym gosudarstvennym sanitarnym vrachom RF A.Yu. Popovoi 19 dekabrya 2014 g.) [Determination of chemical mass concentrations in biological media (blood, urine) with mass spectrometry with inductively coupled plasma (approved by A.Yu. Popova, the Head of Rospotrebnadzor, the RF Chief Sanitary Inspector on December 19, 2014)]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/495856222 (March 15, 2021) (in Russian); MUK 4.1.3161-14. Izmerenie massovykh kontsentratsii svintsa, kadmiya, mysh'yaka v krovi metodom mass-spektrometrii s induktivno svyazannoi plazmoi (utv. vrio rukovoditelya Rospotrebnadzora, Glavnogo gosudarstvennogo sanitarnogo vracha RF A.Yu. Popovoi 24 fevralya 2014 g.) [Determination of mass concentrations of lead, cadmium and arsenic in blood with mass spectrometry with inductively coupled plasma (approved by A.Yu. Popova, acting as the Head of Rospotrebnadzor, the RF Chief Sanitary Inspector on February 24, 2014)]. *MEGANORM: regulatory documents*. Available at: https://meganorm.ru/Data2/1/4293766/4293766470.htm (March 15, 2021) (in Russian).

tions were performed at the Department for Chemical and Analytical Research Techniques of the Federal Scientific Center for Medical and Preventive Health Risk Management Technologies (headed by the T.S. Ulanova, Doctor of Biological Sciences). Reference or regional background concentrations were applied as assessment criteria to estimate the results produced by chemical-analytical examinations of children's biological samples (blood).

The results were statistically analyzed by using conventional statistical procedures and mathematical analysis in Statistica 6.0 and statistical functions built into Microsoft Excel, 2010. Influence exerted by the educational process (how it is organized, meals provided at school and an intra-school environment) and by socioeconomic factors on children's anthropometric parameters, body composition, somatic and mental health was estimated by using one-factor logistic regression models of "dose – likelihood of a response (effect)" relationships. The model significance was estimated as per Fischer's test (F) with giving a constant value (b_0), regression coefficient (b_1), and Nagelkerke determination coefficient (R^2). Any differences were considered statistically significant at $p \leq 0.05$. Overall, the logistic regression model was formulated as follows:

$$p = \frac{1}{1 + e^{-(b_0 + b_1 x)}},$$

where p is a probability that a response will deviate from the standard; x is exposure level; b_0, b_1 are parameters of the mathematical model.

"Optimal" values (x_0) of factors related to the educational process that ensured no negative effects produced on the body were estimated through creating regression models. These models showed how exposure levels influenced "odds ratio" (OR), an indicator characterizing how strong a correlation is between an exposure level and a response. The condition $OR \geq 1$ was taken as a criterion confirming a correlation existed.

We calculated odds ratios for each factor value. The calculations were performed by conventional division of the sampling into two parts: below and above the current level of an exposure marker. For both intervals, a value was calculated that characterized a likelihood of a response marker deviating from the standard: p_i^- and p_i^+ accordingly as a ratio of a number of observations deviating from the standard to the total number of observations. Odds ratio was determined for each observation as per the following relationship:

$$OR_i = \frac{p_i^+}{1 - p_i^+} \Big/ \frac{p_i^-}{1 - p_i^-},$$

where i is an index showing the number of an observation.

Parameters describing dependence between odds ratio and an exposure value were estimated by creating a regression model in the form of an exponential function:

$$OR = e^{a_0 - a_1 x},$$

where a_0, a_1 are model parameters.

An optimal level of an exposure factor (x_0) with respect to a type of a response was calculated considering the condition OR=1 as per the following relationship:

$$x_0 = \frac{a_0}{a_1}.$$

Results and discussion. We assessed how the educational process was organized in the analyzed schools. The assessment revealed that in the first-type school a number of students in a class, an overall number of lessons per day and per week, and a period when technical teaching aids were used during a lesson exceeded the hygienic standards stipulated in the SanPiN 1.2.3685-21 and SR 2.4.3648-20[2] for schoolchildren of all ages. The educational process (duration of breaks both between lessons and between mandatory and optional classes, interchanges between difficult and easy subjects during a school day and distribution of educational loads over a week) was the most intense in this school in comparison with the other analyzed ones.

In the second-type school, only primary schoolchildren had daily and weekly loads that were higher than their maximum permissible levels. However, a number of schoolchildren in one class did not conform to the hygienic standards in primary, middle and senior school whereas the educational process was quite close to conformity with the SR 2.4.3648-20[2].

In the third-type school, only senior schoolchildren had weekly loads that exceeded the maximum permissible levels and the educational process at any level was quite close to meeting the hygienic requirements.

In the fourth- and fifth-type schools, overall number of lessons a day and a week and a period when technical teaching aids were used during a lesson corresponded to the requirements fixed in the SanPiN 1.2.3685-21 and SR 2.4.3648-20[2]; however, the educationnal process was organized improperly at all levels (primary, middle and senior school).

Therefore, we detected several factors related to the educational process that were common for most analyzed schools. These factors created certain health risks for schoolchildren. They included a number of children in a class; too short breaks, either between lessons or between mandatory and optional classes; improper interchange between difficult and easy subjects during a day; and improper distribution of educational loads over a week. We should note that the educational process estimated as per all the violations of the requirements to its organization fixed in the SanPiN 1.2.3685-21 and SR 2.4.3648-20[2] is more intense in schools that have additional education programs with their focus on various subjects than in schools that offer only standard education programs.

Our examinations focusing on nutrition provided by schools revealed that menus in all the analyzed schools were made with improper ratios between macronutrients (fat and carbohydrate contents were by 1.5–1.8 times higher than necessary) and decreased contents of vital micronutrients (vitamins B_1, B_2, C, A, iron, calcium, magnesium, and phosphor, from 5.0 to 45 % lower than necessary). Total caloric contents of a ration did not conform to the recommended values either[4] (95–120 % of the necessary level). We should note that those violations, both as per their absolute values and their frequency, were more typical for schools with additional educational programs. In addition, our research established that a daily ration usually consumed by schoolchildren (both at school and at home, with home meals accounting for 76.0–92.2 % in it) did not satisfy their age–specific physiological needs[4]. Schoolchildren who attended the analyzed schools had by 1.7–2.0 times more sausage, by 1.4–1.5 times more macaroni and by 7.8–8.0 more confectionary than recommended whereas their consumption of vegetables, fruit, fish and cereals was by 1.6–3.8 times lower. A daily ration that was the closest to the recommended one[4] was detected in the third–type school where schoolchildren were provided with three meals a day.

Our sanitary–hygienic assessment of ambient air on the territories where the analyzed schools were located established the following. Concentrations of benzene (0.0025 ± 0.0004–0.0190 ± 0.0027 mg/m^3; $MPC_{av.d.}$ = 0.1 mg/m^3), ethylbenzene (< 0.002–0.0083 ± 0.0009 mg/m^3; $MPC_{av.d.}$ = 0.02 mg/m^3), nickel (0.000009 ± 0.000002–0.000015 ± 0.0000035 mg/m^3; $MPC_{av.d.}$ = 0.01 mg/m^3), lead (0.000006 ± 0.000001–0.000020 ± 0.000004 mg/m^3; $MPC_{av.d.}$ = 0.01 mg/m^3), manganese (0.00004 ± 0.0000008–0.000183 ± 0.000038 mg/m^3; $MPC_{av.d.}$ = 0.001 mg/m^3) and chromium (0.000013 ± 0.0000087–0.000024 ± 0.000004 mg/m^3; $MPC_{av.d.}$ = 0.015 mg/m^3) corresponded to the requirements fixed in the SanPiN 2.1.6.1032-01[12] and HS 2.1.6.1338–03[13], whereas concentrations of phenol (0.0068 ± 0.0024–0.0075 ± 0.0019 mg/m^3; $MPC_{av.d.}$ = 0.006 mg/m^3) and toluene (0.0827 ± 0.0116 mg/m^3; $MPC_{av.d.}$ = 0.05 mg/m^3) were by 1.1–1.7 times higher than $MPC_{av.d.}$ Most frequently, air inside school premises contained elevated concentrations of formaldehyde (0.0124 ± 0.0025–0.02136 ± 0.0044 mg/m^3; $MPC_{av.d.}$ = 0.01 mg/m^3), phenol (0.0062 ± 0.0016–0.0064 ± 0.0016 mg/m^3; $MPC_{av.d.}$ = 0.006 mg/m^3) and toluene (0.0721 ± 0.0145–0.0737 ± 0.0103 mg/m^3;

[12] SanPiN 2.1.6.1032-01. Hygienic Requirements for Atmospheric Air Protection in Populated Areas (approved by the RF Chief Sanitary Inspector on May 17, 2001). *MEGANORM: regulatory documents*. Available at: https://meganorm.ru/Index2/1/4294847/4294847621.htm (March 18, 2021) (in Russian).

[13] HS 2.1.6.1338-03. Predel'no dopustimye kontsentratsii (PDK) zagryaznyayushchikh veshchestv v atmosfernom vozdukhe naselennykh mest: Gigienicheskie normativy (utv. Glavnym gosudarstvennym sanitarnym vrachom RF, Pervym zamestitelem Ministra zdravookhraneniya 21 maya 2003 g.) [Maximum permissible concentrations (MPC) of pollutants in ambient air in settlements: Hygienic Standards (approved by the RF Chief Sanitary Inspector and the First Deputy to the RF Public Healthcare Minister on May 21, 2003)]. Moscow, The Russian register of potentially hazardous chemical and biological substances of the RF Public Healthcare Ministry, 2003, 86 p. (in Russian).

$MPC_{av.d.}$ = 0.05 mg/m^3), which were by 1.2–1.5 times higher than $MPC_{av.d.}$ Quality of drinking water in schools did not conform to the requirements fixed in SanPiN 2.1.4.1074-01[14] and HS 2.1.5.1315–03 as per certain sanitary–hygienic indicators, namely, contents of chloroform (0.138 ± 0.01–0.186 ± 0.007 mg/m^3; $MPC_{av.d.}$ = 0.06 mg/m^3) and formaldehyde (0.094 ± 0.002–0.123 ± 0.004 mg/m^3; $MPC_{av.d.}$ = 0.05 mg/m^3). Their concentrations were by 1.9–3.1 times higher than the existing hygienic standards. Biological media of schoolchildren from primary, middle and senior school most frequently contained elevated concentrations of phenol (0.015 ± 0.005–0.084 ± 0.031 μg/ml; the background level is 0.005 ± 0.001 μg/ml), formaldehyde (0.013 ± 0.008–0.0502 ± 0.0073 μg/ml; the background level is 0.01 ± 0.001 μg/ml), benzene (0.0002 ± 0.0001–0.009 ± 0.0003 μg/ml; the background level is 0.0 μg/ml), toluene (0.0003 ± 0.0001–0.0009 ± 0.0001 μg/ml; the background level is 0.0 μg/ml), ethylbenzene (0.0002 ± 0.0001–0.0005 ± 0.0003 μg/ml; the background level is 0.0 μg/ml), chloroform (0.0002 ± 0.0001–0.0003 ± 0.0001 μg/ml; the background level is 0.0 μg/ml), manganese (0.014 ± 0.003–0.015 ± 0.002 μg/ml; the reference level is 0.013 ± 0.004 μg/ml), lead (0.012 ± 0.0035–0.056 ± 0.0075 μg/ml; the reference level is 0.01 ± 0.0067 μg/ml), nickel (0.023 ± 0.009–0.026 ± 0.0055 μg/ml; the reference level is 0.015 ± 0.007 μg/ml) and chromium (0.0039 ± 0.0018–0.0072 ± 0.0008 μg/ml; the reference level is 0.003 ± 0.002 μg/ml).

We comparatively analyzed socioeconomic factors in children's families. The analysis revealed that typically children who attended secondary schools with additional educational programs (the first-, second- and third-type schools) were from families with incomes per one family member being by 1.6–1.7 times higher than in those families where children attended ordinary secondary schools. Schoolchildren from the schools with additional educational programs had by 2.7–3.4 times greater educational loads and spent by 1.1–3.5 times more time on doing physical exercises or sports. In addition, a number of parents with higher education was by 4.0–19.0 times higher in families with children attending schools with additional educational programs than in families with children going to ordinary secondary schools (the fourth- and fifth-type).

Our anthropometric studies established that primary and middle schoolchildren who attended schools with additional educational programs tended to have average weight and height, chest excursion and circumference as well as grip strength that corresponded to age–specific physiological standards. However, a number of children with drastically disharmonic body development grew among senior schoolchildren. We should note that the maximum number of children with their physical development corresponding to the standards was established in the third-type school (the military school). As for ordinary secondary schools (the fourth- and fifth-type), we detected a growing number of children with overweight and obesity already in primary school; a number of children with drastically disharmonic body development grew substantially among senior schoolchildren in these schools.

We analyzed data produced by bioelectrical impedance analysis in dynamics and established certain differences between the analyzed schools. Thus, in the first-type school, primary schoolchildren tended to have higher body mass index and fate mass; then, both these indicators decreased by 1.8–2.5 times by senior school against a 1.3–2.6-time growth of the phase angle, metabolically active cell and bone and muscle mass indicating that metabolic processes intensified in children's bodies and they became more physically active (p = 0.02). We established that children from the second–type school were physically fit and had enough

[14] SanPiN 2.1.4.1074-01. Pit'evaya voda. Gigienicheskie trebovaniya k kachestvu vody tsentralizovannykh sistem pit'evogo vodosnabzheniya. Kontrol' kachestva. Gigienicheskie trebovaniya k obespecheniyu bezopasnosti sistem goryachego vodosnabzheniya (utv. Glavnym gosudarstvennym sanitarnym vrachom RF, Pervym zamestitelem Ministra zdravookhraneniya G.G. Onishchenko 26 sentyabrya 2001 g. (utratilo silu s 1 marta 2021 g.)) [Drinking water. Hygienic requirements to quality of water from centralized water supply systems. Quality control. Hygienic requirements to providing safety of hot water supply systems (approved by G.G. Onishchenko, the Head of Rospotrebnadzor, the RF Chief Sanitary Inspector on September 26, 2001 (no longer valid since March 01, 2021))]. *KODEKS: electronic fund for legal and reference documents.* Available at: https://docs.cntd.ru/document/901798042 (February 26, 2021) (in Russian).

physical activity in primary, middle and senior school. As a result, their metabolic processes had proper intensity and their bone and muscle mass grew by 3.2 times in senior school, which corresponds to the physiological standard ($p = 0.003$). Indicators describing body composition grew most harmonically and were closest to the age–specific physiological standards in schoolchildren from the third–type school. The results produced by biological impedance analysis indicated they were the fittest and had the most physical activity in primary, middle and senior school than their counterparts from any other analyzed school. This was accompanied by 1.2–2.7 times better physical and metabolic activity, greater metabolically active cell mass and bone and muscle mass ($p < 0.001$). We detected a 2.0–2.3 time growth in a number of schoolchildren from the fourth-type and fifth-type schools in senior school with their body mass index and fat mass being by 1.4–1.8 times higher than the physiological standard ($p = 0.02$). Simultaneously, 14.0–31.0 % of school leavers had metabolically active body cell mass, bone and muscle mass that were lower than the physiological standard. We detected only isolated cases of it in primary school in these schools.

Having analyzed morbidity among schoolchildren, we established an authentic growth in diseases of the eye and adnexa among senior schoolchildren in all the analyzed schools. The maximum number of such diseases was typical for schoolchildren from the first-type school (71.6 %). The minimal number of such pathologies was registered in the third–type school (23.0 %). Senior schoolchildren from the second-, fourth- and fifth-type schools had eye pathologies in 51.6–62.0 % of cases. In addition, children in those schools tended to have digestive diseases much more frequently since they were detected in 91.7–100 % of them. We detected an ascending trend for diseases of the nervous system among schoolchildren who attended the first-type school. Although we did not detect any significant differences, we could still trace a growth in a number of endocrine diseases and it was typical for all the analyzed schools, except the first–type one, where we detected an inverse trend.

We assessed influence exerted by the analyzed factors on schoolchildren's body composition. The assessment revealed that phenol and chromium contents in blood ($R^2 = 0.55–0.71$; $p < 0.001$) led to a smaller probability that metabolically active body cell mass would form; at the same time, when iron and vitamins C and B1 are introduced with food in proper quantities, this results in a greater probability that this mass meets the age–specific physiological standards ($R^2 = 0.34–0.56$; $p < 0.001$).

A probability that bone and muscle mass will form in accordance with its physiological standards grows when children are provided with balanced introduction of calcium, magnesium, phosphor and proteins with food ($R^2 = 0.23–0.86$; $p < 0.001$). This probability goes down, especially when it comes down to senior schoolchildren, when nickel and formaldehyde occur in blood in elevated concentrations ($R^2 = 0.30–0.45$; $p < 0.001$) (Figure). Factors related to the educational process have less significant influence on formation of metabolically active body cell mass and bone and muscle mass in primary schoolchildren ($R^2 = 0.23–0.34$; $p < 0.001$) whereas growing educational loads in middle and senior school produce by 2.2–3.9 times greater effects on formation of these body components ($R^2 = 0.75–0.89$, $p < 0.001$). An increase in monotony of educational loads and greater learning intensity result in an authentic decrease in formation of fat-free mass in the body in primary schoolchildren ($R^2 = 0.79–0.84$; $p < 0.001$). In middle school, greater influence is exerted, according to the modeling results, by shorter breaks and lower recovery index values ($R^2 = 0.87–0.98$; $p < 0.001$). Fat-free mass is to a lesser extent influenced by elevated chromium and formaldehyde contents in blood ($R^2 = 0.62$ and 0.11 accordingly, $p < 0.001$). In senior school, magnesium and protein contents in meals provided at school produce authentically greater effects on fat-free mass formation ($R^2 = 0.76$ and 0.34 accordingly, $p < 0.001$). Basic metabolic indicators in primary and middle schoolchildren go down largely due to influence exerted by such factors related to the educational process as growing educational loads, shorter breaks and lower recovery index values ($R^2 = 0.87–0.98$; $p < 0.001$). In senior school, factors related to the educational process exert by 3.2–3.6 times smaller influence ($R^2 = 0.27$; $p < 0.001$). Quality of metabolic processes deteriorates due to elevated chromium concentrations in blood ($R^2 = 0.74$; $p < 0.001$) and to a lesser extent due to formaldehyde concentrations ($R^2 = 0.49$; $p < 0.001$).

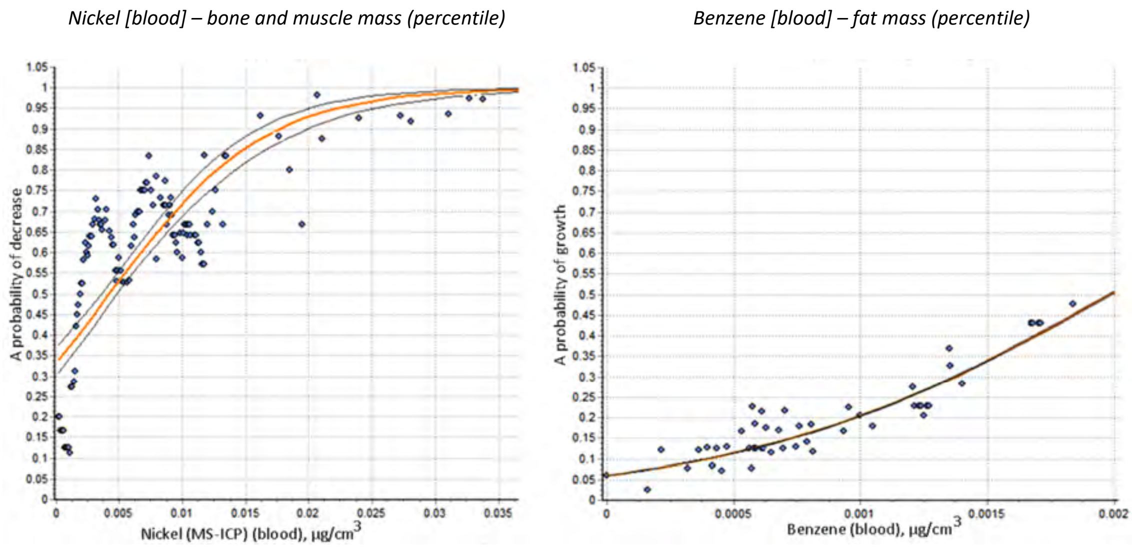

Figure. Influence exerted by nickel and benzene on formation of schoolchildren's bone, muscle and fat mass

Certain factors of the educational process, including lower educational loads and their intellectual components as well as shorter breaks, increase a probability for primary school children that fat mass will accumulate in their bodies and body mass index will grow (R^2 = 0.74–0.87; $p < 0.001$) whereas elevated chromium concentrations in blood reduce a probability of fat mass formation (R^2 = 0.54–0.87; $p < 0.001$). The aforementioned factors related to the educational process produce by 3.7–14.5 times smaller effects in middle school (R^2 = 0.06–0.20; $p < 0.001$). Benzene exerts significant influence on primary school children since its concentration in their blood increases a probability that excessive fat mass will accumulate in their bodies (R^2 = 0.44–0.56; $p < 0.001$) (Figure 1). Influence exerted on fat mass formation in senior schoolchildren by all the factors related to the educational process is insignificant (R^2 = 0.09–0.28; $p < 0.001$). Consumption of proteins, fats and carbohydrates becomes very significant in middle and senior school: (R^2 = 0.15–0.52 and R^2 = 0.20–0.40 accordingly; $p < 0.001$). In primary school, lead and nickel contents in blood deteriorate children's growth (R^2 = 0.42; $p < 0.001$) whereas in middle and senior school macronutrient consumption with food becomes the most important. Height is more likely to correspond to its physiological standards when children are provided with proper quantities of calcium, phosphor, iron, vitamins B1, B2, C in their nutrition (R^2 = 0.23–0.65; $p < 0.001$).

We assessed influence exerted by the analyzed factors on morbidity among schoolchildren. Mathematical modeling revealed that manifestation of cardiovascular diseases was influenced the most significantly by nickel, benzene and lead contents in children's blood (R^2 = 0.70–0.86; $p < 0.001$) as well as by growing daily educational loads (R^2 = 0.67; $p < 0.001$). It was also influenced, though to a lesser extent, by shorter breaks and lower recovery index values (R^2 = 0.26–0.44; $p < 0.001$). In senior school, occurrence of such diseases is influenced by 1.9–2.4 times more greatly by shorter breaks and lower recovery index values (R^2 = 0.83–0.89; $p < 0.001$). Diseases of the nervous system develop more frequently due to caloric contents in school meals being higher than the standards (R^2 = 0.90; $p < 0.001$), as well as due to magnesium and vitamin B1 deficiency (R^2 = 0.53–0.59; $p < 0.001$) and due to lead, formaldehyde and phenol contents in blood (R^2 = 0.47–0.81; $p < 0.001$). These diseases occur most frequently due to such factors related to the educational process as a growing number of lessons a day and growing monotony of learning (R^2 = 0.75–0.80; $p < 0.001$); to a lesser extent, due to excessive daily educational loads and emotional loads (R^2 = 0.23–0.31; $p < 0.001$). Diseases of the genitourinary, digestive and respiratory system are more likely to occur in case of chloroform, nickel, formaldehyde, chromium, lead and phenol contents in blood (R^2 = 0.57–0.86; $p < 0.001$). Diseases of the digestive system can also occur due to factors related to the educational process, including a growing number of lessons a day, growing monotony of learning and excessive daily educational loads ($R^2 = 0.57–0.86$; $p < 0.001$); to a lesser extent, due to shorter breaks and lower recovery index values ($R^2 = 0.22–0.27$; $p < 0.001$) as well as magnesium deficiency ($R^2 = 0.74$; $p < 0.001$). In senior school, digestive diseases become more probable due to protein and vitamin C deficiency ($R^2 = 0.55–0.75$; $p < 0.001$) as well as excessive fat contents ($R^2 = 0.25$; $p < 0.001$) in school meals. Diseases of the respiratory system might occur, to a lesser extent, due to monotony and intensity of learning, a growing number of lessons a day as well as toluene in biological media ($R^2 = 0.21–0.72$; $p < 0.001$). Our further analysis of the created models established a direct correlation between developing diseases of the eye and adnexa and elevated formaldehyde contents in blood ($R^2 = 0.24–0.73$; $p < 0.001$), chronic deficiency of vitamins A and C in school meals ($R^2 = 0.32–0.87$; $p < 0.001$), growing emotional and intellectual loads as well as a growing number of lessons a day (more than recommended) ($R^2 = 0.36–0.63$; $p < 0.001$). We detected a correlation between growing socioeconomic states of primary schoolchildren's families and development of such diseases in them ($R^2 = 0.64$; $p < 0.001$). Diseases of skin and subcutaneous tissues are induced by elevated chromium and nickel contents in blood ($R^2 = 0.65–0.82$; $p < 0.001$) as well as by some factors related to the educational process, including growing monotony and intensity of learning and daily educational loads ($R^2 = 0.76–0.80$; $p < 0.001$). In senior school, effects produced by these factors on development of skin pathologies go down by 1.3–1.5 times ($R^2 = 0.52–0.59$; $p < 0.001$). Factors that induce diseases of the musculoskeletal system probably include excessive caloric contents in school meals and vitamin C deficiency ($R^2 = 0.74–0.86$; $p < 0.001$); to a lesser extent, carbohydrates deficiency and elevated lead and manganese contents in blood ($R^2 = 0.29–0.38$; $p < 0.001$). Such factors related to the educational process as a growing number of lessons a day, growing intensity of learning and its intellectual components produce practically the same effects on primary schoolchildren regarding skin pathologies ($R^2 = 0.45–0.58$; $p < 0.001$). In middle school, development of these diseases is by 2.0–1.1 times more influenced by growing educational loads, a growing number of lessons a day, and shorter breaks ($R^2 = 0.63–0.89$; $p < 0.001$). Diseases of the endocrine system in primary and middle schoolchildren are largely influenced by excessive carbohydrates consumption as well as deficiency of proteins, vitamins C and B1 in school meals ($R^2 = 0.39–0.70$; $p < 0.001$). In senior school, shorter breaks produce by 2.5–3.9 times greater effects ($R^2 = 0.86$; $p < 0.001$) (Table 1).

Our next step was to estimate influence exerted by the analyzed factors on the results produced by psychological testing. We revealed that growing monotony of learning, a growing number of lessons a day/week, growing intellectual and emotional loads impaired visual–spatial short–term operating memory ($R^2 = 0.16–0.66$; $p < 0.0001$) whereas growing recovery index values were likely to help produce better results of Corsi–testing ($R^2 = 0.25$; $p < 0.0001$). Cognitive rigidity decreases authentically due to growing intellectual loads and more intense learning (STROOP–test) ($R^2 = 0.48–0.53$; $p < 0.0001$). A reaction time detected by testing (STROOP–test) grows probabilistically when intellectual loads go up, classes become longer and breaks become shorter in primary school ($R^2 = 0.19–0.27$; $p < 0.0001$). The same effect occurs in middle school when intellectual loads and a number of lessons a day grow ($R^2 = 0.14–0.38$; $p < 0.0001$). In senior school, visual–spatial short–term operating memory deteriorates authentically due to growing educational loads and longer duration of classes ($R^2 = 0.17–0.18$; $p < 0.0001$). At the same time, when recovery index goes up and breaks become longer, it results in greater probability to pass Corsi–testing satisfactorily ($R^2 = 0.12–0.25$; $p < 0.0001$). Factors related to the educational process exert by 1.3–2.8 times smaller influence on cognitive flexibility and a reaction time during testing ($R^2 = 0.08–0.09$; $p < 0.0001$).

Having assessed effects produced by technogenic chemicals on children's mental health, we established that cognitive functions of children in primary, middle and senior school decreased in the same way in case they had elevated concentrations of manganese, lead, nickel ($R^2 = 0.29–0.75$; $p < 0.001$) as

Table 1

The models describing correlations between parameters of the educational process and morbidity among primary schoolchildren

Educational loads	Diseases	*b1*	Error	Fischer's test (*F*)	Authenticity of the model (*p*)	Determination coefficient (R^2)	NOL*
Duration of breaks (minutes)	Diseases of the circulatory system	-0.002	1E-08	398.72	< 0.001	0.44	-
Recovery index (arbitrary units)		-3.38	0.10	109.84	< 0.001	0.26	0.32
Daily educational loads (scores)		0.43	0.0004	506.65	< 0.001	0.67	-
Duration of breaks (minutes)	Diseases of the endocrine system	-0.001	5E-08	39.81	< 0.001	0.07	387.2
Recovery index (arbitrary units)		-2.45	0.49	12.32	0.002	0.03	0.29
Intellectual loads (scores)		1.73	0.01	313.05	< 0.001	0.58	-
Number of lessons a day		0.27	0.009	8.68	0.004	0.03	-
Monotony of learning (scores)		0.39	0.0009	162.65	< 0.001	0.42	-
Weekly educational loads (scores)		0.009	1.79E-09	42.15	< 0.001	0.16	-
Emotional loads (scores)		1.62	0.02	110.45	< 0.001	0.33	-
Duration of breaks a week (minutes)	Diseases of the digestive system	-0.001	2E-08	137.05	< 0.001	0.26	273.5
Recovery index (arbitrary units)		-3.15	0.14	70.91	< 0.001	0.22	0.25
Number of lessons a week		0.08	0.0002	34.85	< 0.001	0.10	23.8
Number of lessons a day		1.66	0.008	348.30	< 0.001	0.52	-
Number of lessons a day	Diseases of the nervous system	1.03	0.021	51.4	< 0.001	0.14	-
Monotony of learning (scores)		2.10	0.005	994.79	< 0.001	0.82	-
Weekly educational loads (scores)		0.02	1.4E-05	27.53	< 0.001	0.08	127.2
Emotional loads (scores)		2.30	0.08	66.96	< 0.001	0.23	1.1
Intellectual loads (scores)	Diseases of the eye and adnexa	1.19	0.004	377.43	< 0.001	0.63	-
Number of lessons a week		0.06	0.0005	9.20	0.003	0.03	25.0
Number of lessons a day		2.19	0.02	270.32	< 0.001	0.46	-
Number of lessons a week	Diseases of the respiratory organs	0.18	0.0004	85.34	< 0.001	0.21	23.6
Number of lessons a day		2.91	0.01	822.93	< 0.001	0.72	-
Duration of classes (minutes)	Diseases of the musculoskeletal system	0.001	6E-08	22.53	< 0.001	0.07	-
Intellectual loads (scores)		2.28	0.03	182.18	< 0.001	0.45	-
Number of lessons a week		0.09	0.0002	48.52	< 0.001	0.13	23.7
Number of lessons a day		1.56	0.006	430.62	< 0.001	0.58	-

Note: * NOL means no-effect level.

well as phenol and chloroform (R^2 = 0.10–0.16; p < 0.001) in their blood. Effects produced by phenol and chloroform become much more significant in senior school (R^2 = 0.56–0.85; p < 0.001). Elevated concentrations of nickel in primary schoolchildren (R^2 = 0.25; p < 0.001), phenol and chloroform in middle schoolchildren (R^2 = 0.27–0.59; p < 0.001), manganese and nickel in senior schoolchildren (R^2 = 0.58; p < 0.001) could impair visual–spatial short–term operating memory. Elevated concentrations of magnesium, nickel, lead, and phenol and chloroform occurrence reduced response rate in schoolchildren of all ages (RT–test) (R^2 = 0.11–0.88; p < 0.001). We estimated influence exerted by nutrition on the results produced by psychological testing and established the following. Cognitive flexibility in primary schoolchildren primarily deteriorated due to chronic deficiency of protein, calcium and vitamin C in school meals (R^2 = 0.30–0.74; p < 0.0001) and to by 2.5–2.7 times lesser extent due to excessive carbohydrate contents and caloric contents (R^2 = 0.12–0.27; p < 0.0001). Cognitive rigidity in middle schoolchildren went down due to protein, calcium, vitamins C, B1 deficiency, and excessive carbohydrates contents (R^2 = 0.34–0.78; p < 0.0001) and to by 2.6–5.2 times lesser extent due to iron deficiency and excessive caloric contents of meals (R^2 = 0.13–0.15; p < 0.0001). Visual–spatial short–term operating memory in primary school children deteriorated due to calcium and vitamin C deficiency and excessive fat contents (R^2 = 0.51–0.95; p < 0.0001) and to a lesser extent due to protein, vitamins A, B2 deficiency (R^2 = 0.07–0.37; p < 0.0001) This indicator in middle schoolchildren depended on a greater number of nutrition components, in particular, on iron, phosphor, calcium, vitamins A, B1, B2, proteins, and fats (R^2 = 0.25–0.58; p < 0.0001). A response time detected by testing in primary and senior schoolchildren impaired authentically due to calcium and protein deficiency (R^2 = 0.58–0.84; p < 0.0001) and to a lesser extent due to magnesium and vitamin

C deficiency as well as excessive carbohydrate contents ($R^2 = 0.13–0.27$; $p < 0.0001$). In middle school, the same effect occurred due to deficiency of magnesium, vitamin C, protein, iron, and calcium ($R^2 = 0.15–0.66$; $p < 0.0001$). Next, we estimated effects produced by socioeconomic factors and established that cognitive functions deteriorated in children of all ages due to growing intensity of optional education ($R^2 = 0.30–0.71$; $p < 0.001$) whereas growing physical activity increased cognitive flexibility ($R^2 = 0.28–0.32$; $p < 0.001$) and the effect was much more apparent in middle and senior schoolchildren, by 1.8–2.5 times ($R^2 = 0.27–0.81$; $p < 0.001$). Effectiveness of operating memory directly depends on a socioeconomic status of a family and exposure to tobacco smoke. However, a share contribution made by these two factors does not exceed 6.0–10.0 % and 17.0–27.0 % accordingly for children of all ages ($R^2 = 0.03–0.12$; $p < 0.001–0.02$).

Therefore, high intensity of learning, children's blood being contaminated with technogenic chemicals, improper macro- and micronutrient balance in meals as well as some socioeconomic factors raise likelihood of disorders in children's physical development, induce risks of a wide range of somatic pathologies, functional disorders and impaired mental health.

At the same time, the aforementioned factors do not produce any negative effects on physical and mental characteristics as well as on somatic health in case their values conform to optimal levels determined by the accomplished mathematical modeling (Table 2).

Therefore, the existing sanitary-hygienic standards were violated to this or that extent in all the analyzed secondary schools and the analyzed factors deviated from the optimal values determined in our research. Thus, duration of the total educational loads was 900–3150 minutes per week for primary schoolchildren in the first- and third-type schools (the optimal value is 984.3 minutes). Duration of breaks was only 222 minutes per week in the fourth- and fifth-type schools (the optimal value is 345.6 minutes). The smallest educational loads were detected in the third-type school, 22.0 scores a day / 131 scores a week; the greatest ones were detected in the first-type school, 34.0 / 203.0 scores accordingly (the optimal value is 22.0 / 130.0).

Meals were provided with violations in all the analyzed schools. The maximum deficiency of macronutrients was established in the first-type school (45 %); the minimum deficiency, in the fourth- and fifth-type school (5.0 %). Macronutrients levels exceeded their standardized values by 1.2–1.6 times in the second- and third-type school. The minimum deficiency of micronutrients was established in the first-type school (calcium and vitamin A) and the maximum deficiency was detected in third-type school (vitamins B1, B2, C, A, iron, calcium, magnesium and phosphor).We should note that calcium was in deficiency in meals provided by all the analyzed secondary schools.

Having analyzed chemical contamination of children's blood, we established that phenol and lead concentrations exceeded regional background and reference values in children of all ages from all the analyzed secondary schools.

Conclusions. Schoolchildren are simultaneously exposed to risk factors related to the educational process; to harmful environmental parameters, both inside school and beyond; to unfavorable socioeconomic living conditions (the educational process being organized improperly, macro- and micronutrients imbalance in meals provided at schools, children's biological media being contaminated with adverse technogenic chemicals). All this induces disorders in body composition, results in higher morbidity and deteriorates children's mental health.

We took four different types of secondary schools as an example and analyzed them profoundly. This enabled us to develop methodical approaches to substantiating optimal values (or their ranges) for factors related to the education environment as well as the environment beyond the educational process. Conformity with these values results in absence of any impermissible health risks for children. These developed approaches make it possible to determine concrete safe levels of various loads under combined exposure to multiple variable risk factors.

The parameters we determined for the analyzed risk factors in our study do not produce any negative effects on schoolchildren's body even under combined exposure to them. This calls for the necessity to conform to the existing hygienic standards when organizing the educational process and providing meals at school. It is also vital to improve the ecological situation,

Table 2

Optimal values of risk factors that do not produce any negative effects on schoolchildren of all ages even under combined exposure to them

Risk factors	Components of risk factors	Age		
		Primary school	Middle school	Senior school
		Optimal (standard) values		
The educational process	Total educational loads, min/week	984.3 (840.0–1170.0)	1326.4 (1305.0–1620.0)	**1494.0** (1530.0–1665.0)
	Duration of breaks, min/week	345.6 (250.0–360.0)	**454.7** (250.0–420.0)	468.8 (300.0–480.0)
	Recovery index, arbitrary units	0.3	–	–
	An average number of lessons a day	4.6 (4.0–5.0)	–	–
	Educational loads as per subjects, day/week, scores	22.0/130.6 (–/–)	40.4/214.0 (–/–)	44.0/257.0 (–/–)
	Intellectual loads, scores	2.1 (2.3–3.3)	–	–
	Emotional loads, scores	1.1 (1.3–2.3)	–	–
	Monotony of learning, scores	1.8 (2.3–2.8)	–	–
	Intensity of learning, scores	1.7 (1.8–2.7)	–	–
Meals provided at school (breakfast / lunch)	Iron, mg	**3.7** (2.4–3.0)	5.8–6.4 (5.4–6.3)	6.0–6.8 (5.4–6.3)
	Magnesium, mg	**64.5–75.7** (50.0–62.5)	108.8 (90.0–105.0)	100.2–108.1 (90.0–105.0)
	Phosphor, mg	260.7 (220.0–275.0)	426.8 (360.0–420.0)	428.4 (360.0–420.0)
	Calcium, mg	260.6–286.2 (220.0–275.0)	360.3 (360.0–420.0)	383.9–414.6 (360.0–420.0)
	Vitamin A, mg	0.1–0.2 (0.2)	0.2 (0.3)	0.3 (0.3)
	Vitamin B1, mg	0.3 (1.2–0.3)	0.4–0.5 (0.4–0.5)	0.5 (0.4–0.5)
	Vitamin B2, mg	0.3–0.5 (0.3–0.4)	0.5 (0.5–0.6)	0.5 (0.5–0.6)
	Vitamin C, mg	11.8–18.4 (12.0–15.0)	20.0–22.1 (21.0–24.5)	23.3–24.4 (21.0–24.5)
	Proteins, g	19.3 (15.4–19.3)	32.6 (27.0–31.5)	32.3(27.0–31.5)
	Fats, g	**20.0–21.8** (15.8–19.8)	31.6–32.5 (27.6–32.2)	32.8–34.9 (27.6–32.2)
	Crabohydrates, g	81.4 (67.0–83.8)	115.3 (114.9–134.2)	124.9 (114.9–134.2)
	Caloric contents, kcal	585.0–590.0 (470.0–587.5)	846.0 (816.0–952.0)	875.7 (816.0–952.0)
Contaminants in blood	Phenol	0.007 (0.005 ± 0.001)	0.001 (0.005 ± 0.001)	0.009 (0.005 ± 0.001)
	Formaldehyde	**0.004** (0.01 ± 0.001)	**0.005** (0.01 ± 0.001)	**0.005** (0.01 ± 0.001)
	Manganese	**0.003** (0.013 ± 0.004)	**0.003** (0.013 ± 0.004)	**0.003** (0.013 ± 0.004)
	Lead	**0.005** (0.01 ± 0.0067)	**0.007** (0.01 ± 0.0067)	0.010 (0.01 ± 0.0067)
	Nickel	**0.006** (0.015 ± 0.007)	0.010 (0.015 ± 0.007)	0.011 (0.015 ± 0.007)
	Chromium	0.007 (0.003 ± 0.002)	0.010 (0.003 ± 0.002)	0.013 (0.003 ± 0.002)
Socioeconomic factors	Socioeconomic status, scores	0.3	1.4	1.6
	Spare time activities, scores	1.2	2.1	2.1
	Intensity of learning, scores	1.0	1.3	1.3
	Physical activity, scores	0.5	1.7	1.7

to make water treatment procedures more effective and to improve drinking water quality. Interaction between teachers and parents is another significant factor since it helps eliminate gaps in parents' knowledge on how to provide a truly health-preserving environment for their children beyond school.

It is advisable to include biological impedance analysis into periodical medical examinations at school, to maintain close oversight of morbidity among schoolchildren during a school year and to provide relevant psychological testing. There is an acute necessity to develop a standardized procedure for assessing indicators describing intensity of learning in middle and senior school.

Still, we should remember that this study is rather limited since it covers only five secondary schools in Perm region. It is advisable to expand it and analyze secondary schools in other RF regions aiming to perform more profound testing whether the existing standards conform to schoolchildren's physiological needs and whether schoolchildren's life activities are truly safe in the contemporary situation.

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