RUSSIAN BULLETIN OF HYGIENE

SCIENTIFIC MEDICAL JOURNAL
FOUNDED BY: BURDENKO VORONEZH STATE MEDICAL UNIVERSITY AND
PIROGOV RUSSIAN NATIONAL RESEARCH MEDICAL UNIVERSITY

SUBMISSION https://rbh.rsmu.press/
COLLABORATION kirillova_av4@rsmu.ru
ADDRESS Ostrovityanov St. 1, Moscow, 119997, Russia

Indexed in RSCI. IF 2018: 0,5

Open access to archive

Issue DOI: 10.24075/rbh.2025–04
The mass media registration certificate PI series № FS77-80908 dated April 21, 2021
Founders: Burdenko Voronezh State Medical University (Voronezh, Russia)
Pirogov Russian National Research Medical University (Moscow, Russia).
Publisher: Pirogov Russian National Research Medical University; adress: Ostrovityanov Street 1, Moscow 119997 Russia

Approved for print 31.12.2025
Circulation: 100 copies. Printed by Print.Formula
www.print-formula.ru

РОССИЙСКИЙ ВЕСТНИК ГИГИЕНЫ

НАУЧНЫЙ МЕДИЦИНСКИЙ ЖУРНАЛ ВОРОНЕЖСКОГО ГОСУДАРСТВЕННОГО МЕДИЦИНСКОГО УНИВЕРСИТЕТА ИМ. Н. Н. БУРДЕНКО И РОССИЙСКОГО НАЦИОНАЛЬНОГО ИССЛЕДОВАТЕЛЬСКОГО МЕДИЦИНСКОГО УНИВЕРСИТЕТА ИМ. Н. И. ПИРОГОВА

ПОДАЧА РУКОПИСЕЙ https://rbh.rsmu.press/

СОТРУДНИЧЕСТВО kirillova_av4@rsmu.ru

АДРЕС РЕДАКЦИИ ул. Островитянова, д.1, г. Москва, 119997, Россия

Журнал включен в РИНЦ. IF 2018: 0,5

Здесь находится открытый архив журнала

DOI выпуска: 10.24075/rbh.2025–04

Свидетельство о регистрации средства массовой информации серия ПИ № ФС77-80908 от 21 апреля 2021 г.

Учредители: Воронежский государственный медицинский университет им. Н.Н. Бурденко (Воронеж, Россия);
Российский национальный исследовательский медицинский университет имени Н.И. Пирогова (Москва, Россия)

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Подписано в печать 31.12.2025
Тираж 100 экз. Отпечатано в типографии Print.Formula
www.print-formula.ru

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ASSESSMENT OF PHYSICAL DEVELOPMENT HARMONICITY IN SCHOOLCHILDREN FROM THE NEW RUSSIAN TERRITORIES

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Physical development is the most important indicator of the health of children and adolescents, since it enables monitoring thereof. This study aimed to assess the harmonicity of physical development in schoolchildren living in the new territories of the Russian Federation. We used the anthropometric data (body length and weight) of schoolchildren aged 7 to 17 years from the Donetsk People's Republic (DPR; 4004 people) and the Kherson region (2902 people). More than 60% of schoolchildren from the DPR had harmonious physical development, and the least number of harmoniously developed children was observed in the age groups of 11–14 years (58.4% of boys and 56.6% of girls); as for the Kherson region, the physical development was harmonious in more than 50% of schoolchildren therefrom, and lowest number of harmoniously developed children was found in the age groups of 11–14 years (43.1% boys and 45.3% of girls). We identified significant differences in the appearance of the relative risk of disharmonious physical development between boys aged 7–10 and 11–14 years in the DPR and the Kherson region ($\chi^2 = 21.6$, $p < 0.001$ and $\chi^2 = 59.328$, $p < 0.001$, respectively), as well as between girls of the same age groups ($\chi^2 = 14.383$, $p < 0.001$ and $\chi^2 = 11.843$, $p < 0.001$). These relative risk figures indicate that there is a direct link between the territories and the likelihood of disharmonious physical development. The correlation analysis and the calculation of relative risk yielded determination of the critical groups among schoolchildren aged 11–14 in which the number of children developed disharmoniously was the largest.

Keywords: physical development, regional regression scales, new Russian territories, schoolchildren

Author contribution: Paramonova VA — development of the study concept, collection of the primary material, processing of the research results, text authoring; Chudinin NV — statistical processing; Dementiev AA, Skoblina NA — text editing; Semicheva VR, Tatarinchik AA — collection of the primary material, statistical processing.

Compliance with ethical standards: the study was approved by the local Ethics Committee of the Pirogov Russian National Research Medical University (Minutes No. 239 of 15 April 2024) and conducted in accordance with generally accepted scientific principles of the Declaration of Helsinki (revision of 2013).

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Received: 03.12.2024 **Accepted:** 12.10.2025 **Published online:** 04.12.2025

DOI: 10.24075/rbh.2025.142

ОЦЕНКА ГАРМОНИЧНОСТИ ФИЗИЧЕСКОГО РАЗВИТИЯ ШКОЛЬНИКОВ НОВЫХ РОССИЙСКИХ ТЕРРИТОРИЙ

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Важнейшим показателем здоровья детей и подростков является физическое развитие — «инструмент контроля за состоянием здоровья ребенка». Целью исследования было изучить гармоничность физического развития школьников новых территорий Российской Федерации. В исследовании были использованы антропометрические данные (длина и масса тела) школьников в возрасте от 7 до 17 лет Донецкой Народной Республики (4004 чел.) и Херсонской области (2902 чел.). Более 60% школьников ДНР имели гармоничное физическое развитие, при этом наименьшее число гармонично развитых детей наблюдалось в возрастных группах 11–14 лет (58,4% мальчиков и 56,6% девочек); более 50% школьников Херсонской области имели гармоничное физическое развитие, при этом наименьшее число гармонично развитых детей выявлено в возрастных группах 11–14 лет (43,1% мальчиков и 45,3% девочек). Выявлены значимые различия в формировании относительного риска дисгармоничного физического развития между мальчиками 7–10 и 11–14 лет в ДНР и Херсонской области ($\chi^2 = 21,6$, $p < 0,001$ и $\chi^2 = 59,328$, $p < 0,001$ соответственно), а также между девочками в тех же возрастных группах ($\chi^2 = 14,383$, $p < 0,001$ и $\chi^2 = 11,843$, $p < 0,001$). Показатели относительного риска школьников ДНР и Херсонской области свидетельствуют о наличии прямой связи между территориями и вероятностью дисгармоничного физического развития. Проведенный корреляционный анализ и расчет относительного риска позволили установить «критические группы» школьников 11–14 лет, в которых наблюдается наибольшее число детей с дисгармоничным физическим развитием.

Ключевые слова: физическое развитие, региональные шкалы регрессии, новые российские территории, школьники

Вклад авторов: В. А. Парамонова — разработка концепции исследования, сбор первичного материала и обработка результатов исследования, написание текста; Н. В. Чудинин — статистическая обработка; А. А. Дементьев, Н. А. Скоблина — редактирование текста; В. Р. Семичева, А. А. Татаринчик — сбор первичного материала, статистическая обработка.

Соблюдение этических стандартов: исследование одобрено локальным этическим комитетом РНИМУ имени Н. И. Пирогова (протокол № 239 от 15.04.2024) и проведено согласно общепринятым научным принципам Хельсинкской декларации Всемирной медицинской ассоциации (ред. 2013 г.).

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Статья получена: 03.12.2024 **Статья принята к печати:** 12.10.2025 **Опубликована онлайн:** 04.12.2025

DOI: 10.24075/rbh.2025.142

Physical development, being the child's condition control tool, is on of the most important indicators of the health of children and adolescents [1, 2]. The degree of harmonicity of the physique reflects how well-balanced the processes of growth and development are, and describes the activity of metabolism in the context of the body-environment interaction at any age [1, 2]. The basic figures used in the physical development assessment are the anthropometric data [1, 2]. The assessment itself involves a comparison of these figures with those considered standards at the regional, national, and international levels. Most researchers believe it is best to prioritize regional standards, since they factor in the specifics of the given territory (climatogeographic, ethnic, ecological, socio-economic conditions, etc.) [3, 4].

On September 30, 2022, there were signed international agreements admitting the new regions to the Russian Federation (RF). In this regard, the physical development of children and adolescents there is of interest to both scientists and healthcare professionals [5].

The purpose of this study was to assess the harmonicity of physical development of schoolchildren in the new territories of the Russian Federation.

METHODS

The study relied on the anthropometric data (body length and weight) of schoolchildren aged 7 to 17 years from the Donetsk People's Republic (DPR; 4004 people) and the Kherson region (2902 people). The data were taken from the official medical documentation (preventive medical examination cards for minors, Form No. 030-PO/u-17). The schoolchildren were divided into three age periods: 7–10 years old, 11–14 years old and 15–17 years old, according to the age division practiced in the Russian Federation. The assessment of the physical development of schoolchildren was based on the regional age and sex modified body length-dependent weight regression scales [6, 7]. The study yielded a conclusion describing how harmonious (disharmonious) the physical development of schoolchildren in the new Russian territories is [6, 7].

For statistical processing of the obtained data, we used the Statistica 13 software package (StatSoft; USA) and Excel 2016 (Microsoft; USA). The mathematical analysis of the data involved calculation of the statistical indicators using methods of descriptive statistics. Since the analyzed indicators are attributive and measured on a nominal scale, we represented them as calculated proportions — how often each occurs in the sample — and determined the 95% confidence Wilson score intervals. To analyze the attributive data on a nominal scale, we used the four-field conjugacy tables and calculated the Pearson's chi-square criterion (χ^2), the relative risk (RR), and its 95% confidence interval. The critical significance level for all statistical methods (criteria) used was $p \leq 0.05$.

RESULTS

More than 60% of schoolchildren in the DPR had harmonious physical development; the smallest number of harmoniously developed children was observed in the age group of 11–14 years (58.4% boys and 56.6% girls) (Table).

In the Kherson region, physical development was harmonious in over 50% of schoolchildren; the largest number of disharmonious development cases was registered in the 11–14 years age group (43.1% boys and 45.3% girls).

In DPR, the common reason behind the disharmonious physical development in the 7–10 years age was short stature, registered in 14.3% of boys and 16.2% of girls; it may indicate a possible delay in biological development. The main reason in the 11–14 years age group was excess body weight, seen in 18.3% of boys and 18.7% of girls. In the 15–17 years age group, disharmonious physical development stemmed from insufficient body weight in boys (25.5%) and excess body weight in girls (15.0%).

In the Kherson region, the key reason for disharmonious physical development in the 7–10 years age group was excess body weight in boys (21.6%) and insufficient body weight in girls (16.3%). In the 11–14 years age group, it was also excess body weight in boys (28.0%) and insufficient body weight in girls (19.7%). As for the 15–17 years age group, the common reason behind disharmonious physical development was excess body weight, found in 20.8% of boys and 15.8% of girls.

Assessing the conjugacy of age groups in DPR and calculating the RR of disharmonious development, we identified significant differences between male schoolchildren aged 7–10 and 11–14 years ($\chi^2 = 9.841$, $p < 0.05$), and schoolchildren aged 11–14 and 15–17 years ($\chi^2 = 6.272$, $p < 0.05$). The RR of disharmonious physical development in boys from DPR belonging to the 11–14 years age group exceeded that in other age groups by 1.3 and 1.2 times, respectively (RR = 1.308 (1.104–1.551) and RR = 1.248 (1.047–1.489)); in girls aged 11–14 years, the RR was also 1.3 times higher than in the 15–17 years age group (RR = 1.423 (1.171–1.722)).

In the Kherson region, we revealed significant gender differences in the degree of disharmonious physical development among schoolchildren aged 11–14 and 15–17 years ($\chi^2 = 13.044$, $p < 0.001$ and $\chi^2 = 16.618$, $p < 0.01$, respectively). The RR in boys and girls aged 11–14 years was 1.2 and 1.4 times higher than in the 15–17 years age group, respectively (RR = 1.248 (1.047–1.489), (RR = 1.403 (1.155–1.706)).

The assessment of RR of disharmonious physical development in the same-age schoolchildren (both boys and girls) from DPR and the Kherson region revealed no significance of gender as a risk factor.

We identified significant differences in the causes of RR of disharmonious physical development between boys aged 7–10 and 11–14 in DPR and the Kherson region ($\chi^2 = 21.6$, $p < 0.001$ and $\chi^2 = 59.328$, $p < 0.001$, respectively), and between girls in similar age groups ($\chi^2 = 14.383$, $p < 0.001$ and $\chi^2 = 11.843$, $p < 0.001$). The RR indicators of schoolchildren in DPR and the Kherson region confirm the direct link between the territories they reside in and the likelihood of disharmonious physical development: in boys aged 7–10 and 11–14 years from the Kherson region, the said likelihood was 1.5 and 1.4 times higher, respectively, than for in their peers from DPR (RR = 1.526 (1.278–1.821) and RR = 1.367 (1.201–1.557)). In the Kherson region, girls aged 7–10 and 11–14 had a 1.4 and 1.3 times higher risk of disharmonious development than girls in DPR, respectively (RR = 1.407 (1.180–1.677) and RR = 1.268 (1.109–1.450)).

DISCUSSION

Stature and body weight are the main anthropometric indicators traditionally used in pediatric practice to assess physical development [1, 2]. Deviations of these parameters from the age standards indicate the need for a more extensive examination, and further on — planning and implementation of preventive and health improvement programs, including those designed specifically for the premises of the educational institution [8].

Table. Physical development indicators, schoolchildren of the Kherson region and DPR

Harmonicity of physical development	Age groups	Kherson region				DPR			
		Boys		Girls		Boys		Girls	
		Number	Share (%) (95% CI)	Number	Share (%) (95% CI)	Number	Share (%) (95% CI)	Number	Share (%) (95% CI)
H(N)PhD	7–10 years	160	51.6 (46.88–53.94)	163	52.2 (46.71–57.73)	310	68.2 (63.86–72.39)	284	66.0 (61.45–70.36)
	11–14 years	205	43.1 (38.74–47.63)	172	45.3 (40.89–50.93)	296	58.4 (54.16–62.71)	304	56.9 (52.69–61.06)
	15–17 years	132	59.7 (53.15–65.98)	124	61.0 (54.23–67.53)	253	68.0 (61.86–71.31)	227	63.2 (58.13–68.05)
DPhD, including	7–10 years	150	48.3 (42.88–53.94)	149	47.7 (42.27–53.29)	144	31.7 (27.61–36.14)	146	34.0 (29.64–38.55)
	11–14 years	269	56.0 (52.37–61.26)	207	54.6 (50.14–60.16)	210	41.5 (37.29–45.84)	230	43.1 (38.94–47.31)
	15–17 years	89	40.3 (34.02–46.85)	79	38.9 (32.47–45.77)	126	33.2 (28.69–38.14)	132	36.8 (31.95–41.87)
BWD	7–10 years	46	14.8 (11.31–19.23)	51	16.3 (12.66–20.85)	29	6.3 (4.48–9.02)	16	10.6 (8.12–13.97)
	11–14 years	59	12.5 (9.79–15.76)	75	19.7 (16.26–24.34)	59	11.6 (9.15–14.75)	75	14.0 (11.35–17.25)
	15–17 years	22	9.9 (6.67–14.61)	18	8.8 (5.68–13.58)	20	25.3 (23.44–28.01)	39	10.8 (8.05–14.51)
EBW	7–10 years	67	21.6 (17.39–26.53)	47	15.0 (12.93–19.78)	23	5.0 (3.40–7.49)	13	3.0 (1.78–5.10)
	11–14 years	132	28.0 (24.06–32.11)	100	18.7 (15.65–22.25)	94	18.3 (15.43–22.2)	100	18.7 (15.65–22.25)
	15–17 years	46	20.8 (16.98–26.64)	57	15.8 (12.46–20.02)	67	18.0 (14.17–21.84)	57	15.0 (12.46–20.02)
SS	7–10 years	22	7.0 (4.73–10.51)	36	11.5 (8.45–15.56)	65	14.3 (11.39–17.84)	70	16.2 (13.09–20.06)
	11–14 years	68	14.4 (11.50–17.83)	41	7.6 (5.71–10.23)	39	7.7 (5.69–10.36)	41	7.6 (5.71–10.23)
	15–17 years	17	7.6 (4.86–11.97)	33	9.1 (6.62–12.63)	20	5.3 (3.44–8.01)	33	9.1 (6.62–12.63)
TS	7–10 years	15	4.8 (2.95–7.83)	15	4.8 (2.93–7.78)	27	5.9 (4.12–8.51)	17	3.9 (2.48–6.24)
	11–14 years	8	1.6 (0.86–3.36)	14	2.6 (1.57–4.35)	18	3.5 (2.22–5.55)	14	2.6 (1.57–4.35)
	15–17 years	4	1.8 (0.71–4.56)	3	0.8 (0.28–2.43)	20	5.3 (3.44–8.01)	3	0.8 (0.28–2.43)

Note: H(N)PhD — harmonious (normal) physical development; DPhD — disharmonious physical development; BWD — body weight deficiency; EBW — excess body weight; SS — short stature; TS — tall stature.

In a population of children, adolescents and youth who grow and develop in favorable conditions, the proportion of children with normal (harmonious) physical development approaches 68% (consistent with the normal distribution law) [9].

Earlier studies that involved schoolchildren from Moscow and Kiev found the share of normally developed people in these populations to be exactly that number [10].

However, in our study, we discovered a fairly large proportion of schoolchildren with disharmonious physical development.

As reported in the scientific literature, 2 to 3 percent of children show a delay in biological development of various origins, regardless of gender. At the same time, the high prevalence of overweight and obesity among minors (about 27.1%) is a matter both Russian and foreign specialists are concerned about [11–16].

We found that 14.3% of boys and 16.2% of girls from the 7–10 years age group (DPR) had a short stature, which may indicate a possible delay in biological development.

Excess body weight was the predominant sign of disharmonious physical development among boys in all age groups from the Kherson region (21.6, 28.0 and 20.8%, respectively) and in the 11–14 years age groups among boys from DPR (18.3%), as well as among girls of the Kherson region aged 15–17 years (15.8%) and girls from DPR aged 11–14 years and 15–17 years (18.7% and 15.0%, respectively).

Body weight deficiency was less common; we registered it in older boys from DPR (25.3%) and in girls of younger and middle age groups from the Kherson region (16.3 and 19.7%, respectively).

The correlation analysis and calculation of the RR showed that age was a factor in disharmonious physical development in the 11–14 years age group, regardless of gender and territory of residence; this is comparable with the results of other studies, because this is the puberty age, when the entire body undergoes rapid transformation [1, 2]. The greatest risk of disharmonious development occurs at the age of 11–14 years, which is a sensitive period associated with the most active changes in the adolescent's body.

A long-term analysis of the dynamics of physical development of children and adolescents indicates a direct dependence of their health status on environmental and socio-economic

factors present in their territory of residence [17]. This study revealed differences between the studied territories: the indicators of disharmonious physical development of schoolchildren in the Kherson region were higher than those in DPR. At the same time, correlation analysis and RR calculation point to a direct relationship between the specifics of the territories and the likelihood of disharmonious physical development in younger children and those in the medium age groups of the sample.

The current scientific publications lack sufficient information on the level of physical development and health of the child population in the new territories of the Russian Federation. Therefore, further research in this area will help practical healthcare in planning science-based preventive measures. Thus, it is necessary to continue studying children, adolescents and youth residing in the said regions [18].

CONCLUSIONS

This study investigated level of physical development of schoolchildren in the new Russian territories using regional age-sex modified stature-dependent body weight regression scales. We identified deviations in physical development (short stature, overweight and underweight), and the correlation analysis and calculation of the relative risk defined the "critical groups" of schoolchildren aged 11–14 years that included the largest number of people with disharmonious physical development.

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EXPERIENCE IN DELIVERING "HYGIENE AND SANITATION" AND "HYGIENIC EDUCATION" PROGRAMS TO POSTGRADUATE STUDENTS VIA DISTANCE LEARNING

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At the current stage of societal development, there is an increasing need to introduce innovative approaches to the pedagogical process to enhance the quality and accessibility of postgraduate education. The specifics of modern education are the widespread use of computer technology and the Internet, which provide connection to intelligent information systems and technologies. Such tools enable training when there is a significant distance between the student and the teacher. Telecommunication and network technologies are well integrated into postgraduate education, including programs for paramedics. This study aimed to evaluate the effectiveness of distance learning in delivering advanced training programs in "Hygiene and Sanitation" and "Hygienic Education" to postgraduate paramedics enrolled in a part-time curriculum. We surveyed 30 general hygiene assistants. The main research methods were logical analysis, generalization, systematization of published information, and reflection on digitalization experience. In the survey ranking, the highest mean score — 6.84 (6.77; 6.91) — was assigned to three questions related to the organization of the advanced training cycle and the clarity of learning goals and content. The lowest score, corresponding to the third rank, was given to the question on the effectiveness of distance learning. Although this question received a mean score of 5.37 (5.23; 5.51), it was still above the neutral level of 4 points. The results of the survey allowed suggesting that the introduction of distance learning significantly increases motivation to learn and reduces the time spent on periodic professional development.

Keywords: distance learning, postgraduate education, paramedical personnel, information systems, technology, efficiency

Compliance with ethical standards: all students gave informed consent to participate in the study.

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Received: 10.07.2025 **Accepted:** 15.11.2025 **Published online:** 10.12.2025

DOI: 10.24075/rbh.2025.143

ОПЫТ ИСПОЛЬЗОВАНИЯ ДИСТАНЦИОННОГО ОБУЧЕНИЯ ПО ПРОГРАММАМ «ГИГИЕНА И САНИТАРИЯ» И «ГИГИЕНИЧЕСКОЕ ВОСПИТАНИЕ» В ПОСТДИПЛОМНОМ ОБРАЗОВАНИИ

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В актуальных реалиях развития общества растет необходимость использования инновационных преобразований педагогического процесса, в том числе для повышения качества и доступности постдипломного образования. Спецификой современного обучения является широкое использование компьютерной техники, Интернета с возможностью подключения к интеллектуальным информационным системам и технологиям. Такие средства позволяют проводить обучение, когда обучаемый и обучающий разделены значительным географическим расстоянием. Использование телекоммуникаций и сетевых технологий довольно обширно представлено в постдипломном образовании, в том числе для среднего медицинского персонала. Целью исследования было оценить метод дистанционного обучения на очно-заочном цикле повышения квалификации по программам «Гигиена и санитария» и «Гигиеническое воспитание» в постдипломном образовании среднего медицинского персонала. Проведено анкетирование среди 30 респондентов, работающих помощниками врача по общей гигиене. Ключевыми методами исследования были логический анализ, обобщение, систематизация опубликованной информации и осмысление опыта цифровизации. При ранжировании результатов анкетирования первый ранг с наибольшим средним баллом 6,84 (6,77; 6,91) присвоен трем вопросам, касающимся организации цикла повышения квалификации, ясности цели обучения и наполняемости информационным материалом, третий ранг с наименьшим количеством баллов получил вопрос об эффективности дистанционной формы обучения — 5,37 (5,23; 5,51), вместе с тем эта оценка была выше 4-балльного нейтрального уровня. Результаты анкетирования обучающихся позволили предположить, что внедрение дистанционного обучения показывает значительное увеличение мотивации к овладению знаниями, а также возможность сокращения рабочего времени, затрачиваемого на периодическое повышение квалификации специалистов.

Ключевые слова: дистанционное обучение, постдипломное образование, средний медицинский персонал, информационные системы, технологии, эффективность

Соблюдение этических стандартов: все обучающиеся дали добровольное информированное согласие на участие в исследовании.

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Статья получена: 10.07.2025 **Статья принята к печати:** 15.11.2025 **Опубликована онлайн:** 10.12.2025

DOI: 10.24075/rbh.2025.143

The 2017–2030 Strategy for the Development of the Information Society in the Russian Federation (RF) approved by Decree of the President of the Russian Federation No. 203 of 9.05.2017 sets nine main tasks involving use of information and communication technologies for the development of the social sphere, the public administration system, and interaction between citizens and the state. Four of these tasks relate to postgraduate medical education. They include: implementing projects to improve access to high-quality medical services and products; creating technological platforms for distance learning to expand access to quality education; motivating companies and organizations to enable remote work; and developing technologies for electronic

interaction among citizens, organizations, state agencies, and local authorities, while preserving the option for non-digital interaction [1] .

Being a medical doctor implies lifelong learning, therefore, in order to maintain professional competence, doctors have to be constantly improving, updating, and revising their knowledge. Information and communication technology is a powerful tool that enhances the quality and effectiveness of education. In the third millennium, e-learning is no longer an alternative, it is a mandatory component that should be considered by the ever-increasing number of developers and organizers of educational programs.

In addition, the COVID-19 pandemic triggered significant changes in the field of education [2–4]. Therefore, currently, the process of teaching and studying graduates to a fundamentally new level, pushed up by the various information and communication infrastructures based on the Internet-enabled equipment and integration of software and hardware constituents [5, 6]. As a result, traditional education acquires new shapes: the role of the student, who turns into an active participant of the process, becomes more prominent [7]. A new paradigm of education is emerging, characterized by global accessibility and lifelong learning that fits seamlessly into one's main activities [8]. The innovative technologies used imply an analysis through the lens of synergetics, when an individual becomes a leading factor in social development, and the inputs by this individual have an increasing value [9]. Distance learning is a form of education that provides structured and purposeful guidance for learners who are physically separated from the educational institution, using electronic and telecommunication technologies [10].

This study aimed to evaluate the effectiveness of distance learning in delivering advanced training programs in "Hygiene and Sanitation" and "Hygienic Education" to postgraduate paramedics enrolled in a part-time curriculum.

PATIENTS AND METHODS

The study was conducted in 2021–2022 at the East-Siberian Institute of Medical and Ecological Research as part of educational activities. Methodologically, processing of materials on distance learning for postgraduate paramedics in evening advanced training programs involved logical analysis, generalization, and systematization of published information, as well as reflection on digitalization experience.

The study focused on two programs, "Hygiene and sanitation" and "Hygienic education," totaling 144 hours. The sample included 30 students working as general hygiene assistants at Rospotrebnadzor institutions in the Republic of Buryatia and the Irkutsk Region. The mean age of the students was 45.26 years (44.40; 46.13); most of them — 94.7% — were female. Inclusion criteria: secondary vocational education in the specialty 32.02.01 "Therapy and Preventive Medicine"; a specialist certificate in "Hygiene and Sanitation"; and at least five years of relevant work experience.

Upon completion of the training, the students were given the questionnaire shown in Table 1. Its purpose was to collect information to assess the effectiveness of distance learning. The answers were rated on a seven-point scale. Picking an answer from the extreme left part of the questionnaire scored 1 point, selection of one from the extreme right part — 7 points. Points from 2 to 6 were in-between the extreme options, with a neutral standpoint yielding 4 points.

Mathematical processing of the survey results was performed using Microsoft Excel (Microsoft; USA) and Jamovi 2.3 statistical software (The Jamovi Project; Australia). We ranked the results of the survey and calculated the arithmetic mean (M), the standard error of the mean (SEM), and 95% confidence intervals.

RESULTS

The distance learning advanced training program in "Hygiene and Sanitation" included the following sections: maintaining medical records and organizing the work of medical personnel; providing emergency medical care; collecting environmental and food samples for sanitary and hygienic testing; conducting sanitary and epidemiological studies and surveys with instrumental measurements of environmental factors; practical training; and final exams. The program "Hygienic Education" included the following sections: fundamentals of hygiene and epidemiology; promoting a healthy lifestyle; principles of hygienic education; content of hygienic education; organization and delivery of hygienic education; popularization of healthy living in institutions and organizations; practical training; and final examinations. In the practical training component, students independently prepared visual campaign materials — multimedia presentations, posters, flyers, etc. The distance learning concept was realized in the form of video lectures and webinars. The degree of knowledge acquisition was controlled through testing. The students sent the completed tasks and practical projects by e-mail. The quality of the practical part was assessed by several parameters: relevance, aesthetics, practical significance, independence of presentation, creativity and personal contribution, novelty and non-standard thinking in exploration of the subject, formalization rules compliance. The quality of practical work was discussed during in-person classes, which were organized to teach, advise, and analyze mistakes.

The training was supposed to not only give the students subject matter basics and a set of useful skills, but also teach them to perceive and master new knowledge. Education should foster a person's ability to create; the most optimal way to activate a student's creative potential is to teach them to work independently. A proper example of the implementation of this approach are tasks involving preparation of visual agitation — Power Point presentations; the advantages of such tasks are as follows:

– the purpose of the independent work of the students is consistent with the practical necessity;

– the contradictions between the abstract nature of the educational process and the real professional needs are eliminated;

– the acquired knowledge is systematized and attributed to the programs;

– the range of the problems considered is extended, and the depth of their comprehension increased;

– the tasks are consistent with the logic of professional activity, and imply improvement of the social interaction and professional communication skills;

- the students enjoy greater involvement, since independent preparation of visual materials implies feedback that is more meaningful than marks given by automated knowledge verification systems;

- the personal qualities of the students are well reflected in the results, their self-esteem is adjusted, and they acquire their professional activity stereotype;

– the processes of reflection is encouraged, along with those of interpretation and comprehension of the ultimate results.

Having defined the purpose and the task as well as set the conditions of independent work, the teacher gives the general

Table 1. Methodology for evaluating the effectiveness of distance learning

The level of computer skills: insufficient	1	2	3	4	5	6	7	The level of computer skills: professional
Internet skills: lacking	1	2	3	4	5	6	7	Internet skills: professional
It is quite difficult to study using distance learning technologies	1	2	3	4	5	6	7	It is easy to study using distance learning technologies
The information content of the program is insufficient	1	2	3	4	5	6	7	The information content of the program is sufficient
The purpose of our training is unclear	1	2	3	4	5	6	7	The purpose of our training is clear and understood
Essentially, the studying was fruitless for me.	1	2	3	4	5	6	7	The studying was fruitful for me, I will use the updated knowledge in my practical activities
I felt uncomfortable from the beginning to the end of the advanced training	1	2	3	4	5	6	7	Initially, I felt uncomfortable, but then my situation improved
I did not feel confident, like an outsider, from the beginning to the end of the advanced training	1	2	3	4	5	6	7	I felt confident, as a full member of the process, from the beginning to the end of the advanced training
In my opinion, traditional form of education is the most effective	1	2	3	4	5	6	7	In my opinion, distance learning is the most effective form of education
Generally, I find the organization of distance learning unsatisfactory.	1	2	3	4	5	6	7	Generally, I find the organization of distance learning done well.

patterns and procedure for the students. The experience gained by the students while they are preparing their projects should subsequently be used in the practical activities as physician assistants for general hygiene, same as the skills learned in the advanced training program. Preparing the projects, students employ many theoretical and practical approaches. The projects are the final stage of the program; they are offered after the students have mastered the course and updated their knowledge of the hygienic education and general hygiene theory, which are delivered as video lectures posted on the Internet. In addition, preparing the projects, the students relied on the practical experience previously acquired in the context of implementation of preventive measures under Chapter 10 of the Federal Law No. 248-FZ "On State Control (Supervision) and Municipal Control in the Russian Federation" of July 31, 2020 [11]

When the students submitted the filled questionnaires, we calculated the mean scores for all the parameters shown in Table 2.

In the survey ranking, the highest mean score — 6.84 (6.77; 6.91) — was assigned to three questions related to the organization of the advanced training cycle, the clarity of the learning goals, and the content of the program. The mean index of satisfaction with the actual results was 6.63 (6.55; 6.71); the score reflecting how confident and comfortable the students felt during the training — 6.26 (6.17; 6.36) and 5.95 (5.85; 6.04), respectively; the mean score indicating how simple it was for them to use distance learning technology — 5.84 (5.73; 5.95) points. The students rated their mastery of personal computer skills at 5.74 (5.62; 5.86) points and Internet skills at 5.68 (5.59; 5.78) points, respectively. The question that received the lowest mean score concerned the effectiveness of distance learning: 5.37 (5.23; 5.51) points. However, this value was still above the neutral level of 4 points.

DISCUSSION

The problems of digitalization of medical education involve a comprehensive assessment of the ongoing modernization, including the introduction of intelligent information systems and technologies [12, 13]. Many experts [14, 15] have indicated that educators need to revise the classical approaches and teaching methods in order to increase the motivation of students. Computers and the Internet enable training when the student and the teacher are separated by a significant geographical distance. Telecommunications and network technology are quite common in postgraduate education, including that for paramedics.

Distance learning involves the transfer of knowledge through video lessons, which are equivalent to regular lectures or introductory classes [16], but differ in several ways. According to the authors of [17], there are two most widely used forms of distance learning: synchronous (live communication) and asynchronous (text-based process). The first form employs lecture recordings and other information resources that allow the educator and the students to interact in real time.

Table 2. Survey results (points)

Questionnaire items	Arithmetic mean (M)	SEM	95% confidence interval of the arithmetic mean		Rank
			M-(1,96 × SEM)	M+(1,96 × SEM)	
Personal computer skills	5.68	0.05	5.59	5.78	7
Internet skills	5.74	0.06	5.62	5.86	6
Ease of knowledge acquisition using distance learning technologies	5.84	0.06	5.73	5.95	5
The information content of the program	6.84	0.02	6.80	6.88	1
The purpose of the training	6.84	0.02	6.80	6.88	1
The actual result	6.63	0.04	6.55	6.71	2
How comfortable the process was	5.95	0.05	5.85	06.04	4
How confident the students felt	6.26	0.05	6.17	6.36	3
How effective the training was	5.37	0.07	5.23	5.51	8
Organization of distance learning	6.84	0.04	6.77	6.91	1

The second form does not include a live online component but relies on written messages, audio and video posts, and discussions in chats for interactivity. There are many studies demonstrating the benefits of distance learning [18–21]. For example, a systematic review [20] showed that this mode of education delivery is more flexible and accessible. It allows for an academic dialogue between students and educators, offers a convenient learning environment, rich experience, good work-life balance, and easy access to educational materials. Some scholars claim that interactive video is a viable alternative to online learning. Many educational organizations supplement traditional education with online learning [19, 21, 22].

In the case considered in this study, postgraduate paramedics enrolled in the evening advanced training programs "Hygiene and Sanitation" and "Hygienic Education", where they acquired comprehensive theoretical knowledge applicable to their practical work. To learn the subjects, the students relied on various additional resources, which greatly facilitated the preparation process [18]. One of such resources were video materials, which gave information, offered computer-labeled tasks, and involved subsequent testing. The said materials were lectures given by educators to empty audiences; they were stored locally or online, and delivered to the students using various tools and media. Digitalization offers postgraduate trainees a growing array of opportunities and advantages, primarily by allowing them to save time through the ability to watch videos at their convenience.

At the same time, the question about the effectiveness of distance learning received the lowest mean score, which is due to the certain difficulties and problems experienced by the students because of the lack of exchange of opinions and interaction between the educator and the students characteristic of traditional learning. This rationale is consistent with the opinion of a number of researchers [23–25]. Changes in society driven by technological progress entail transformation of postgraduate education and qualification requirements for the State Sanitary and Epidemiological Service specialists: computer and Internet skills are among those they need to master mandatorily. In this regard, some of the advanced training programs prepared for such specialists should cover new software, graphic editors, useful resources and technologies; these programs can be comprised of online courses, video tutorials, and specialized literature.

The last decade's experience of distance learning [26–29] confirms adoption of the basic principles that revolve around active training with an emphasis on deep learning and understanding. The concept passes the responsibility to the students, encourages independent exploration, and draws upon the interdependence between the teacher and the student, mutual respect, and a reflective approach to the learning process practiced by both parties.

CONCLUSIONS

This study has shown that introduction of distance learning into evening advanced training cycles significantly increases motivation to acquire knowledge and allows students to dedicate less time to periodic professional development. It should be noted that the question about the effectiveness of distance learning scored the lowest in the survey, which may be due to insufficient self-discipline or self-control, spending personal rather than working time on studying and assimilating material during business trips to the place of daytime education, etc. Thus, the positive experience of using distance learning once again confirms the need to continue to introduce training programs with mixed forms of education.

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COMPARISON OF UTERINE BODY CANCER INCIDENCE AMONG WOMEN LIVING IN ENVIRONMENTALLY DISADVANTAGED AREAS (2000–2019)

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Living in ecologically compromised regions can significantly increase the risk of malignant neoplasms in the female reproductive system, including uterine body cancer (UBC). This study aimed to calculate the relative risk (RR) and the frequency of primary incidence of UBC among women aged 41–60 years living in areas with different levels of exposure to radiation, chemical, and combined environmental factors. The analysis considered high-, moderate-, and low-grade forms of UBC over a 20-year period (2000–2019). Information for the study was provided by Bryanskstat (Bryansk Region Statistical Bureau), Bryansk Regional Oncological Dispensary, Rospotrebnadzor and Rostechnadzor. We found that the RR of initial occurrence of high-grade forms of UBC in women living in ecologically compromised regions was considerably higher than that in female population of ecologically safe (control) territories, reaching the mean value of 1.28 (95% CI: 1.00–1.64); $p = 0.047$). Other findings include an increased RR of occurrence of both high- and, to a greater extent, low-grade forms of UBC in areas with high radioactive and chemical contamination — 1.19 (95% CI: 0.87–1.63) and 1.36 (95% CI: 0.70–2.65), respectively; the relative risks for combined and chemical contamination areas were 1.18 (95% CI: 0.90–1.55) and 1.34 (95% CI: 0.75–2.39), respectively; no increase was observed between the territories with combined and radioactive contamination — 0.99 (95% CI: 0.67–1.46) and 0.98 (95% CI: 0.44–2.21). In all likelihood, the data from this study indicate that accident-related radiation contamination plays a more significant role in the development of high-grade — and especially low-grade — forms of UBC than does chemical contamination.

Keywords: Chernobyl accident, malignant neoplasms of the endometrium, radioactive contamination, chemical pollution, combined contamination, relative risk, Bryansk region

Acknowledgements: the authors thank A.I. Maklashova, Chief Medical Officer at the Bryansk Regional Oncological Dispensary, for providing anonymized statistical information on the incidence of endometrial cancer in women in the cities and districts of the Bryansk region for the period from 2000 to 2019.

Author contribution: Kryukova AE — literature search, statistical processing, authoring, editing, and discussion of the article; Korsakov AV — analysis of literary data, concept and design of the study, interpretation of the results, approval of the final version of the article; Troshin VP — data analysis and interpretation, authoring, editing, and discussion of the article; Milushkina OYu — analysis of literary data, analysis and interpretation of data, editing and discussion of the article; Pivovarov YuP, Korolik VV — analysis and interpretation of data, editing and discussion of the article.

Compliance with ethical standards: the study used anonymized statistical information on the incidence of UBC in the Bryansk region in 2000–2019.

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Received: 18.04.2025 **Accepted:** 16.10.2025 **Published online:** 22.12.2025

DOI: 10.24075/rbh.2025.144

СРАВНИТЕЛЬНАЯ ОЦЕНКА ЗАБОЛЕВАЕМОСТИ ЗЛОКАЧЕСТВЕННЫМИ НОВООБРАЗОВАНИЯМИ ТЕЛА МАТКИ ЖЕНЩИН, ПРОЖИВАЮЩИХ НА ЭКОЛОГИЧЕСКИ НЕБЛАГОПОЛУЧНЫХ ТЕРРИТОРИЯХ (2000–2019 ГГ.)

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Проживание на экологически неблагополучных территориях может существенно увеличивать риск развития злокачественных новообразований женской репродуктивной системы, в том числе злокачественных новообразований тела матки (ЗНОТМ). Целью исследования было провести расчет относительного риска (ОР) и частоты первичной заболеваемости женщин 41–60 лет, проживающих на территориях с различным уровнем радиационного, химического и сочетанного воздействия окружающей среды, высоко-, умеренно и низкодифференцированными формами ЗНОТМ за двадцатилетний период (2000–2019 гг.). Информация для исследования была предоставлена Брянскстатом, Брянским областным онкологическим диспансером, Роспотребнадзором и Ростехнадзором. Выявлено существенное превышение ОР первичной заболеваемости высокодифференцированными формами ЗНОТМ у женщин, проживающих на экологически неблагополучных территориях (суммарно в зонах химического, радиоактивного и сочетанного загрязнения), по сравнению с женщинами, проживающими на экологически благополучных (контрольных) территориях. ОР составил 1,28 (95% ДИ: 1,00–1,64); $p = 0,047$). Выявлен повышенный ОР заболеваемости высоко- и в большей степени низкодифференцированными формами ЗНОТМ между территориями радиоактивного и химического загрязнения — ОР 1,19 (95% ДИ: 0,87–1,63); 1,36 (95% ДИ: 0,70–2,65); сочетанного и химического загрязнения — ОР 1,18 (95% ДИ: 0,90–1,55); 1,34 (95% ДИ: 0,75–2,39); при этом не установлено повышение риска между территориями сочетанного и радиоактивного загрязнения — ОР 0,99 (95% ДИ: 0,67–1,46); 0,98 (95% ДИ: 0,44–2,21). По всей вероятности, полученные данные свидетельствуют о большей роли влияния аварийного радиационного фактора на формирование высоко- и особенно низкодифференцированных форм ЗНОТМ относительно химического.

Ключевые слова: Чернобыльская катастрофа, злокачественные новообразования тела матки, радиоактивное загрязнение, химическое загрязнение, сочетанное воздействие, относительный риск, Брянская область

Благодарности: авторы благодарят главного врача Брянского областного онкологического диспансера А. И. Маклашову за предоставление обезличенной статистической информации о заболеваемости женщин злокачественными заболеваниями эндометрия в городах и районах Брянской области за период с 2000 по 2019 г.

Вклад авторов: А. Е. Крюкова — поиск литературы, статистическая обработка, написание рукописи, редактирование и обсуждение статьи; А. В. Корсаков — анализ литературных данных, концепция и дизайн исследования, интерпретация полученных результатов, утверждение окончательного варианта статьи; В. П. Трошин — анализ и интерпретация данных, написание, редактирование и обсуждение статьи; О. Ю. Милушкина — анализ литературных данных, анализ и интерпретация данных, редактирование и обсуждение статьи; Ю. П. Пивоваров, В. В. Королик — анализ и интерпретация данных, редактирование и обсуждение статьи.

Соблюдение этических стандартов: использована обезличенная статистическая информация о заболеваемости женщин ЗНОТМ на территориях Брянской области за 2000–2019 гг.

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Статья получена: 18.04.2025 **Статья принята к печати:** 16.10.2025 **Опубликована онлайн:** 22.12.2025

DOI: 10.24075/rbh.2025.144

Statistics based on GLOBOCAN 2022 (estimates from the International Agency for Research on Cancer) indicates that the number of new cases of malignant neoplasms (MNs) in the world has reached 20 million [1]. It is estimated that approximately one in five men or women develops MN during their lifetime, and about one in nine men and one in twelve women die from it [1]. Projections indicate that new MN cases will surpass 35 million in 2050, representing a 77% increase over 2022. Demographic transition is a key factor determining the extent of cancer spread: in 2022, the global population was about 8 billion people, and by 2050 it will reach 9.7 billion [1]. Malignant neoplasms of the endometrium (uterine corpus) are the sixth most frequently diagnosed cancer in women (4.3%) [1].

According to the Hertsen Moscow Oncology Research Institute, in 2022, endometrial cancer ranked fourth among all cancers, accounting for 7.1% of the total number of MN cases [2].

Living in ecologically compromised territories can significantly increase the risk of diseases of the female reproductive system [3–9]. According to researchers [3], chronic exposure to heavy metals can lead to breast cancer, endometriosis, hypertension, menstrual disorders, and spontaneous abortions, as well as premature birth and stillbirth. It was established that metalloestrogen cadmium induces UBC, elevated lead levels have a teratogenic effect and can cause spontaneous abortion, and mercury affects the menstrual cycle and can lead to infertility [3]. According to [4], cadmium is a potential risk factor for hormone-dependent tumors, such as UBC, because the vascular endothelium is a target of cadmium toxicity, which can affect coagulation processes and the fibrinolytic system. Patients with fibroids and especially UBC were found to have disrupted coagulation and fibrinolysis, which translate into hypercoagulation [4]. A monitoring of 62,534 women who survived the atomic bombing (1958–2009) [5] revealed a significant relationship between the radiation dose and the risk of UBC, which indicates that the uterine corpus is particularly sensitive to the carcinogenic effect of radiation.

According to [10–12], the southwestern territories of the Bryansk Region remain highly contaminated with cesium-137 (^{137}Cs) from the Chernobyl accident. The contamination levels exceed those that classify the area as radioactively contaminated, and the average annual effective doses exceed 1 mSv per year, reaching maximum values of up to 5.6 mSv/year [13, 14]. In recent years, the Bryansk region has seen an increase in the release of gaseous pollutants into the atmosphere [15, 16]. It is important to note in some areas of the region the population is exposed to both radioactive and chemical contamination factors (combined exposure) [17–19]. A study [19] found that the relative risk (RR) of UBC among women aged 18–80 years living in ecologically compromised areas was significantly higher than in control regions. In addition, continued environmental pollution accelerates the mutation process, which increases the population load [20].

This study aimed to calculate the relative risk (RR) and the frequency of primary incidence of UBC among women aged 41–60 years living in areas with different levels of exposure to radiation, chemical, and combined environmental factors. The analysis considered high-, moderate-, and low-grade forms of UBC over a 20-year period (2000–2019).

METHODS

The post-Chernobyl radioactive contamination density data (^{137}Cs and ^{90}Sr) were taken from [12], the average annual effective dose data — from [14], the data on the level of CO, NO_x, SO_2 and volatile organic compounds (VOCs) in the air — from [15]. The study covered the years 2000–2019.

Based on official data from the Bryansk Regional Oncological Dispensary [21], we calculated the RR and the frequency of primary incidence of high-, moderate-, and low-grade forms of UBC, taking into account the levels of chemical and radioactive contamination. The study covered the period from 2000 to 2019. We performed a histological analysis of UBC samples collected from 1,030 women aged 41–60 years.

For statistical analysis, we used the Shapiro–Wilk test, the Mann–Whitney *U* test, and calculated 95% confidence intervals. Levels of statistical significance were set at $p < 0.05$, $p < 0.01$, and $p < 0.001$. The absolute values of the incidence of UBC were recalculated per 100,000 female population [15]. We used MyOffice package (New Cloud Technologies; Russia) for analysis of the data collected.

RESULTS

Based on the degrees of radioactive and chemical contamination and the level of primary incidence of UBC over a twenty-year period (2000–2019), we divided the Bryansk region into four groups. The results of this effort are given in Table 1; the analysis of the data therefrom was part of an earlier work [19].

The incidence of high-, moderate-, and low-grade forms of UBC is 21.0%, 18.1% and 14.4% higher in women living in contaminated areas (combined, radioactive, and chemical contamination) compared to the female population of the control areas: 29.4 ± 4.8; 28.7 ± 5.1 and 27.8 ± 4.1 versus 24.3 ± 4.2 (Table 2). However, no significant differences between the groups were found ($p > 0.05$). The frequency of high-grade forms of UBC is higher in women living in territories with radioactive (15.6 ± 3.1) and combined (15.4 ± 3.2) contamination compared to those residing in chemically contaminated areas (13.1 ± 2.0) and control territories (10.6 ± 2.0). A similar trend was registered for low-grade forms of UBC: territories with radioactive contamination — 3.6 ± 1.5, combined contamination — 3.5 ± 1.0, chemically contaminated areas — 3.1 ± 0.6, and control territories — 2.7 ± 0.7. The incidence rate of moderately differentiated forms of UBC varies only slightly through cities and districts of the Bryansk region — from 10.5 to 11.7. The environmental conditions have no effect thereon; the peak value of 11.7 is registered in the territories with chemical pollution (Table 2). It should be noted that we did not observe significant differences between the groups, whether divided by the form of UBC or by the grade of the disease (Table 2).

Based on the data from Table 3, it can be concluded that women living in the environmentally compromised areas (including territories with chemical, radioactive, and combined contamination) have an increased incidence of high-, moderate- and low-grade forms of UBC compared with women living in environmentally safe (control) areas. The mean RR is 1.16 (95% CI: 0.98–1.36); its values are generally higher than those calculated for the control areas: in the chemically contaminated territories, the RR is 1.14 (95% CI: 0.97–1.35), in the areas of radioactive pollution — 1.18 (95% CI: 0.91–1.54), combined pollution — 1.21 (95% CI: 0.96–1.53). We did not register increased RR for primary incidence of UBC in comparison of the territories with different types of contamination: the values vary between 1.02 and 1.06.

An analysis of data from Table 4 revealed a significant ($p = 0.047$) increase of the RR of incidence of UBC. The highest RR was registered for high-grade forms of the disease in women residing in ecologically compromised areas (chemical, radioactive, and combined contamination jointly). In the control areas, the RR was 1.28 (95% CI: 1.00–1.64).

Table 1. Territories of the Bryansk region grouped by the degree of chemical, radioactive, and combined contamination and by the incidence of primary UBC among women aged 18–80 years (per 100,000 population) (2000–2019) [19]

Areas of the Bryansk region	The main gaseous pollutants of atmospheric air					The density of radioactive contamination, kBq/m²		UBC M ± *m*
	Total	Including:				^{137}Cs	^{90}Sr	
		VOCs	NO_x	SO_2	CO			
	Gross emissions of gaseous pollutants per district area, g/m²							
Environmentally safe areas								
Rognedinsky	13	0	6	0	7	21.7	0.8	21.5 ± 5.5
Suzemsky	28	5	9	1	13	18.6	2.5	46.6 ± 7.5
Mglinsky	31	6	6	2	17	6.6	0.6	23.3 ± 4.7
Kletnyansky	47	27	5	5	10	5.4	0.5	25.2 ± 4.4
Navlinsky	54	12	13	4	25	18.9	0.8	35.5 ± 4.2
Dubrovsky	56	13	17	0.4	26	7.2	0.4	25.0 ± 5.0
Brasovsky	64	10	19	6	29	25.2	0.4	37.1 ± 4.3
Sevsky	68	20	10	24	14	18.9	1.4	35.3 ± 4.5
Komarichsky	99	25	19	9	46	27.1	1	30.6 ± 4.5
Karachevsky	115	29	34	1	51	13.9	0.8	37.7 ± 5.0
Surazhsky	128	35	35	6	52	8.2	0.4	27.8 ± 3.9
Mean	**63.9**	**16.5**	**15.7**	**5.3**	**26.4**	**15.6**	**0.9**	**32.3 ± 3.0* –8.7%**
Chemically polluted territories								
Pogarsky	123	65	22	4	32	29.9	1.1	45.6 ± 6.4
Zhiryatinsky	156	104	16	1	35	5.4	0.8	32.6 ± 6.3
Zhukovsky	195	22	53	40	80	6.6	0.8	28.3 ± 3.1
Trubchevsky	275	88	27	2	158	23.6	0.8	38.0 ± 5.1
Pochepsky	365	223	33	3	106	5.4	0.5	31.9 ± 4.2
Unechsky	559	292	58	32	177	7.2	0.8	31.1 ± 3.0
Vygonichsky	858	749	37	2	70	9.5	0.4	12.7 ± 3.9
Bryansky	959	813	47	13	86	5.7	0.4	32.6 ± 3.8
Town of Seltso	5209	773	2405	97	1934	4.4	0.8	33.8 ± 5.6
Dyatkovsky	8045	339	3760	1139	2807	38.4	1.1	35.7 ± 3.9
City of Bryansk	32190	5217	10886	2617	13470	8.8	5.9	41.6 ± 3.1
Mean	**4448.5**	**789.5**	**1576.7**	**359.1**	**1723.2**	**13.2**	**1.2**	**38.2 ± 3.0* +8.0%**
Radioactively contaminated areas								
Krasnogorsky	15	1	5	0	9	303.4	9.3	51.3 ± 7.2
Gordeevsky	28	2	11	0.2	15	328.6	5	31.2 ± 6.6
Zlynkovsky	38	5	11	4	18	412.4	16.3	26.7 ± 4.4
Novozybkovsky	51	10	0	0	41	460.6	8.4	18.2 ± 4.5
Klimovsky	72	16	8	15	33	139.6	6.4	38.6 ± 7.4
Klintsovsky	169	17	70	2	80	194.4	4.7	18.6 ± 3.1
Mean	62.2	8.5	17.5	3.5	32.7	306.5	8.4	32.5 ± 3.8* –8.1%
Territories of combined radioactive and chemical contamination								
Starodubsky	392	316	24	9	43	45.4	1.4	26.1 ± 3.0
Town of Klintsy	7264	2059	2616	139	2450	195.6	3	39.9 ± 3.3
Town of Novozybkov	7422	1778	2159	406	3079	456.5	9.7	42.4 ± 4.7
Mean	**5026**	**1384.3**	**1599.7**	**184.7**	**1857.3**	**232.5**	**4.7**	**36.9 ± 2.7* +4.3%**

Note: * — the difference (in %) from the all-Russian indicator of primary incidence (2000–2019).

Compared to environmentally safe areas, the RR growth rates were 1.47 (95% CI: 1.01–2.13) for territories of radioactive contamination, 1.45 (95% CI: 1.04–2.03) in the combined contamination areas, and 1.23 (95% CI: 0.96–1.59) in the chemically contaminated territories. The form-wise comparison to the overall UBC incidence rate revealed an increased RR between the territories of radioactive and chemical contamination — 1.19 (95% CI: 0.87–1.63), combined and chemical contamination — 1.18 (95% CI: 0.90–1.55). However, there was no RR increase between the territories of combined and radioactive contamination — 0.99 (95% CI: 0.67–1.46). In all likelihood, these data suggest that accident-related radiation plays a greater role in the formation of highly differentiated forms of UBC than chemical pollution.

There was no increase in the primary incidence of moderate-grade (Table 5) and low-grade (Table 6) forms of UBC in women living in ecologically compromised areas compared with environmentally safe areas: the RR for moderately differentiated

Table 2. Comparative assessment of the primary incidence rates of high-, moderate-, and low-grade forms of UBC among women aged 41–60 living in areas of the Bryansk region with varying environmental conditions, 2000–2019 (per 100,000 population)

Territories under study	Environmentally safe areas (control)	Chemically polluted territories	Radioactively contaminated areas	Territories of combined radioactive and chemical contamination
Forms of UBC	I (*N* = 169)	II (*N* = 662)	III (*N* = 81)	IV (*N* = 118)
All forms	24.3 ± 4.2	27.8 ± 4.1	28.7 ± 5.1	29.4 ± 4.8
Including:				
High-grade	10.6 ± 2.0	13.1 ± 2.0	15.6 ± 3.1	15.4 ± 3.2
Moderate-grade	10.9 ± 2.1	11.7 ± 1.9	10.6 ± 2.7	10.5 ± 2.5
Low-grade	2.7 ± 0.7	3.1 ± 0.6	3.6 ± 1.5	3.5 ± 1.0

Note: the differences between the groups by the areas are insignificant at $p > 0.05$.

forms was 1.06 (95% CI: 0.82–1.34), low-grade forms — 1.03 (95% CI: 0.63–1.69). In addition, we registered no growth of RR for moderate-grade UBC between control territories and territories of chemical radioactive and combined contamination — the values range from 0.97 to 1.07 (Table 5).

The rates of primary incidence of moderately differentiated forms of UBC between the areas of chemical, radioactive and combined contamination vary between 0.64 and 0.98, and there are significant differences (p = 0.019) between the chemically and radioactively contaminated areas:

Table 3. Relative risk of the primary incidence of high-, moderate-, and low-grade forms of UBC among women aged 41–60 living in areas of the Bryansk region with varying environmental conditions, 2000–2019 (per 100,000 population)

Type of area	Population size	Got sick, abs.	Did not get sick, abs.	RR (95% CI)
The total rate of high-, moderate-, and low-grade forms of UBC				
Chemical, radioactive and combined contamination (total)	153394	861	152364	1.16 (0.98–1.36)
Environmentally safe areas	34823	169	34654	
Chemically contaminated areas	119153	662	118491	1.14 (0.97–1.35)
Environmentally safe areas	34823	169	34654	
Radioactively contaminated areas	14127	81	14046	1.18 (0.91–1.54)
Environmentally safe areas	34823	169	34654	
Areas of combined contamination	20114	118	19996	1.21 (0.96–1.53)
Environmentally safe areas	34823	169	34654	
adioactively contaminated areas	14127	81	14046	1.03 (0.82–1.30)
Chemically contaminated areas	119153	662	118491	
Areas of combined contamination	20114	118	19996	1.06 (0.87–1.28)
Chemically contaminated areas	119153	662	118491	
Areas of combined contamination	20114	118	19996	1.02 (0.77–1.36)
Radioactively contaminated areas	14127	81	14046	

Table 4. Relative risk of primary incidence rates of high-grade forms of UBC among women aged 41–60 living in areas of the Bryansk region with varying environmental conditions, 2000–2019

Type of area	Population size	Got sick, abs.	Did not get sick, abs.	RR (95% CI)
Chemical, radioactive and combined contamination (total)	153394	418	152902	1.28 (1.00–1.64)
Environmentally safe areas	34823	74	34749	
Chemically contaminated areas	119153	312	118841	1.23 (0.96–1.59)
Environmentally safe areas	34823	74	34749	
Radioactively contaminated areas	14127	44	14083	1.47 (1.01–2.13)
Environmentally safe areas	34823	74	34749	
Areas of combined contamination	20114	62	20052	1.45 (1.04–2.03)
Environmentally safe areas	34823	74	34749	
Radioactively contaminated areas	14127	44	14083	1.19 (0.87–1.63)
Chemically contaminated areas	119153	312	118841	
Areas of combined contamination	20114	62	20052	1.18 (0.90–1.55)
Chemically contaminated areas	119153	312	118841	
Areas of combined contamination	20114	62	20052	0.99 (0.67–1.46)
Radioactively contaminated areas	14127	44	14083	

Table 5. Relative risk of primary incidence of moderately differentiated forms of UBC among women aged 41–60 living in areas of the Bryansk region with varying environmental conditions, 2000–2019

Type of area	Population size	Got sick, abs.	Did not get sick, abs.	RR (95% CI)
Chemical, radioactive and combined contamination (total)	153394	350	152968	1.06 (0.82–1.34)
Environmentally safe areas	34823	76	34747	
Chemically contaminated areas	119153	278	118875	1.07 (0.83–1.38)
Environmentally safe areas	34823	76	34747	
Radioactively contaminated areas	14127	30	14097	0.97 (0.64–1.48)
Environmentally safe areas	34823	76	34747	
Areas of combined contamination	20114	42	20072	0.96 (0.66–1.39)
Environmentally safe areas	34823	76	34747	
Radioactively contaminated areas	14127	30	14097	0.64 (0.44–0.93)
Chemically contaminated areas	119153	278	118875	
Areas of combined contamination	20114	42	20072	0.89 (0.65–1.24)
Chemically contaminated areas	119153	278	118875	
Areas of combined contamination	20114	42	20072	0.98 (0.62–1.57)
Radioactively contaminated areas	14127	30	14097	

RR 0.64 (95% CI: 0.44–0.93). These data indicate a higher incidence of moderately differentiated forms of UBC in women living in areas of chemical contamination relative to areas of radioactive contamination. In contrast to the primary incidence of moderate-grade forms of UBC, we found an increased relative risk of low-grade forms thereof between control territories, territories of radioactive contamination (RR 1.30 (95% CI: 0.60–2.79)) and territories of combined exposure (RR 1.28 (95% CI: 0.64–2.54)) (Table 6). However, between chemically contaminated areas and control territories the RR was not increased: 0.95 (95% CI: 0.57–1.59) (Table 6).

As Table 6 shows, there is an increased RR of low-grade forms of UBC between territories of radioactive and chemical contamination — 1.36 (95% CI: 0.70–2.65), and areas of combined and chemical contamination — 1.34 (95% CI: 0.75-2.39). There was no such increase registered between territories of combined and radioactive contamination — RR 0.98 (95% CI: 0.44–2.21). The data for low-grade forms of UBC (Table 6) are similar to the results for highly differentiated forms of UBC (Table 5); they suggest that, in all likelihood, accident-related radiation plays a greater role in the formation of low-grade forms of UBC than chemical pollution.

DISCUSSION

There are many risk factors affecting the occurrence of UBC, and it is virtually impossible to make provisions for them [22, 23].

A study [24] that investigated the dependence of the UBC incidence rate on anthropogenic impact found that before the age of 45, its role in the development of endometrial cancer is less significant than after 45.

In [25], it was found that the combined effects of radiation and chemical contamination increase the incidence of low-grade ovarian malignancies compared with areas affected by only one pollution factor. Consequently, the authors of that study concluded that radiation and chemical factors act synergistically. In this study, no such pattern was observed, but we established an increased RR of incidence of high- and, to a greater extent, low-grade forms of UBC between territories of radioactive and chemical contamination, combined and chemical

Table 6. Relative risk of primary incidence rates of low-grade forms of UBC among women aged 41–60 living in areas of the Bryansk region with varying environmental conditions, 2000–2019

Type of area	Population size	Got sick, abs.	Did not get sick, abs.	RR (95% CI)
Chemical, radioactive and combined contamination (total)	153394	86	153289	1.03 (0.63–1.69)
Environmentally safe areas	34823	19	34804	
Chemically contaminated areas	119153	62	119091	0.95 (0.57–1.59)
Environmentally safe areas	34823	19	34804	
Radioactively contaminated areas	14127	10	14117	1.30 (0.60–2.79)
Environmentally safe areas	34823	19	34804	
Areas of combined contamination	20114	14	20100	1.28 (0.64–2.54)
Environmentally safe areas	34823	19	34804	
Radioactively contaminated areas	14127	10	14117	1.36 (0.70–2.65)
Chemically contaminated areas	119153	62	119091	
Areas of combined contamination	20114	14	20100	1.34 (0.75–2.39)
Chemically contaminated areas	119153	62	119091	
Areas of combined contamination	20114	14	20100	0.98 (0.44–2.21)
Radioactively contaminated areas	14127	10	14117	

contamination, although no increased RR was found between territories of combined and radioactive contamination.

A limitation of this study was that it did not take into account the stage of the disease or its immunohistochemical profile.

CONCLUSIONS

1. The incidence of high-, moderate-, and low-grade forms of UBC is 21%, 18%, and 14% higher among women living in areas of combined, radioactive, and chemical contamination compared with control areas; however, there are no significant differences between the groups.

2. The relative risk (RR) of developing a high-grade form of UBC is higher among women residing in ecologically compromised territories (chemically, radioactively contaminated areas and areas with combined pollution factors) compared with those living in environmentally safe (control) territories: RR 1.28 (95% CI: 1.00–1.64); $p = 0.047$).

3. The RR of primary incidence of moderate- and low-grade forms of UBC among women living in ecologically compromised areas is comparable to that of women in control territories, with values ranging from 1.03 to 1.06.

4. Other findings include an increased relative risk (RR) of occurrence of both high- and, to a greater extent, low-grade forms of UBC in areas with high radioactive and chemical contamination — 1.19 (95% CI: 0.87–1.63) and 1.36 (95% CI: 0.70–2.65), respectively; the relative risks for combined and chemical contamination areas were 1.18 (95% CI: 0.90–1.55) and 1.34 (95% CI: 0.75–2.39), respectively; no increase was observed between the territories with combined and radioactive contamination — 0.99 (95% CI: 0.67–1.46) and 0.98 (95% CI: 0.44–2.21).

5. In all likelihood, the data from this study indicate that accident-related radiation contamination plays a more significant role in the development of high-grade — and especially low-grade — forms of UBC than does chemical contamination.

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ASSESSMENT OF THE EFFECTS OF USING DIGITAL DEVICES ON PSYCHOMOTOR FUNCTION INDICATORS IN PRIMARY SCHOOL STUDENTS

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A significant change in the lifestyle of modern children associated with the active use of digital devices in educational and leisure activities can affect their psychomotor development. The study aimed to assess the effect of using smartphones and computers on psychomotor function indicators in primary school students. A questionnaire survey of 333 parents of the 1–4-year students attending Zemskaya Gimnasia in Balashikha on issues of children's life was conducted. The students' screen time when using a computer and smartphone throughout the day and week was estimated. To assess the students' psychomotor functions, the Little House test and motometric test conducted by teachers were used. Assessment of the effect of computer use on psychomotor development indicators revealed a correlation. Thus, when using a computer, a deterioration in fine motor skills was noted; the correlation coefficient (r) for the parameters of visual-motor coordination and the duration of computer use per day was 0.320 (p = 0.002). The correlation coefficient for the duration of computer use and the primary school students' final psychomotor development score was 0.235 (p = 0.028). The same result was obtained for the integrated assessment of fine motor skill development and its association with the duration of computer use per day: r = 0.253 (p = 0.025). However, there was no correlation between screen time when using a smartphone and psychomotor functions. The findings can be used in the development and justification of preventive technologies to prevent the negative impact of digital devices on the development of psychomotor functions in children, especially at the initial stage of systematic education.

Keywords: fine motor skills, visual-motor coordination, digital device, smartphone, screen time

Funding: the study was carried out under the State Task "Systemic preventive health-supporting technologies for attendees of educational organizations (2022–2024)".

Author contribution: Khramtsov PI — theoretical basis and organization of the research, final version of the manuscript; Kurgansky AM — statistical data processing, manuscript writing; Berezina NO — data acquisition, preparing a database; Antonova EV — organization of the research, final version of the manuscript; Krayeva AYu — literature review; all authors — discussion and work on the manuscript.

Compliance with ethical standards: the study was approved by the Ethics Committee of the National Medical Research Center for Children's Health (protocol No. 3 dated 25 March 2021).

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Received: 01.08.2025 **Accepted:** 19.11.2025 **Published online:** 23.12.2025

DOI: 10.24075/rbh.2025.145

ОЦЕНКА ВЛИЯНИЯ ИСПОЛЬЗОВАНИЯ ЦИФРОВЫХ УСТРОЙСТВ НА ПОКАЗАТЕЛИ ПСИХОМОТОРНЫХ ФУНКЦИЙ У МЛАДШИХ ШКОЛЬНИКОВ

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Существенное изменение образа жизни современных детей, связанное с активным использованием цифровых устройств в учебной и досуговой деятельности, может влиять на их психомоторное развитие. Целью исследования было оценить влияние использования смартфонов и компьютеров на показатели психомоторных функций у младших школьников. Проведено анкетирование 333 родителей обучающихся 1–4-х классов МАОУ «Земская гимназия» г. Балашиха по вопросам жизнедеятельности детей. Было оценено экранное время школьников при использовании компьютера и смартфона в течение дня и недели. Для оценки психомоторных функций обучающихся использовали тест «Домик» и мотометрический тест, который проводили педагоги. Оценка влияния использования компьютера на показатели психомоторного развития выявила корреляционную зависимость: так, при использовании компьютера отмечено ухудшение состояния мелкой моторики; коэффициент корреляции (r) между параметрами зрительно-моторной координации и длительностью использования компьютера в день составил 0,320 (p = 0,002). Коэффициент корреляции между длительностью использования компьютера и итоговой оценкой уровня психомоторного развития у младших школьников составил 0,235 (p = 0,028). Аналогичный результат был получен для показателя интегральной оценки уровня развития мелкой моторики и его связи с длительностью использования компьютера в день: r = 0,253 (p = 0,025). При этом корреляционная связь между продолжительностью экранного времени при использовании смартфона и психомоторными функциями отсутствует. Полученные результаты могут быть использованы при разработке и обосновании профилактических технологий для предупреждения отрицательного влияния цифровых устройств на развитие психомоторных функций у детей, особенно на начальном этапе систематического обучения.

Ключевые слова: мелкая моторика, зрительно-моторная координация, цифровое устройство, смартфон, экранное время

Финансирование: работа выполнена в рамках Госзадания «Системные профилактические технологии формирования здоровья обучающихся в образовательных организациях (2022–2024)».

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Соблюдение этических стандартов: исследование одобрено этическим комитетом ФГАУ «НМИЦ здоровья детей» Минздрава России (протокол № 3 от 25 марта 2021 г.).

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Статья получена: 01.08.2025 **Статья принята к печати:** 19.11.2025 **Опубликована онлайн:** 23.12.2025

DOI: 10.24075/rbh.2025.145

The study of psychomotor function development in the context of the widespread use of digital devices in everyday life is an urgent problem of health preservation in children. There are many studies focused on the digital media [1, 2], while the studies of the effects of gadgets on fine motor skills are much fewer.

The scientific research results show that the level of psychomotor function development has an effect on the reading skills [3], handwriting [4, 5], gross motor skill formation [6], and even development of imagination [7].

This issue is extensively studied by both domestic [8–10] and foreign scientists [11–13]. A number of authors point to the importance of the problem of negative effects of gadgets on fine motor skills in preschoolers and primary school students [14–17].

Some studies are focused on specific games for fine motor skill development, which can be used to prevent the effects of long screen time exposure [18].

When assessing the impact of various digital devices on psychomotor function indicators, it is worth noting a considerable number of studies focused on assessing the impact of tablets on the development of fine motor skills, and the effect is assessed as both negative [19, 20] and positive [13, 21–23]. In a number of studies, the effects of developmental toys were assessed relative to that of the touch screen [24].

However, despite numerous studies of the effects of digital devices on students' bodies, differential assessment of the impact of smartphones and computers on psychomotor function indicators in primary school students remains poorly understood.

The study aimed to assess the effect of using smartphones and computers on psychomotor function indicators in primary school students.

METHODS

We conducted a questionnaire survey of 333 parents of the 1–4-year primary school students attending Zemskaya Gimnasia in Balashikha using a specially developed questionnaire. The duration and frequency of using the computer and smartphone per day and week were assessed.

To assess the level of psychomotor function development in primary school students, a cross-sectional study was conducted that involved the Little House test and motometric test, allowing one to assess the development of arbitrary attention, spatial perception, visual-motor coordination. These indicators were considered when determining the final score of psychomotor development. The integrated assessment of fine motor skill development involved assessment of the Little House test and motometric test results [25].

The correlation analysis was performed using the Pearson's correlation coefficient, and mean values were compared using Student's t-test for unrelated samples for the screen time and psychomotor development indicators. The results were considered significant at $p < 0.05$. MS Excel (Microsoft; USA), SPSS v. 23 (IBM; USA), online risk calculator (https://medstatistic.ru/calculators/calcrisk.html) were used for statistical analysis.

RESULTS

The duration and frequency of using various digital devices by primary school students were assessed per day and week (Tables 1, 2).

The results of the study show that 64.4% of primary school students use the computer less than an hour a day; 61.4% of children are less than an hour a day on their smartphones.

According to [26], the time of using electronic learning tools, including for leisure activities, recommended for 1–2-year students is 80 min, and that recommended for 3–4-year students is 90 min. Thus, inappropriate duration (two hours or more) of using the computer is observed in 32.4% of children, and that of using the smartphone is reported for 66.9 of primary school students.

When analyzing the data in Table 2, it can be concluded that 34.3% of children prefer to use the computer 1–2 times a week, 25.5% of children — daily, 24,5% of children — on weekends only. At the same time, 53.2% of primary school students prefer to use the smartphone daily.

The results of psychomotor function development assessment in primary school students are provided in Table 3.

Statistical analysis of psychomotor function indicators has made it possible to determine that high level of the arbitrary attention function development is found in 75.5% of children, spatial perception — in 27.9%, visual-motor coordination — in 23.4%. Based on final assessment, high level of psychomotor function development has been determined only in 11.4% of children.

Medium levels of arbitrary attention development are reported in 10.0% of students, spatial perception — in 59.7%, visual-motor coordination — in 72.8%. Based on final assessment,

Table 1. Duration of computer and smartphone use per day in primary school students

Duration of use	Computer, $n = 101$			Smartphone, $n = 171$		
	Abs.	%	95% CI	Abs.	%	95% CI
Less than 30 min	32	31.7	22.6–40.8	52	30.4	23.5–37.3
Between 30 min and 1h	33	32.7	23.5–41.8	53	31	24.1–37.9
Between 1 h and 2 h	17	16.8	9.5–24.1	29	17	11.3–22.6
Between 2 h and 3 h	6	5.9	1.3–10.6	19	11.1	6.4–15.8
More than 3 h	13	12.9	6.3–19.4	18	10.5	5.9–15.1

Table 2. Frequency of computer and smartphone use per week in primary school students

Frequency of use	Computer, $n = 102$			Smartphone, $n = 205$		
	Abs.	%	95% CI	Abs.	%	95% CI
Only on weekends	25	24.5	16.2–32.9	19	9.3	5.3–13.2
1–2 times a week	35	34.3	25.1–43.5	15	7.3	3.8–10.9
3–4 times a week	9	8.8	3.3–14.3	34	16.6	11.5–21.7
5–6 times a week	7	6.9	2.0–11.8	28	13.7	9.0–18.4
Daily	26	25.5	17.0–33.9	109	53.2	46.3–60.0

Table 3. Psychomotor function development levels in primary school students (n = 290)

Development level	Arbitrary attention			Spatial perception			Visual-motor coordination			Final score of psychomotor development		
	Abs.	%	95% CI	Abs.	%	95% CI	Abs.	%	95% CI	Abs.	%	95% CI
High	279	75.5	94.0–98.4	81	27.9	22.8–33.1	68	23.4	18.6–28.3	33	11.4	7.7–15.0
Medium	29	10	6.5–13.5	173	59.7	53.7–65.0	211	72.8	67.6–77.9	179	61.7	56.1–67.3
Low	42	14.5	10.4–15.0	36	12.4	8.6-16.2	11	3.8	1.6–6.0	78	26.9	21.8–32.0

the medium level of psychomotor function development is reported for 61.7% of children.

The data obtained suggest that high levels of arbitrary attention development, medium levels of spatial perception and visual-motor coordination development predominate in primary school students.

Low level of the arbitrary attention development is observed in 14.5%, spatial perception — in 12.4%, visual-motor coordination — in 3.8% of children.

Based on final assessment, low level of psychomotor development is reported for 26.9%.

The results of the analysis of the correlation of psychomotor function indicators with the frequency and duration of using digital devices by children are provided in Table 4.

According to Table 4, weekly duration of the digital device use has no effect on psychomotor development. Table 4 shows that the daily computer use leads to a decrease in a number of indicators that is observed when using the smartphone.

When using the computer, deterioration in fine motor skills was noted. The correlation coefficient (r) for the parameters of visual-motor coordination and duration of computer use per day was 0.320 (p = 0.002).

The risk analysis has shown that using a computer for more than an hour a day is a risk factor for underdeveloped visual-motor coordination functions: RR = 1.38 (1.13–1.69).

When assessing the impact of computer use on psychomotor development indicators, a correlation was also found between the duration of computer use is primary school students and the final score of their psychomotor development (r = 0.235; p = 0.028). The same result was obtained for the integrated assessment of fine motor skill development and its association with the duration of computer use per day: r = 0.253 (p = 0.025). When using the computer for more than an hour a day, the risk of fine motor skill underdevelopment based on the integrated assessment was as follows: RR = 1.40 (1.12–1.75).

When using the smartphone, no correlations between screen time and psychomotor function indicators were found.

DISCUSSION

In modern digital devices, there are two main technical methods of entering information: using buttons or touch panels — gestures (swipe).

When using physical (mechanical) keyboard buttons, a certain amount of pressure is required to press the key until the corresponding click occurs (between 0.25 and 1.5 H) [27], i.e. only the suprathreshold effort is required. The tactile feedback is reduced to a minimum — whether there is a press or not. When using a keyboard, for example for games, only the speed of sensorimotor reaction is important without taking into account its quality.

When using gestures typical for smartphone use, the movements, on the contrary, are more highly coordinated, requiring greater balance and flexibility of nervous processes. Kinesthetic feedback plays a major role in this case. Objects on the touch screen are smaller than keyboard keys, requiring more precise force and more complex movements.

Table 4. Relationship between psychomotor function indicators, frequency and duration of digital device use in primary school students

Psychomotor function indicators		Frequency of computer use per week	Frequency of smartphone use per week	Duration of computer use per day	Duration of smartphone use per day
Attention	r	0.109	0.116	0.15	0.143
	p	0.306	0.112	0.163	0.07
	n	90	190	88	162
Spatial perception	r	0.037	–0.017	–0.025	–0.014
	p	0.727	0.811	0.815	0.855
	n	90	190	88	162
Visual-motor coordination	r	0.076	0.037	0.320**	0.153
	p	0.474	0.613	0.002	0.052
	n	90	190	88	162
Final score of psychomotor development	r	0.156	0.013	0.235*	0.065
	p	0.141	0.855	0.028	0.413
	n	90	190	88	162
Fine motor skills (motometric test)	r	–0.043	0.047	0.032	0.006
	p	0.7	0.553	0.777	0.941
	n	83	165	82	146
Integrated assessment of fine motor skill	r	0.033	0.055	0.253*	0.152
	p	0.773	0.486	0.025	0.071
	n	79	161	79	142

Note: * — $p < 0.05$; ** — $p < 0.001$.

It should be noted that similar arguments are presented in the paper [28]. According to the author, tactile sensation forms a holistic polymodal perception of an object, which is impossible when using digital devices, when only a swipe or a button press is required.

It is important to note that there are studies that compare keyboard writing with handwriting [29] and assess the impact of various touch screens on fine motor skill development indicators. The results of these studies are contradictory [30, 31]. No comparative studies of keyboard writing and touch screen use have been found.

Keyboard writing and touch screen use are two fundamentally different sensorimotor tasks.

When typing using the keyboard, finger movements are discrete and precise. Parameters such as rhythm and automation of motor acts associated with motor memory come to the fore.

When using a touch screen, gestures are more variable and have more amplitude. Touching, swiping, zooming are present, great importance is given to visual-spatial processing, and the processing of tactile information. The role of positive emotional reinforcement is great.

Thus, the use of physical buttons has a positive effect on work productivity and the development of tempo and accuracy, while virtual buttons and gestures have a positive effect on the development of tactile and visual-motor functions of fine motor skills, which is correlated to a greater extent with the performance indicators embedded in the Little House test. Furthermore, as the study has shown, excessive stimulation of functions related to tempo and accuracy during keyboard writing leads to a significant disruption of tactile and visual-motor interactions more typical for the use of touch screens.

Thus, the use of touch screens with tactile gestures by children is physiologically more justified than using a keyboard, since there is no disruption to the development of fine motor skill functions.

However, it is important to note that keyboard writing must be taught to develop the skill of productive work, which depends on the speed and accuracy of task completion.

CONCLUSIONS

Assessment of the impact of computer use on psychomotor development indicators revealed a correlation. When using a computer, a deterioration in fine motor skills was noted, the correlation coefficient (r) for the visual-motor coordination parameters and duration of computer use per day was 0.320 (p = 0.002). The correlation coefficient for the duration of computer use by primary school students and the final score of their psychomotor development was 0.235 (p = 0.028). The same result was obtained for the integrated assessment of fine motor skill development and its association with the duration of computer use per day (r = 0.253; p = 0.025).

Using touch screen devices does not negatively influence fine motor skills development based on the Little House test results.

The findings can be used in the development and substantiation of preventive technologies to prevent negative effects of digital devices on the development of fine motor skills in primary school children, especially in schoolchildren with the decreased psychomotor function indicators.

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HYGIENIC ASSESSMENT OF COFFEE AND CAFFEINATED BEVERAGE CONSUMPTION AND THE IMPACT OF THOSE ON THE HEALTH OF YOUNG ADULTS

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Currently, there is an increase in the consumption of caffeinated beverages, including coffee, in all age groups, including adolescents and young adults. The health risks associated with caffeine consumption are especially high in the youth, which results from the features of their physiological development and behavioral factors. For many age groups, including children, adolescents, and young adults, safe daily caffeine intake levels have not been established. The study aimed to perform hygienic assessment of coffee and caffeinated beverage consumption by medical students, as well as to determine possible health risks. A questionnaire survey of students of the medical and pediatric faculties (n = 300) was conducted using the standardized quastionnaire. Statistical data processing was performed using descriptive statistics, Student's t-test, Pearson's correlation coefficient. The findings highlight the heterogeneity of caffeine consumption patterns among students. Along with those who do not experience any noticeable effects from coffee, there is a significant group that experiences both positive (energy boost, calmness) and negative (tachycardia, sleep problems) consequences. The study found that frequent consumption of caffeinated beverages has a negative impact on the cardiovascular system and sleep. The regular consumption of those causes anxiety and leads to tolerance. The findings emphasize the relevance of the problem uncontrolled and early consumption of caffeine among young people. It is recommended to develop and implement the measures to inform the youth about safe levels of caffeine consumption.

Keywords: hygienic assessment, coffee, caffeine, students, health

Author contribution: all authors contributed to preparation of the paper equally.

Compliance with ethical standards: the study was compliant with biomedical ethics requirements. The written informed consent was obtained from each participant.

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Received: 12.11.2025 **Accepted:** 30.11.2025 **Published online:** 24.12.2025

DOI: 10.24075/rbh.2025.146

ГИГИЕНИЧЕСКАЯ ОЦЕНКА ПОТРЕБЛЕНИЯ КОФЕ И КОФЕИНСОДЕРЖАЩИХ НАПИТКОВ И ИХ ВЛИЯНИЯ НА СОСТОЯНИЕ ЗДОРОВЬЯ МОЛОДЕЖИ

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В настоящее время имеет место рост уровня потребления кофеинсодержащих напитков, в том числе кофе, во всех возрастных группах, включая подростков и молодежь. Риски для здоровья при потреблении кофеина особенно высоки среди молодежи, что обусловлено особенностями физиологического развития и поведенческими факторами. Для многих возрастных групп, в том числе детей, подростков и молодежи, безопасные уровни суточной нормы кофеина не определены. Целью исследования было выполнить гигиеническую оценку потребления кофе и кофеинсодержащих напитков учащимися медицинского университета и выявить возможные риски здоровью. Проведено анкетирование студентов лечебного и педиатрического факультетов (n = 300) с использованием стандартизованной анкеты. Статистическую обработку данных выполняли с использованием методов описательной статистики, t-критерия Стьюдента, корреляционного анализа Пирсона. Полученные данные подчеркивают неоднородность особенностей потребления кофеина студентами. Наряду с теми, кто не испытывает выраженных эффектов от кофе, существует значительная группа, у которой наблюдаются как положительные (прилив энергии, спокойствие), так и отрицательные (тахикардия, проблемы со сном) последствия. Проведенное исследование свидетельствует об отрицательном влиянии частого употребления кофеинсодержащих напитков на сердечно-сосудистую систему и сон. Их регулярное потребление вызывает тревожность, ведет к толерантности. Полученные данные подчеркивают актуальность проблемы неконтролируемого и раннего потребления кофеина в молодежной среде. Рекомендуется разработать и внедрить меры по информированию молодежи о безопасных уровнях употребления кофеина.

Ключевые слова: гигиеническая оценка, кофе, кофеин, студенты, здоровье

Вклад авторов: все авторы внесли равный вклад в подготовку публикации.

Соблюдение этических стандартов: проведенное исследование соответствовало требованиям биомедицинской этики. От каждого участника получено письменное добровольное информированное согласие.

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Статья получена: 12.11.2025 **Статья принята к печати:** 30.11.2025 **Опубликована онлайн:** 24.12.2025

DOI: 10.24075/rbh.2025.146

Coffee is one of the most common drinks, regularly consumed by half of the world's population. Its popularity is due to a number of factors, including pharmacological effects, gastronomic qualities and social aspects. Coffee lifts one's mood and improves memory, increasing mental and physical activity. On the other hand, high doses of caffeine may cause heart rhythm disturbances in adolescents with heart diseases. Caffeine can increase feelings of anxiety and worry, which in turn can lead to increased blood pressure. Abruptly stopping regular caffeine consumption can cause withdrawal symptoms, which

include headache, fatigue, irritability, and changes in blood pressure [1].

In recent decades, the coffee chemical composition and its impact on human health have attracted increasing attention from scientists and researchers. Coffee contains over a thousand compounds, from volatile low-molecular to high-molecular ones. Its composition depends on many factors — variety, country of origin, soil composition, growing conditions, roasting technology, etc. The widespread consumption of coffee has prompted clinicians to actively study the effects of this beverage on health [2].

Caffeine (1,3,7-trimethylxanthine) representing white, silky, needle-shaped crystals with a slightly bitter taste belongs to purine alkaloids. Being a the central nervous system stimulant, it regulates and enhances excitation processes in the cerebral cortex. As a result, mental and physical performance increases, reaction time is shortened, vigor appears, and drowsiness temporarily disappears or decreases [3, 4].

Instant coffee usually contains less caffeine than whole bean coffee, but the exact amount depends on the type and preparation method. This is due to the production technology: instant coffee is made from beans that undergo multi-stage processing, during which most of the natural caffeine is destroyed.

Caffeine is a psychostimulant and diuretic found in the beans of the coffee plant and is an ingredient in coffee, cola drinks, chocolate, a number of patented "energy drinks" and weight-loss products. It is the most commonly used psychoactive substance in the world. A number of clinical conditions associated with its use have been described, although given its widespread use, severe disorders are relatively rare. Caffeine intoxication is associated with the consumption of relatively high doses (i.e. more than 1 g per day). Caffeine withdrawal is a common phenomenon reported in people who have consumed caffeine over a long period of time or in large quantities. Anxiety disorders may develop as a result of caffeine consumption, often occurring after intoxication or heavy consumption [5, 6].

If abused and doses exceeded (the values are individual for each person), signs of intoxication may be observed: increased anxiety, insomnia, tachycardia, arrhythmia, increased blood pressure, nausea. With chronic use of caffeine-containing substances, addiction occurs, which is associated with the formation of new adenosine receptors in brain cells, and the effect of caffeine gradually decreases [6, 7].

In addition to caffeine, energy drinks contain taurine, theobromine, and theophylline (cocoa alkaloids), which block adenosine and enhance the effects of caffeine. Even common carbohydrates, such as glucose, fructose, and sucrose, have a stimulating effect on the brain and prevent sleep. This effect complements and enhances the stimulating effect of caffeine.

According to Rospotrebnadzor, mixing coffee with energy drinks can lead to unpredictable consequences, such as mental agitation, nervousness, or, conversely, apathy and depression [8].

Despite recommendations to start drinking coffee no earlier than 16 years old, young people start drinking coffee at the age of 10–12 years old, when organs and systems are still developingAt this age, even small amounts of caffeine can cause more severe effects: anxiety, irritability, decreased ability to concentrate, sleep problems, increased heart rate and blood pressure. Caffeine is especially harmful for children with increased excitability or hidden cardiac problems. By the age of 18–20 years, such young people more often complain of headache, including migraine-type one.

According to the pediatric community guidelines, the maximum daily dose of caffeine is 2.5–3 mg per 1 kg of body weight. That is, a teenager weighing 40 kg can consume no more than 100–120 mg of caffeine per day in beverages, which is roughly equivalent to one cup of weak coffee or a cup of tea. For adults, the recommended daily intake is 400 mg of caffeine, which is approximately 3–4 cups per day [9].

According to the director of the Federal Research Center of Nutrition and Biotechnology D.B. Nikityuk, reducing coffee consumption is recommended for people with gastrointestinal and cardiovascular diseases. According to nutritionists, cold coffee is especially harmful, as it causes vascular spasms and slows down digestion [10, 11].

According to other authors, up to 80% of students consume caffeinated beverages, including coffee, daily [12–14]. Medical students also tend to drink more coffee especially when preparing for exams, doing a lot of homework, or under heavy academic pressure, which reduces their sleep time and quality. Coffee only provides a temporary boost of energy, and drinking it during a session can be harmful, as the caffeine contained in the drink contributes to the nervous system exhaustion and reduces the body's functional reserves.

The aim of the study was to provide a hygienic assessment of the consumption of coffee and caffeinated beverages by medical university students to examine their impact on health and to identify possible risks.

METHODS

To achieve the intended goal, the following research stages were identified and implemented:

– a sociological study in the form of an anonymous survey of a student audience aimed at studying the prevalence and characteristics of coffee and caffeinated beverage consumption in this target group;

– assessment of the impact of coffee consumption on physiological state and cognitive functions of the body, including an analysis of potential negative health consequences.

A questionnaire survey of students of medical and pediatric faculties (n = 300) was conducted using the standardized questionnaire containing questions about the frequency, volume and type of beverage consumed. The respondents' average age was 20 ± 0.6 years.

Statistical data processing was performed using descriptive statistics, Student's t-test, Pearson's correlation coefficient to assess the strength and direction of the relationship between the variables considered. The qualitative data were compared using the chi-squared test (X^2). The differences were considered significant at $p < 0.05$.

RESULTS

The sample consisted of 28% male students and 71% female students. It was found that half of those surveyed regularly consume energy drinks, including coffee (41%). According to the data obtained, 70% of students prefer instant coffee, and 30% prefer bean coffee.

A significant proportion of respondents (40%) began drinking coffee at an early age (13 years), usually limiting themselves to one cup a day. In our study, 47% of students drink 2–3 cups daily, and 20% of students drink more than three cups of coffee daily, which could potentially affect their health.

The frequency of coffee consumption during the day has been determined: The majority of students (48%) drink coffee in the morning, 27% in the afternoon, 20% in the evening, and 5% at night. This regime may be associated with the need

to maintain working capacity during periods of intense academic workload.

The study shows that 16% of students experience negative effects from coffee consumption, including increased heart rate and sleep problems. Thus, in this group of respondents, 30% report occasional tachycardia, which is consistent with the known cardiac stimulating effect of caffeine mediated by adenosine receptor blockade. Our findings indicate a positive correlation between coffee consumption and heart rate (HR, r = 0.68). Increased heart rate indicates possible risks and the need to pay close attention to the dosage and timing of the caffeinated beverage consumption.

The impact on sleep appears to be minor for 81% of respondents, but 17% report trouble falling asleep, which is a classic side effect of caffeine, especially when consumed in the evening. A significant correlation was found between drinking coffee at night and difficulty falling asleep (r = 0.58). The energizing effect expected by many caffeine consumers does not occur in 65% of students. For the rest, the duration of stimulation varies: in 17% it lasts 2–3 hours, and in 12% it lasts only an hour. Such variability may be due to individual characteristics of caffeine metabolism, genetic predisposition, and tolerance.

A small percentage reported dry mouth (13.4%) and headache (3%), suggesting that these side effects are rare. However, it is important to consider that self-reports may not show the real picture due to the symptom perception subjective nature.

When studying the effects of caffeine on cognitive function, taking into account gender differences, it was found that girls require a higher dose of caffeine than boys to achieve a similar level of performance. This difference may be due to a number of factors. First, differences in caffeine metabolism between males and females may affect the rate at which it is absorbed and eliminated from the body. Second, hormone levels, such as estrogen levels, can influence sensitivity to caffeine. Third, differences in body weight and body fat percentage may also matter for how caffeine is distributed in the body. The results demonstrate the importance of carefully monitoring one's own response to caffeine and adjusting the dosage according to your individual needs and characteristics.

Many students (54%) do not associate the caffeinated beverage consumption with specific situations, which may indicate the spontaneous nature of consumption and the absence of a pronounced dependence. The remaining 46%, on the contrary, indicate situational conditioning, which is consistent with the data from studies demonstrating the use of caffeine as a means of enhancing cognitive activity during periods of intense mental load, such as during exams [13, 15, 16].

The correlation between coffee consumption and work productivity seems to be more complex and nonlinear. While moderate coffee consumption may help improve attention and concentration, excessive consumption may lead to nervousness and decreased performance, as has been shown, in particular, in papers by other authors [17, 18].

This study showed a high level of awareness among medical students about the potential harm of caffeine (81%), but this awareness does not always translate into changes in consumer behavior.

DISCUSSION

The findings highlight the heterogeneity of caffeine consumption patterns among students. Along with those who do not experience any pronounced effects of coffee, there is a significant group in which both positive (energy boost, calmness) and negative (tachycardia, sleep problems) consequences occur. The data obtained are consistent with the results of other authors who studied the characteristics of coffee consumption by medical students [2, 4, 9, 17]. These studies also noted a significant number of respondents reporting negative effects associated with caffeine consumption, despite a conscious desire to improve cognitive function. This indicates the importance of taking into account individual characteristics of the body (genetic factors, age, gender, body weight, fact of having chronic diseases, etc.) and the dosage of caffeine when formulating guidelines on coffee consumption, especially in the student environment, where the access to energy drinks and coffee is relatively free.

The reported positive correlation between coffee consumption and heart rate is consistent with the results of studies by other authors [1, 2, 9]. The heart rate increases proportionally with caffeine consumption due to stimulation of the sympathetic nervous system.

The study revealed mixed effects of coffee on the cardiovascular and nervous systems. Further research is needed to understand individual differences in response to caffeine.

It should be noted that traditionally, coffee consumption is often considered in the context of potential cardiometabolic risks, especially in young adults and in the student population. However, a simplistic view of coffee as an exclusively negative factor overlooks the multifaceted nature of its effects on the body and the results of current research. Recent scientific papers demonstrate that regular coffee consumption is associated not only with potential risks, but also with a number of positive effects. The effect of coffee on reducing abdominal obesity, hyperglycemia, and lipogenesis has been shown. It is believed that caffeine and other bioactive compounds found in coffee may stimulate lipolysis and thermogenesis, promoting fat loss. Some research shows that coffee consumption is associated with increased insulin sensitivity and reduced hyperglycemia [4].

Thus, a comprehensive analysis of the impact of coffee consumption on student health requires consideration of not only potential risks, but also the benefits related to weight control, glycemia, and lipid metabolism that are documented in the literature.

The observed significant gap in preferences between instant and bean coffee deserves the closest attention and points to a complex interaction of material, pragmatic and, possibly, cultural aspects. The significant predominance of instant coffee can be explained by several reasons. Most likely, the choice of instant coffee is due to its availability and speed of preparation, which corresponds to the fast pace of life typical of the student environment. Availability plays an important role: instant coffee is ubiquitous in dormitories, student cafeterias and cafes. In turn, the preference for grain coffee by 30% of students may reflect a desire for higher quality and natural taste. This choice is made by students who have an increased interest in the culture of coffee consumption. It is worth noting that whole-grain coffee, as a rule, wins in terms of its taste and content of nutrients, which is consistent with the data of other authors [6] and allows for a deeper understanding of the impact of coffee and caffeinated beverages on the health of young adults.

The need to maintain concentration while studying is certainly an important factor influencing caffeine consumption, which is confirmed by a number of other authors, such as A. Mulica, who report on the effect of caffeine on students' short-term memory [19].

The impact of caffeine on mental performance has been the subject of numerous studies, the results of which are often contradictory. Many studies show that moderate caffeine consumption can improve short-term memory, reaction time, and attention, while some people may experience adverse

effects (anxiety, insomnia, nervousness) that can negatively impact cognitive functions [2, 5].

Despite widespread awareness of its potential harm, caffeine consumption among students remains high. This may be due to several factors: the need for increased concentration while studying, the desire to cope with fatigue and the pressure of the academic process, social habits and rituals associated with coffee consumption.

It's also important to remember that knowledge about the dangers of caffeine alone doesn't always lead to behavioral changes. Personal belief, motivation, and access to alternative ways to improve performance and manage stress play an important role [2, 5]. Therefore, information campaigns and educational programs should be aimed not only at raising awareness, but also at developing a conscious attitude towards caffeine consumption and developing self-regulation skills.

In addition, other aspects of students' lives should also be taken into account. Fatigue caused not only by academic workload, but also by social activity and part-time jobs, can push one to consume caffeinated beverages as a way to cope with these "challenges."

Social habits and rituals also play a role. Going to a cafe together, discussing academic issues over a cup of coffee, or even just starting the day with coffee — all of this forms stable habits that may be associated not only with the physiological need for caffeine, but also with the need for socialization and a sense of stability.

To better understand the phenomenon of caffeine consumption by students, further study of these relationships, analysis of motivation, and the development of educational programs aimed at developing a conscious and responsible attitude towards the caffeinated beverage consumption are necessary.

Further research should be aimed at understanding the motives and factors that determine caffeine consumption, such as the need for increased concentration during learning, the desire to cope with fatigue and the pressure of the academic process, as well as developing effective prevention strategies and promoting a healthy lifestyle among students.

CONCLUSIONS

The widespread consumption of coffee and caffeinated beverages among young people requires increased attention from public health experts. It is recommended that measures be developed and implemented to inform young people about safe levels of caffeine consumption. The findings highlight the relevance of the problem of uncontrolled and early caffeine consumption by the youth. Exceeding the recommended doses of caffeine can lead to anxiety, irritability, increased heart rate, and other unwanted effects. Of particular concern is the popularity of energy drinks, which contain high doses of sugar and other stimulants that are potentially dangerous to health in addition to caffeine. It is important to keep in mind that individual sensitivity to caffeine can vary, and even moderate doses can cause negative reactions in some people. Further research is needed to more thoroughly assess the impact of caffeine on various aspects of youth health, including cognitive function, mental health, and reproductive health.

As a preventative measure, it is proposed to introduce information campaigns in educational institutions aimed at raising awareness about the risks associated with excessive caffeine consumption among young adults. It is also reasonable to collaborate with caffeinated beverage manufacturers to develop healthier alternatives with reduced caffeine and sugar content.

We believe it is necessary to teach the younger generation healthy lifestyle strategies, including adequate sleep, regular physical activity, and a balanced, healthy diet. This will help reduce the need for stimulants, such as caffeine.

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HYGIENIC ASSESSMENT OF ATMOSPHERIC AIR IN KUZBASS INDUSTRIAL CENTERS AS PART OF THE "CLEAN AIR" FEDERAL PROJECT

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Novokuznetsk and Kemerovo, major industrial centers in Kuzbass, participate in the "Clean Air" federal project. Since 2018 and 2023, respectively, they have been implementing Comprehensive Action Plans devised to decrease contaminating emissions and thus improve the quality of the air and the quality of life of the population. The Plans are part of the "Ecology" national project. This study aimed to hygienically assess the quality of atmospheric air as part of the implementation of the "Clean Air" federal project, which involves improving the air monitoring system in the industrial centers of Kuzbass. Hazard identification and assessment of exposure levels were performed using the methodology provided in MR (methodological recommendations) 2.1.6.0157-19. In Novokuznetsk, air pollutant emissions decreased by 18.1%, while in Kemerovo they increased by 12.4%. The atmospheric pollution index was rated as "extremely high" and "high", respectively. As part of the study, we evaluated the spatial relationship between stationary and route air quality monitoring stations, identified emission impact zones for major industrial complexes, assessed the rationality of observation point locations, and implemented the necessary adjustments. Improving air quality monitoring will make it possible to obtain adequate and timely information on air quality and develop measures to improve the living environment and public health

Keywords: clean air, stations and monitoring program, emission dynamics, air quality monitoring, priority pollutants, air pollution index

Author contribution: Bachina AV — study concept and design, analysis and interpretation of the results; Koskina EV — study concept and design, manuscript writing and editing; Glebova LA — data acquisition, analysis and interpretation of the results.

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Received: 03.12.2025 **Accepted:** 09.12.2025 **Published online:** 29.12.2025

DOI: 10.24075/rbh.2025.147

ГИГИЕНИЧЕСКАЯ ОЦЕНКА РЕАЛИЗАЦИИ ФЕДЕРАЛЬНОГО ПРОЕКТА «ЧИСТЫЙ ВОЗДУХ» В ПРОМЫШЛЕННЫХ ЦЕНТРАХ КУЗБАССА

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Крупные промышленные центры Кузбасса — города Новокузнецк и Кемерово являются участниками федерального проекта «Чистый воздух». С 2018 и 2023 гг. соответственно в них реализуют Комплексные планы мероприятий по снижению выбросов загрязняющих веществ, направленные на повышение качества воздушной среды и жизни населения, предусмотренные национальным проектом «Экология». Целью исследования было выполнить гигиеническую оценку атмосферного воздуха в рамках реализации мероприятий федерального проекта «Чистый воздух» для совершенствования системы мониторинга воздушной среды промышленных центров Кузбасса. Проведены оценка динамики выбросов загрязняющих веществ, анализ результатов измерений атмосферного воздуха на 16 стационарных постах. Идентификацию опасности и оценку уровней формируемой экспозиции выполняли с использованием методических подходов МР 2.1.6.0157-19. В г. Новокузнецке объем выбросов загрязняющих веществ в атмосферный воздух снизился на 18,1%, а в г. Кемерово — увеличился на 12,4%. Индекс загрязнения атмосферы оценен как «чрезвычайно высокий» и «высокий» соответственно. Оценено взаимное расположение стационарных и маршрутных постов наблюдения качества атмосферного воздуха, определены зоны влияния выбросов ведущих предприятий, дана оценка рациональности расположения точек наблюдения, внесены необходимые коррективы. Совершенствование мониторинга воздушной среды позволит получать адекватную и своевременную информацию о качестве атмосферного воздуха и разрабатывать мероприятия по улучшению среды обитания и здоровья населения.

Ключевые слова: чистый воздух, посты и программа наблюдения, динамика выбросов, мониторинг качества атмосферного воздуха, приоритетные загрязнители, индекс загрязнения атмосферы

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Статья получена: 03.12.2025 **Статья принята к печати:** 09.12.2025 **Опубликована онлайн:** 29.12.2025

DOI: 10.24075/rbh.2025.147

Maintaining the health and increasing the life expectancy of the population are strategic objectives of the state. It has been proven that atmospheric air pollution in urban areas leads to increased morbidity, mortality, and disability due to cardiovascular diseases, cancer, and other conditions. [1, 2].

The need to improve the general environment and, consequently, to enhance the medical and demographic situation in cities with high levels of anthropogenic pollution justified the development and implementation of the Clean Air federal project. One of the project's targets reflecting realization of the Russian

Federation Presidential Decree is to reduce emissions of dangerous pollutants in large industrial centers by at least 20% of the total volume [3–5].

The achievement of such targets is especially important in regions like Kuzbass (the Kemerovo region), where the concentration of coal-chemical plants, mechanical engineering factories, and thermal power facilities is among the highest in the country. Kuzbass accounts for a significant volume of coal mining and processing, as well as the production of rolled ferrous metals, ferrosilicon, and railway main rails. In large industrial agglomerations such as Novokuznetsk and Kemerovo, emissions from major plants and factories have resulted in high levels of anthropogenic pollution, including severe air contamination. The results of tests and studies indicate that in regions where the condition of air is unsatisfactory, the population's quality of life and life expectancy decline [6, 7].

The climate in the Kemerovo region is severely continental, characterized by significant annual and daily temperature fluctuations, frequent inversions, predominantly low atmospheric pressure, and weak winds combined with intense seasonal solar radiation, which contribute to the formation of photochemical smog. The weather conditions promote dispersion of the contaminants for up to 100 days a year, and the negative consequences of this factor are especially pronounced in industrial centers [8]. The primary reason for this situation is the location of these centers in the Kuznetsk Basin — in the southwestern part of Western Siberia — and their proximity to the junction of the Kuznetsk Depression with the mountain ranges of the Kuznetsk Alatau, Gornaya Shoria, and Salair. Thus, the climatic and geographical features of Kuzbass create conditions that prevent the dispersion of pollutants in the atmospheric air [9].

Another aggravating factor lies in historical urban planning: in the industrial cities of Kuzbass, plants and factories were often situated in close proximity to residential districts. The high concentration of numerous pollution sources within a relatively small area, combined with the insufficient effectiveness of current technological and sanitary measures, highlights the urgent need to develop and implement comprehensive plans to protect atmospheric air and assess the effectiveness of these measures.

The current key scientific and practical tasks include assessing the zone of influence and spatial distribution of industrial pollutant emissions, optimizing control measures, and creating a reliable air quality monitoring system focused on substances that negatively affect public health. The particularly important activities are assessing the relative locations of stationary and route monitoring posts, identifying priority pollution components, determining exposure areas where concentrations pose the greatest risk to human health, and locating areas most unfavorable for living [10, 11].

Consequently, the enhancement of atmospheric air quality and the development of improved hygienic assessment methods are essential for the successful implementation of the federal project "Clean Air" [12, 13].

This study aimed to hygienically assess the quality of atmospheric air as part of the implementation of the "Clean Air" federal project, which involves improving the air monitoring system in the industrial centers of Kuzbass.

METHODS

This study focused on the cities of Novokuznetsk and Kemerovo of the Kemerovo region, which are the priority locations in terms of atmospheric air pollution. Kemerovo, with a population of 542,928 and an area of 294.8 km^2, is a major chemical industry center and the most densely populated city of the Region. The key chemical plants and factories of Kemerovo are Azot, which produces ammonium nitrate, nitric acid, caprolactam, and Khimprom, which specializes in chlorine products (chlorine, hydrochloric acid, caustic soda) and organic synthesis (polyesters, polypropylene glycol).

Novokuznetsk, with a population of 546,951 and an area of 424.27 km^2, is one of the largest industrial centers in Russia. The city is a metallurgical production and coal mining hub; its industrial complex includes an integrated metallurgical works, ferrous and non-ferrous metallurgy plants, coal mines, and thermal power plants.

The methodological approaches developed for the "Clean Air" federal project underpinned the assessment of the sanitary and epidemiological factors influencing atmospheric air quality and its impact on public health, and supported the development of measures to reduce emissions and enhance the existing monitoring network [14–16].

The hygienic assessment included the analysis of social and hygienic monitoring data collected from 2017 to 2024, i.e., from the beginning of the implementation of the "Clean Air" federal project. The data included information about pollutant emission sources, their parameters and spatial characteristics, as well as exposure levels specified in the draft standards regulating maximum permissible emissions (MPE) of pollutants into the atmosphere, which are part of the comprehensive emission quota plan.

The assessment of air pollutant emission dynamics was based on materials from a report by the Ministry of Natural Resources and Ecology of Kuzbass [17].

For hygienic assessment of the atmospheric air quality, we used the results of instrumental observations from stationary posts set up by the Hydrometeorology and Environment Monitoring Center, which is a branch of the West Siberian Territorial Hydrometeorology and Environment Monitoring Administration. There are eight such stationary posts in every city; they are linked into a state monitoring network. The monitoring program included registration of the amounts of the key atmospheric air pollutants and marker substances specific to a particular production process, characterizing its features. Instrument readings were taken every 20 minutes.

In Novokuznetsk, automatic devices continuously monitored a number of substances, including suspended solids, nitrogen dioxide, carbon monoxide, sulfur dioxide, black carbon (soot), phenol, formaldehyde, lead, nitrogen oxide, ozone, ammonia, hydrogen sulfide, suspended particles PM2.5 and PM10. The samples were collected in standard mode, according to the full program, at 01:00, 07:00, 13:00, and 19:00 local time.

In Kemerovo, the samples were taken at stationary posts according to an abridged monitoring program at 07:00, 13:00, and 19:00 local time. The list of controlled substances included hydrogen fluoride, hydrogen cyanide, suspended solids, nitrogen dioxide, carbon monoxide, sulfur dioxide, black carbon (soot), phenol, formaldehyde, and lead.

Hygienic assessment of the level of atmospheric air pollution in the considered cities involved a comparison of the concentrations registered at the observation posts with the maximum permissible concentrations approved in SanPiN 1.2.3685-21 “Hygienic standards and requirements for ensuring the safety and (or) harmlessness of environmental factors for humans”. The values from a single sample were compared with the maximum permissible single concentrations (MPC_s), while the daily mean values were compared with the maximum permissible average daily concentrations (MPC_{ad}). The average annual concentration was calculated after each year of the observation

Table 1. Dynamics of pollutant emissions into the atmosphere from stationary sources in the cities of Kemerovo and Novokuznetsk (thousand tons per year)

Territory	2017	2018	2019	2020	2021	2022	2023	2024
Novokuznetsk	313.331	295.794	294.195	277.528	268.297	263.211	260.971	256.683
Kemerovo	41.106	36.111	55.834	52.542	45.947	65.053	57.033	59.08

period; the values were compared with the maximum permissible average annual concentration (MPC_{aa}), since as a minimum, each post collected over 300 samples of every monitored substance.

To determine the degree of pollution, we calculated the atmospheric air contamination index (ACI): the sum of the mean annual concentrations (in fractions of MPC, with the correlation of the hazard class of each pollutant with the hazard class of sulfur dioxide) of the five pollutants that contaminated the city's air the most.

Based on the calculation of the total hazard coefficient in accordance with MR 2.1.6.0157-19, we conducted a spatial analysis of the influence of Novokuznetsk plants on the residential areas. The analysis yielded an assessment of the relative locations of the route and stationary observation posts and the city's industrial facilities. The spatial analysis was carried out using the ArcGIS software (ESRI; USA) (license agreement No. 2010RUS7342).

The calculations were performed in MS Excel 2016 (Microsoft, USA); we calculated the sum, the mean values, and the trends.

RESULTS

The comprehensive action plan to reduce pollutant emissions into the atmosphere of Kemerovo and Novokuznetsk aims to achieve targets for air quality and ensure favorable living conditions for residents.

The program and the action plan under the "Clean Air" federal project are based on integrated approach that includes technological, sanitary, urban planning, and organizational measures. In particular, for Kemerovo and Novokuznetsk, the "Clean Air" federal project envisages the following: modernization of the transport rolling stock and its conversion to environmentally friendly fuels; introduction of new technological and production solutions, including effective dust and gas purification methods and facilities; gasification of the single-family neighbourhoods, demolition of dilapidated housing, modernization and overhaul of thermal power facilities; optimization of atmospheric air quality monitoring, including modernization of the existing monitoring network, expansion of social and hygienic monitoring, advanced automation of data control, re-equipment of the laboratories subordinate to Rosprirodnadzor and Rospotrebnadzor.

According to the regional Ministry of Ecology and Natural Resources, 24 measures are being implemented. In Kemerovo, the plan is to reduce the total volume of atmospheric air emissions by 88.165 thousand tons by 2036, which would result in a two-fold decrease compared to 2020. By the end of 2026, Novokuznetsk's total atmospheric emissions will decrease by 83.769 thousand tons, or 25.1% of the 2017 level. The reduction in total emissions of pollutants by the end of 2026 will amount to 51.069 thousand tons — 59.5% of the 2017 level.

In addition, Rosprirodnadzor has approved a list facilities for which a quota is set. These facilities contribute the most to the contamination of atmospheric air; under this initiative, they will be given the maximum permissible emission values and long-term action plans to achieve them.

In the Kuzbass industrial centers, industrial facilities and utilities infrastructure were responsible for 78–94% of air pollution. The share of autonomous heat supply sources (in private residencies) was 6–21%, and that of motor transport did not exceed 0.5%. In single-family residential areas, emissions are released at low altitudes, creating a risk of pollution in the surface layer of the atmosphere that directly affects residents. The situation is worsened by unfavorable meteorological conditions that hinder the dispersion of pollutants, especially during the cold season, when a “black sky” effect occurs and negatively affects public health.

Through the period of implementation of the "Clean Air" federal project in Novokuznetsk, the volume of pollutants released into the atmosphere from stationary sources decreased by 56.6 thousand tons (18.1%). In particular, the emissions of solids went down by 13.6 thousand tons (37.7%), liquid gaseous substances — by 43 thousand tons (15.5%), including sulfur dioxide — by 21.7 thousand tons (38.7%), carbon monoxide — by 31.7 thousand tons (11.0%), nitrogen dioxide — by 3.3 thousand tons (18.8%) (Table 1).

For Kemerovo, 2020 was taken as the baseline year against which emission trends were assessed. The volume of pollutants released into the atmospheric air from stationary sources increased by 6.5 thousand tons (12.4%) in 2024. The specific growth was as follows: solids — by 3.9 thousand tons (39.1%), liquid gaseous substances — by 2.6 thousand tons (6.2%), including carbon monoxide — by 0.8 thousand tons (5.7%), nitrogen dioxide — by 2.0 thousand tons or 18.0%.

Summary calculations of atmospheric air pollution were made for Novokuznetsk and Kemerovo, and the priority pollutants included in the monitoring program were identified.

In 2024, 1106386 measurements of atmospheric air pollutants were carried out at stationary posts in Novokuznetsk. Of these, 13654 samples did not meet the hygiene standards, which amounted to 1.23%. Regarding single concentrations, hydrogen sulfide and carbon monoxide exceeded the MPC_s by a factor of 5, while nitrogen dioxide, nitric oxide, ammonia, suspended solids, formaldehyde, and fluorinated gaseous compounds exceeded them by a factor of 2 to 5.

In Kemerovo, stationary monitoring posts made 56529 air pollution measurements; 217 samples (0.38%) had the content of contaminants exceeding the MPC. Among the single concentrations, no exceedance of 5 or more MPC_s was recorded; exceedances of 2 to 5 MPC_s were observed for nitrogen dioxide, suspended solids, formaldehyde, and phenol (Table 2).

An assessment of atmospheric air pollution levels in populated areas showed that, at stationary monitoring posts in Kemerovo, the air was most contaminated with benz(a)pyrene and formaldehyde, whose average annual concentrations exceeded the maximum permissible concentrations (MPC_{aa}) by 2.6–3.1 and 2.0–2.6 times, respectively. In 2024, compared to 2017, the average annual concentration of ammonia in the atmosphere increased by 30%, nitrogen (II) oxide by 9.5%, carbon monoxide by 5.3%, and formaldehyde by 28.3%. The levels of some contaminants decreased during this period: hydrogen chloride by 60.0%, black carbon (soot) by 66.7%, phenol by 30.0%, hydrogen cyanide by 20.0%, and benzo(a)pyrene by 16.1% (Table 3).

In Kemerovo, the ACI calculation took into account the concentrations of five priority pollutants: benz(a)pyrene, suspended solids, formaldehyde, nitrogen dioxide, and ammonia.

Table 2. Some indicators of atmospheric air pollution registered at stationary posts in Kemerovo and Novokuznetsk (2024)

Pollutants	Novokuznetsk					
	Number of single samples, average monthly	% exceeding the MPC	Maximum concentration among single samples	The order of MPC_s exceedance	Mean concentration, daily average	The order of MPC_{ad} exceedance
Nitrogen dioxide	104253	0.72	0.56	2.82	0.029	0.71
Ammonia	10423	0.0029	0.7	3.5	0.0086	0.22
Benz(a)pyrene*	–/36	–/80.56	0.000039	–	0.0000063	6.31
Suspended substances	9348	0.28	1.35	2.7	0.094	1.25
PM10 suspended particles	28693	0.035	1.2	4	0.038	0.95
PM2.5 suspended particles	28693	1	0.29	1.83	0.03	1.2
Ozone	91338	1.19	0.29	1.84	0.04	1.33
Hydrocyanide	2338	–	0.035	–	0.0012	0.012
Manganese and its compounds	–/24	–/0.00	0.00006	0.006	0.000025	0.025
Hydrogen sulfide	198947	5.03	0.04	5	0.0022	1.1
Sulfur dioxide	205190	0	0.3	0.6	0.0027	0.05
Carbon monoxide	206901	0.3	44.5	8.9	0.59	0.2
Phenol	7016	0.01	0.011	1.1	0.00085	0.28
Formaldehyde	7016	2.27	0.16	3.14	0.012	3.88
Fluoride gaseous compounds	8185	0.78	0.041	2.05	0.0017	0.34
Nitrogen oxide	104238	0.63	0.92	2.29	0.03	0.5
TOTAL	1106386/60	1.23/48.3				
Kemerovo						
Nitrogen dioxide	6998	0.51	0.557	2.79	0.038	0.95
Nitrogen oxide	4375	0.11	0.5	1.25	0.023	0.38
Ammonia	6994	0.41	0.33	1.65	0.039	0.98
Benz(a)pyrene*	–/36	–/41.67	0.000012	–	0.0000026	2.6
Suspended substances	5964	0.72	1.052	2.1	0.057	0.76
Hydrochloride	2617	0.08	0.31	1.55	0.008	0.4
Hydrocyanide	2623	–	0.04	–	0.0008	0.08
Lead	–/36	–/0.0	0.00004	–	0.000001	0.003
Sulfur dioxide	3510	0	0.067	0.13	0.0026	0.05
Carbon	5088	0	0.15	1	0.003	0.12
Carbon monoxide	6993	0.51	9.4	1.88	1	0.33
Phenol	6120	0.1	0.032	3.2	0.0007	0.23
Formaldehyde	5247	1.14	0.176	3.52	0.0077	2.57
Chrome (VI)	–/36	-/0.00	0.00001	–	0.000001	0.00067
TOTAL	56529/108	0.38/14.8				

In 2017, the value of the index was 10.85, and in 2024 — 10.34, classified as "high." The rate of decline was 4.6%.

In Novokuznetsk, data from stationary observation posts on the average annual concentrations of air pollutants showed that benz(a)pyrene exceeded the MPC_{aa} by 6.0–6.3 times, formaldehyde by 1.7–4.0 times, suspended solids by 1.2–1.5 times, and ozone by 1.3 times. Compared to 2017, in 2024 the air had significantly higher concentrations of hydrogen sulfide (a 4.0-fold increase), nitrogen oxide (a 3.0-fold increase), formaldehyde (a 2.4-fold increase), and hydrocyanic acid (a 20% increase). The concentration of the following substances decreased during the study period: ammonia — by 78.5%, sulfur dioxide — by 73.0%, phenol — by 71.7%, carbon monoxide — by 60.7%, fluorinated gaseous compounds — by 43.3%, and suspended solids — by 15% (Table 3).

In Novokuznetsk, the ACI calculation too into account the concentrations of five priority pollutants: benz(a)pyrene, suspended solids, formaldehyde, nitrogen dioxide, and hydrogen sulfide. During the study period, the value of the index increased from 14.9 to 19.3 (a 1.3-fold increase) and was classified as "extremely high." A marked increase in the surface concentration of hydrogen sulfide — a substance that not only produces an unpleasant odor but can also cause respiratory damage, sometimes moderate or severe — has raised significant concern.

The industrial facilities contributing to atmospheric air pollution underwent a hazard identification procedure, and total normalized hazard coefficients were calculated for each plant and factory. In Novokuznetsk, a subsequent ranking identified four industrial complexes with the greatest impact of emissions

Table 3. Dynamics of average annual concentrations of atmospheric air pollutants as registered at the stationary posts in Kemerovo and Novokuznetsk

Pollutants	Hazard class	MPC_{aa}, mg/m³	Average annual concentration, mg/m³		The order of MPC_{aa} exceedance		Growth rate in 2024 vs. 2020, %
			2020	2024	2020	2024	
Kemerovo							
Suspended substances	3	0.075	0.06	0.057	0.80	0.76	–5.0
Hydrochloride	2	0.02	0.02	0.008	1.00	0.40	–60.0
Ammonia	4	0.04	0.03	0.039	0.75	0.98	+30
Nitrogen (II) oxide	3	0.06	0.021	0.023	0.35	0.38	+9,5
Sulfur dioxide	3	0.05	0.007	0.0026	0.10	0.05	–62.8
Carbon monoxide	4	3	0.95	1.00	0.32	0.33	+5.3
Carbon black (soot)	3	0.025	0.009	0.003	0.13	0.12	–66.7
Nitrogen (IV) oxide	3	0.04	0.04	0.038	0.75	0.95	–5.0
Phenol	2	0.003	0.001	0.0007	0.33	0.23	–30.0
Formaldehyde	2	0.003	0.006	0.0077	1.67	2.57	+28.3
Hydrocyanide	2	0.01	0.001	0.0008	0.06	0.08	–20.0
Benz(a)pyrene	1	0.000001	0.0000031	0.0000027	3.00	2.70	–16.1
Novokuznetsk							
Suspended substances	3	0.075	0.11	0.09	1.5	1.20	–15
Hydrocyanide	2	0.01	0.001	0.0012	0.1	0.12	+20
Ammonia	4	0.04	0.04	0.0086	1.0	0.22	–78.5
Nitrogen (II) oxide	3	0.06	0.01	0.03	0.17	0.50	+200
Sulfur dioxide	3	0.05	0.01	0.0027	0.20	0.05	–73.0
Hydrogen sulfide	2	0.002	0.0005	0.0022	0.25	1.10	+340
Carbon monoxide	4	3	1.5	0.59	0.50	0.20	–60.7
Ozone	1	0.03	–	0.04	–	1.33	–
Nitrogen (IV) oxide	3	0.04	0.03	0.029	0.75	0.73	–3.3
Phenol	2	0.003	0.003	0.00085	1.00	0.28	–71.7
Formaldehyde	2	0.003	0.005	0.012	1.7	4.00	+140
Fluoride gaseous compounds	2	0.005	0.003	0.0017	0.60	0.34	–43.3
PM10 suspended particles		0.04	–	0.038	–	0.95	–
PM2.5 suspended particles		0.025	–	0.03	–	1.20	–
Benz(a)pyrene	1	0.000001	0.000006	0.0000063	6.00	6.30	+5

on public health — EVRAZ ZSMK, RUSAL Novokuznetsk Aluminum Plant, Kuznetskiye Ferrosplavy, and Kuznetskaya TPP. In Kemerovo, there are six such complexes: Koks, Azot, Kemerovskaya GRES, Khimprom, Novo-Kemerovskaya TPP. All these facilities are included in the Comprehensive Action Plan for the long-term reduction of air pollution in Kemerovo and Novokuznetsk until 2026 and 2036, respectively. The Plan is part of the "Clean Air" federal project.

Currently, the atmospheric air quality monitoring network covers 90% of the residential areas of the studied urban agglomerations. The implementation of the "Clean Air" federal project began earlier in Novokuznetsk than in Kemerovo; therefore, the data collected in Novokuznetsk were used to assess the relative locations of stationary and route atmospheric air quality monitoring posts. Based on the spatial distribution of the total hazard coefficient shaped by industrial emissions, we determined the respective exposure zones (Fig.). It has been established that residential areas within the exposure zones are mainly controlled by the stationary and route observation posts. However, given the prevailing winds, some territories are not covered by the air quality monitoring network.

An assessment of the rationality of the locations of stationary and route observation posts (based on spatial analysis) showed that the distance between them is less than 2 km; it is feasible to increase this distance and establish additional posts in the pollution exposure zones.

DISCUSSION

It has been established that the atmospheric air of the industrial centers of Kuzbass contains substances with unidirectional effects that, under certain conditions, can negatively affect the health of the population. For example, suspended solids, nitrogen oxides, sulfur dioxide, hydrogen sulfide, phenol, formaldehyde, and carbon can cause respiratory diseases, while phenol and formaldehyde may also lead to visual impairments [18, 19].

The results of this study indicate the need to optimize the monitoring posts placement system and assess the spatial distribution of exposure levels as well as risks to public health. Significant air pollution registered by the observation posts is the reason for the deployment of extra posts in the cities; generally, the posts can collect and report the data for evaluation of the sanitary and hygienic situation in the areas where adequate field observations are unavailable. Determining where to place observation posts, refining the existing monitoring system, and establishing an effective observation program are urgent tasks [19, 20].

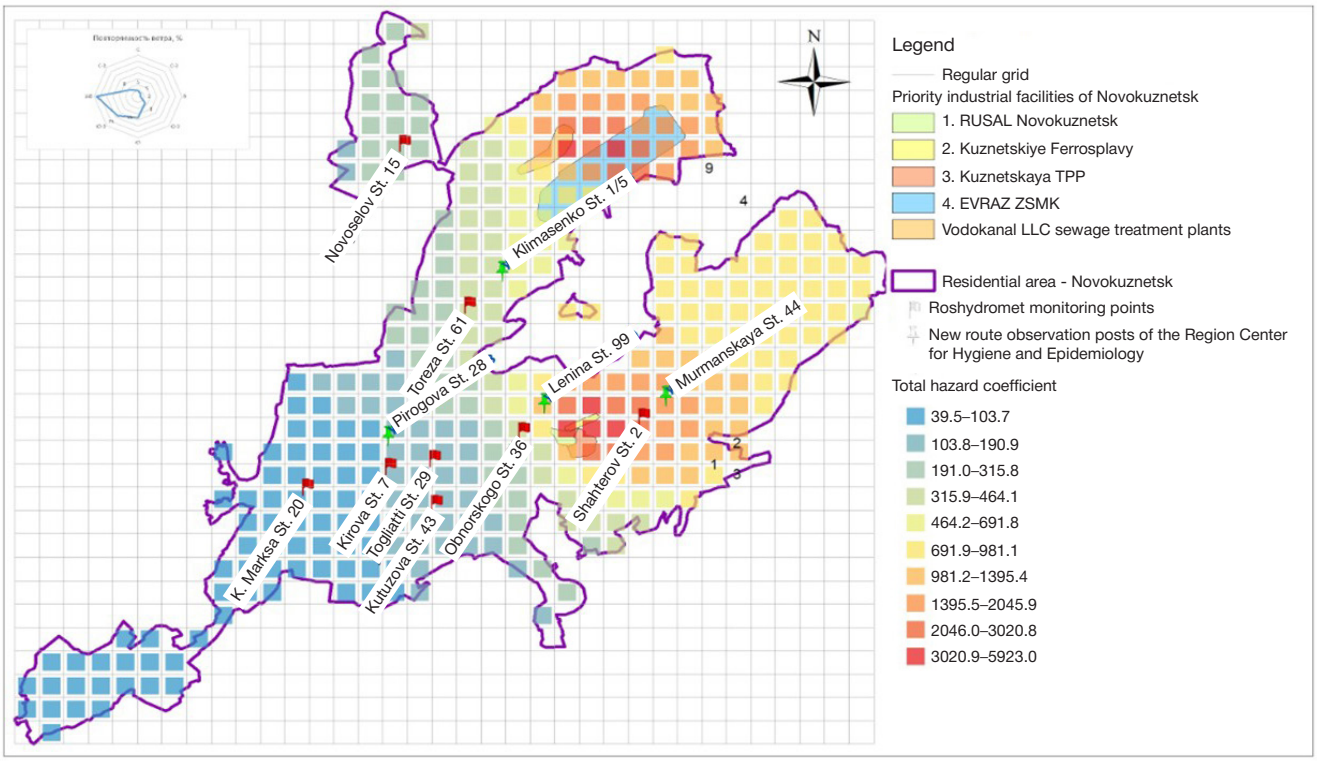

Fig. Spatial distribution of the total hazard coefficient by city's industrial facilities and relative to route and stationary posts

Given the significant contribution of autonomous (household) heating systems to overall air pollution, and taking into account the level of gas supply in the studied agglomerations (one of the lowest in Kuzbass and Siberia in general), it is advisable to consider expanding the comprehensive emission reduction plan to include measures for extending mainline gas service to single-family residential neighborhoods [21, 22].

Managerial decisions concerning environmental protection and public health are guided by monitoring data, and high pollution levels make it increasingly urgent to assess how effective planned air protection measures will be. At the same time, the most important aspect of such an assessment should be evaluating whether the programs and action plans are adequate for achieving the desired improvements in population health [23].

CONCLUSIONS

A hygienic assessment of air pollution in Kuzbass industrial centers found that, during the study period, emissions from stationary sources decreased by 18.1% in Novokuznetsk and increased by 12.4% in Kemerovo. The atmospheric pollution index was rated as "extremely high" and "high", respectively.

The study provides a rationale for selecting priority atmospheric air pollutants to monitor. We identified hazards, and found the facilities emitting substances that harm population's health the most. These facilities have been included in the Comprehensive Action Plan of the "Clean Air" federal project.

In Novokuznetsk, we evaluated the relative locations of stationary and route air quality monitoring posts, identified the zones exposed to emissions from the leading plants, and assessed the rationality of the observation point locations.

Taking into account the negative impact of emissions from industrial complexes, it is recommended to set up additional monitoring posts and to increase the distance between the existing stationary and route posts.

As part of the implementation of the "Clean Air" federal project, a hygienic assessment was conducted, and measures were developed to improve the air quality control system under changing sanitary and epidemiological conditions, as well as to ensure the timely collection of information on pollution levels in Kuzbass's industrial centers.

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ANALYSIS OF INFECTIOUS DISEASE RATE IN CHILDREN OF DIFFERENT AGES AIMED AT DEVELOPING HYGIENE

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The persistently high rate of infectious diseases requires constant monitoring, in-depth analysis of age-related characteristics of the disease spread and dynamics, and also necessitates improving the sanitary and epidemiological well-being of the population, specifically, children, adolescents, and their parents. The study aimed to to study epidemiological trends and identify the most vulnerable age groups among the pediatric population in the context of the incidence of key infections, such as acute intestinal infections (AIIs), enterovirus infection, viral hepatitis A, measles, whooping cough and enterobiasis. A retrospective epidemiological analysis of official statistical data over a seven-year period (2018–2024) was carried out covering the pediatric population of the Western Administrative Okrug (ZAO) of Moscow. Age differences in the structure of infectious morbidity have been determined. In children under one year, viral AIIs (rotavirus, norovirus) and airborne infections prevailed. A similar trend for viral AIIs is reported in children aged 1–2 years. High prevalence of enterobiasis is reported for children aged 3–6 years (attending preschool educational institutions), and a significant increase in the incidence of enterovirus infection and airborne infections is reported in all age groups, especially in school students and adolescents. As for the viral hepatitis A incidence, the situation remains stable throughout the assessed period in all age groups. High incidence of key infections among children persisting in all age groups demonstrates an urgent need for the development and implementation of the targeted and adapted hygiene education programs for pediatric population and parents.

Keywords: children and adolescents, age groups, infectious diseases, morbidity, hygiene education

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Received: 07.09.2025 **Accepted:** 11.12.2025 **Published online:** 30.12.2025

DOI: 10.24075/rbh.2025.148

АНАЛИЗ ИНФЕКЦИОННОЙ ЗАБОЛЕВАЕМОСТИ ДЕТЕЙ РАЗНОГО ВОЗРАСТА С ЦЕЛЬЮ РАЗРАБОТКИ ПРОГРАММ ГИГИЕНИЧЕСКОГО ВОСПИТАНИЯ

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Сохраняющийся высокий уровень инфекционных заболеваний требует постоянного мониторинга, глубокого анализа возрастных особенностей распространения и динамики заболеваемости, а также обусловливает необходимость повышения санитарно-эпидемиологического благополучия населения — в частности, детей, подростков и их родителей. Целью работы было изучить эпидемиологические тенденции и выявить наиболее уязвимые возрастные группы среди детского населения в контексте заболеваемости ключевыми инфекциями, такими как острые кишечные инфекции (ОКИ), энтеровирусная инфекция, вирусный гепатит А, корь, коклюш и энтеробиоз. Выполнен ретроспективный эпидемиологический анализ официальных статистических данных за семилетний период (2018–2024 гг.), охватывающий детское население Западного административного округа (ЗАО) г. Москвы. Установлены возрастные различия в структуре инфекционной заболеваемости. У детей до года преобладали вирусные ОКИ (ротавирусная, норовирусная) и инфекции, передающиеся воздушно-капельным путем. Схожая тенденция для вирусных ОКИ отмечена у детей 1–2 лет. Установлена высокая распространенность энтеробиоза среди детей 3–6 лет (посещающих дошкольные образовательные учреждения), помимо этого выявлено значительное увеличение заболеваемости энтеровирусной инфекцией и инфекциями, передающимися воздушно-капельным путем, во всех возрастных группах, особенно среди школьников и подростков. По заболеваемости вирусным гепатитом А ситуация стабильная на протяжении всего анализируемого периода во всех возрастных группах. Сохраняющаяся во всех возрастных группах высокая заболеваемость детей ключевыми инфекциями демонстрирует острую потребность в разработке и внедрении целенаправленных и адаптированных программ гигиенического воспитания детского населения и родителей.

Ключевые слова: дети и подростки, возрастные группы, инфекционные болезни, заболеваемость, гигиеническое воспитание

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Статья получена: 07.09.2025 **Статья принята к печати:** 11.12.2025 **Опубликована онлайн:** 30.12.2025

DOI: 10.24075/rbh.2025.148

Since the children's immune system is still developing, they are often susceptible to infectious diseases. The lack of specific immunity to various pathogens, along with other factors, leads to high morbidity among children. The child's immune system begins to form even before birth, from the first weeks of intrauterine development. The immune system structure and functions are formed during the body's growth, starting from birth and ending with the onset of puberty. Identification and subsequent removal of foreign antigenic agents of both external (e.g., pathogenic microorganisms) and internal (e.g., virus-infected or malignant cells) origin are the immune response central elements. The body's defense system against foreign substances is based on synergy of the innate and adaptive (acquired) immunity, which complement each other and are being continuously communicating [1–3].

Airborne infectious diseases and diseases transmitted by household contacts are especially common among children and adolescents, that is why the key role in prevention of such infectious diseases is played by hygiene education and training of children and adolescents, since in children's

groups, poor hygiene is one of the main causes of the spread of infections. Children should acquire basic sanitary and hygienic skills, knowledge and abilities already in preschool years or in elementary school. At this age it is necessary to develop sustainable habits: be sure to wash your hands before eating, take precautions if you may come into contact with sick people — keep your distance, regularly ventilate the premises, wear protective masks, and use personal utensils. At an older age, the child should understand his/her responsibility for the possible spread of infections — for example, understand that it is unacceptable to attend school with symptoms of ARVI. In addition, the prevention of vaccine-preventable infections is an important link in the hygiene education for children and adolescents. Vaccination is the most effective means of protection against infectious diseases, and refusal of vaccination leads to irreversible consequences, including death. For example, in the 1990s, a major outbreak of diphtheria occurred in the Russian Federation (RF) and the countries of the former USSR. From 1990 to 1996, 111,144 people got infected in the RF alone, including 35,928 children, of whom 3,047 people (729 children) died. Almost all of those, who died of diphtheria (95%), were not vaccinated. Systemic shortcomings in the vaccination campaign organization were the key factors of the unfavorable epidemiological situation: decreased vaccination rate in both children and adults due to refusal of vaccination, which is general suggested low hygiene education levels [4].

Acute intestinal infections (AIIs) are among the most prevalent infectious diseases reported in Russian children. In 2019, the pediatric population accounted for more than 70% of the overall number of registered cases (more than 960,000) [5, 6]. Furthermore, the share of AIIs with the identified causative agents in children was 79% (196,424 cases), which was several times higher than the general population rate. The vast majority of pediatric AII cases occur in younger age groups. Viral infections predominate (up to 70%), in particular rotavirus and norovirus ones, mixed viral-bacterial forms are also encountered [7, 8].

Enterovirus infection is showing a general upward trend in Russia. After a decline in 2018, the incidence rate increased by 25% in 2019, with 91.8% of cases (17,003 people) registered in children.

The incidence of acute viral hepatitis A in children also increased by 12.1% in 2019, reaching 4.98 per 100,000 population. Children under the age of 17 accounted for 34% of the total number of cases (1,441 cases) in 2019, despite minimal incidence rates in the previous year [9, 10].

Along with intestinal infections, airborne infections are common among children and adolescents. For many years, isolated cases of measles have been registered in the RF, and cases of importation from foreign countries have been noted. However, at the end of 2019 – beginning of 2020, there was a significant increase in the incidence of measles in children and adults, first in Europe and then in the RF. For example, in the Republic of Sakha (Yakutia), children under the age of 17 accounted for 29.4% of those infected, and the largest number of infected children was registered in the age group 1–2 year: 10 cases (5.9%) [11].

An increase in the incidence of whooping cough has also been noted in all population groups, especially in children. In 2023 in the Orenburg Region, children under the age of 14 made up the overwhelming majority (81.3%) of all whooping cough cases. Of particular concern is the sharp increase in the incidence among the youngest children: for children under the age of one year, the rate exceeded the 2019 level by 6.4 times (from 52.63 to 338 per 100,000 children). The incidence rate among adolescents aged 15–17 also increased significantly, rising from 7.58 to 207.53 per 100,000 compared to the pre-pandemic 2019 level [10, 12].

Parasitic diseases, in particular enterobiasis, also remain common in children and adolescents [13]. In the Astrakhan Region, 11,502 cases of helminthic and protozoal infestations were registered in 2016–2020, with 93.7% of those (10,777 cases) occurring in children under the age of 17. During this period enterobiasis accounted for 84% of all pediatric parasitic infestations (9,052 cases). The largest proportion of cases (58.5% or 5,295 cases) was registered in school-age children (7–17 years). In children aged 1–7 years, enterobiasis was diagnosed in 38.2% of cases (3,702 cases), which was 1.5 times less often than in school students. The lowest incidence rate was reported for infants aged 5–12 months (0.6%, 54 cases) and children under the age of one year (0.3%, 14 cases) [14].

The study aimed to analyze the incidence of infectious diseases in the pediatric population in order to improve hygiene education of children of different age groups and their parents.

METHODS

The study included a comprehensive analysis of infectious morbidity in children of different age groups. The main objective of the analysis was to identify age groups most susceptible to infectious diseases in order to develop hygiene education programs considering age characteristics.

In a retrospective study, statistical data on the incidence of infectious diseases in adolescents were used: data from statistical accounting and reporting annual forms No. 2 "Information on infectious and parasitic diseases" of the Center for Hygiene and Epidemiology in Moscow in the Western Administrative Okrug (ZAO) of Moscow for the years 2018–2024, as well as information on the population size for each age group based on the data from the tables of estimated populations of the Moscow administrative districts for the years 2018–2024. The incidence rates of the infections analyzed were calculated per 1000 people in each age group using the MS Office 2016 software package (Microsoft; USA).

RESULTS

Differences in morbidity in different age groups of children and adolescents have been determined. Fig. 1 shows changes in the infectious morbidity over 7 years (2018–2024) among children of various age groups in the ZAO of Moscow. Airborne infectious diseases and those transmitted by household contacts (aerogenic and fecal-oral routes of infection transmission) that are especially widespread among children were included in the analysis. Among the infectious diseases identified in this population, the highest incidence rates are typical for AIIs and enterobiasis. In the structure of morbidity, the leading places are occupied by AIIs caused by the identified bacterial and viral pathogens, as well as foodborne toxic infections of known etiology, enterovirus infection, viral hepatitis A, enterobiasis, whooping cough, measles.

In 2018–2024, in the age group of children under the age of one year the maximum levels of viral AIIs (including rotavirus and norovirus ones), as well as airborne infections, such as whooping cough and measles, were reported (Fig. 2).

In the age group of 1–2 years, there is a consistently high level of incidence of AIIs of viral etiology (in particular, rotavirus and norovirus ones) in 2018–2024 (Fig. 3).

In the age group of 3–6 years, there is an alarming increase in the incidence of airborne vaccine-preventable infections

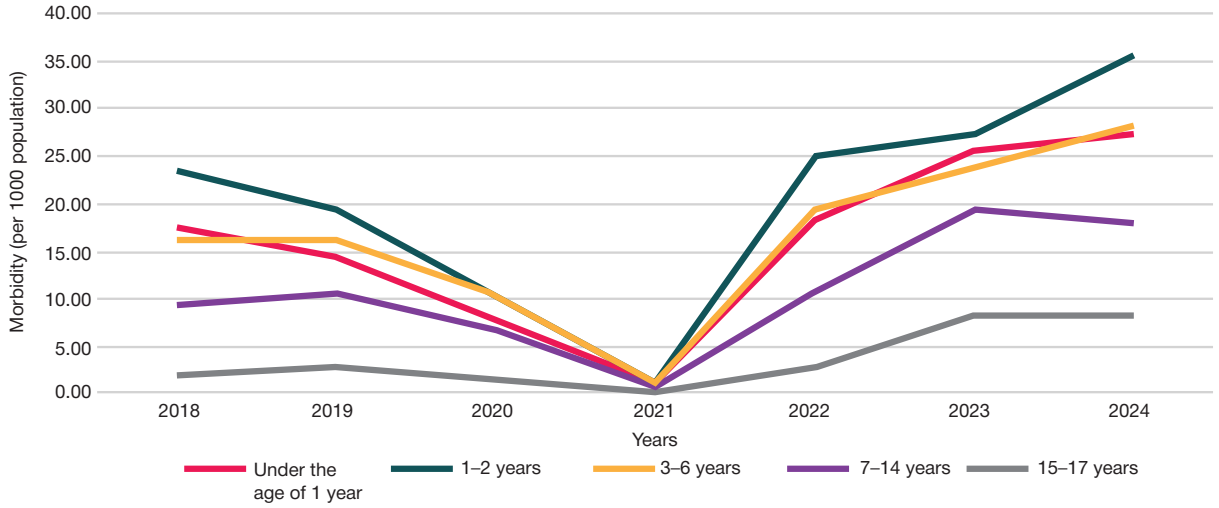

Fig. 1. Infectious morbidity rates in pediatric population of the ZAO of Moscow for the years 2018–2024 (7-year average)

(measles, whooping cough). Furthermore, the number of cases of enterobiasis has increased (Fig. 4).

In children aged 7–14 years, a multiple increase in the incidence of airborne infections (whooping cough, measles) has been also noted, and the incidence of acute intestinal and enterovirus infections increased several times. Furthermore, the enterobiasis incidence rate has increased (Fig. 5).

In children aged 15–17, as well as in those aged 7–14, an increase in the incidence of almost all analyzed infections was noted: the incidence of airborne infections (whooping cough, measles) increased, the incidence of acute intestinal and enterovirus infections increased several times; the incidence of enterobiasis increased as well (Fig. 6).

DISCUSSION

Based on the results of the analysis of infectious morbidity in children of different age groups living in the ZAO of Moscow, it can be noted that there is a high incidence of AIIS (caused by the identified bacterial and viral pathogens, as well as foodborne toxic infections of known etiology) not only among young children, but also among school students and adolescents (3–6 years — an increase of 48%, 7–14 years — 188.5%, 15–17 years — 291.3%). This is consistent with the data of studies of the RF [5, 6].

There is a significant increase in the incidence of enterovirus infection in children of all age groups (under the age of one year — an increase of 273.8%, 1–2 years — 490.8%, 3–6 years — 645.4%, 7–14 years — 502%, 15–17 years — 292.6%), which is also in line with the previously published research data for the RF [9, 10].

The situation with viral hepatitis A in children and adolescents in the ZAO of Moscow in the selected period is stable, the largest age group based on the incidence of this infection are children aged 7–14 years (17% of the total number of cases — 118 cases), in contrast to the situation in the RF, where, according to previously published data, the increase in the incidence of the disease was reported for the entire child population [9, 10].

Among those with enterobiasis, children and adolescents attending preschool and general education institutions are the predominant groups. They accounted for 96.5% of the total number of people infected with enterobiasis, which is consistent with previously published data on the enterobiasis incidence in the Astrakhan region [14].

In the ZAO of Moscow, an upward trend of the incidence of measles has been reported. Children under the age of 17 accounted for 56.9% of all cases, and the largest number of cases were detected in the age group of 7–14 years: 1,216 cases (24.1%). A similar trend was identified in the Republic of Sakha (Yakutia) [11].

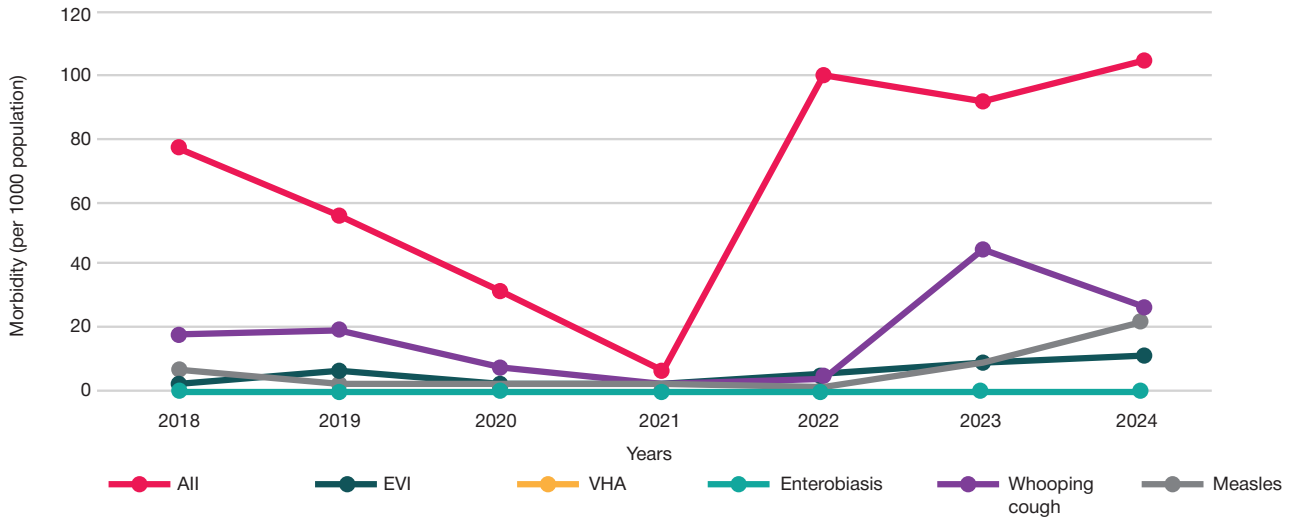

Fig. 2. Infectious morbidity rates in children under the age of one year in the ZAO of Moscow for the years 2018–2024. Note: AII — acute intestinal infections; EVI — enterovirus infection; VHA — viral hepatitis A

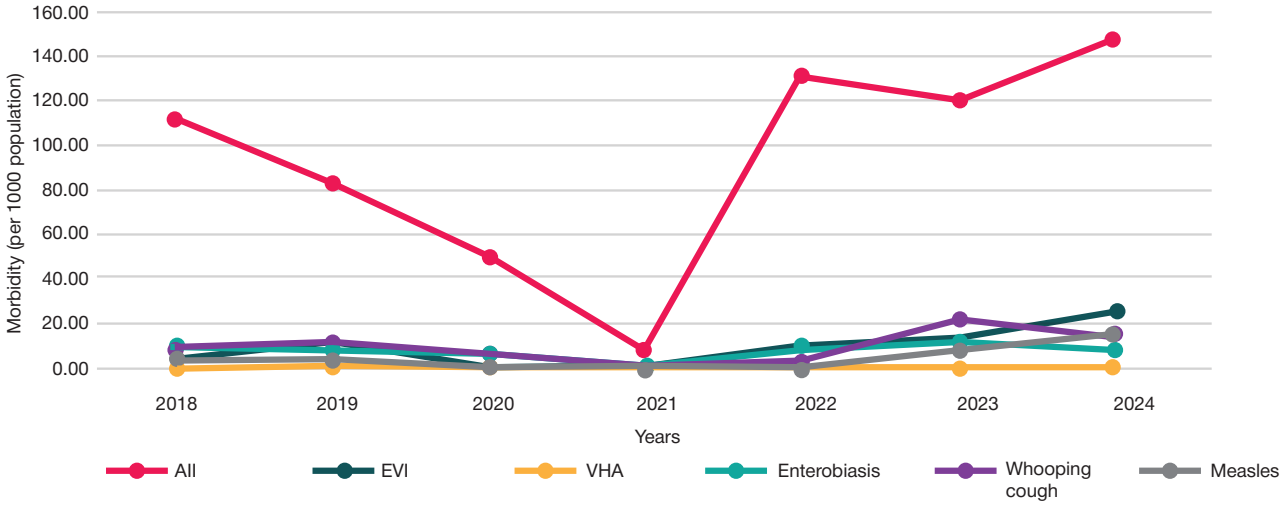

Fig. 3. Infectious morbidity rates in children aged 1–2 in the ZAO of Moscow for the years 2018–2024. Note: AII — acute intestinal infections; EVI — enterovirus infection; VHA — viral hepatitis A

The incidence of whooping cough in the ZAO of Moscow has increased significantly in all age groups. The majority of cases also occurred among children aged 7–14 years attending general education institutions (38.2% of all whooping cough cases), which is consistent with the data of the whooping cough incidence studies conducted in the Orenburg Region [10, 12].

Hygiene education and the healthy lifestyle promotion provide the basis for the infectious disease prevention. These areas are implemented consistently and continuously: from the moment the child enters school and throughout the entire educational path. Preventive work with children should be carried out continuously in a variety of settings: at home, during school classes, extracurricular activities, as well as in places of children's recreation and health improvement. Futhermore, it is important to take into account two interrelated aspects of impact. The first is individual, namely direct training of the child, his/her acquisition of the necessary knowledge and practical skills in the field of hygiene. The second is the influence of the immediate social environment, where parents play a key role. It is the family that helps the child consolidate what he/she has learned in the educational institution. The coordinated efforts of teachers and parents yield tangible results. Firstly, all participants in the process develop a common understanding of the importance of hygiene standards and rules of conduct. Secondly, the continuity of learning is ensured: the knowledge acquired at school is successfully transferred into everyday life. Thirdly, theoretical information is firmly absorbed through the regular practical application. And finally, repeating actions over and over again helps to form sustainable habits. For students, more effective methods of improving hygiene education could be various competitions, quizzes, immunization lessons, game activities, thematic dictations, essays, and gameplay videos. It is necessary to conduct seminars and meetings (on the importance of vaccination, on how to protect a child from infection, etc.) for teachers and parents with a survey to determine their knowledge. The combined efforts of children, parents, and teachers contribute to the deeper understanding of hygiene knowledge, which, in turn, results in reduction of the infectious disease rate.

CONCLUSIONS

During the study we examined epidemiological trends and identified the most vulnerable age groups among the pediatric population for key infectious diseases (acute intestinal infections (AIIs), enterovirus infection, viral hepatitis A, measles, whooping cough, enterobiasis). Younger age groups are the most vulnerable: children under the age of one year show maximum incidence rates of viral AIIs (rotavirus, norovirus ones), as well as airborne

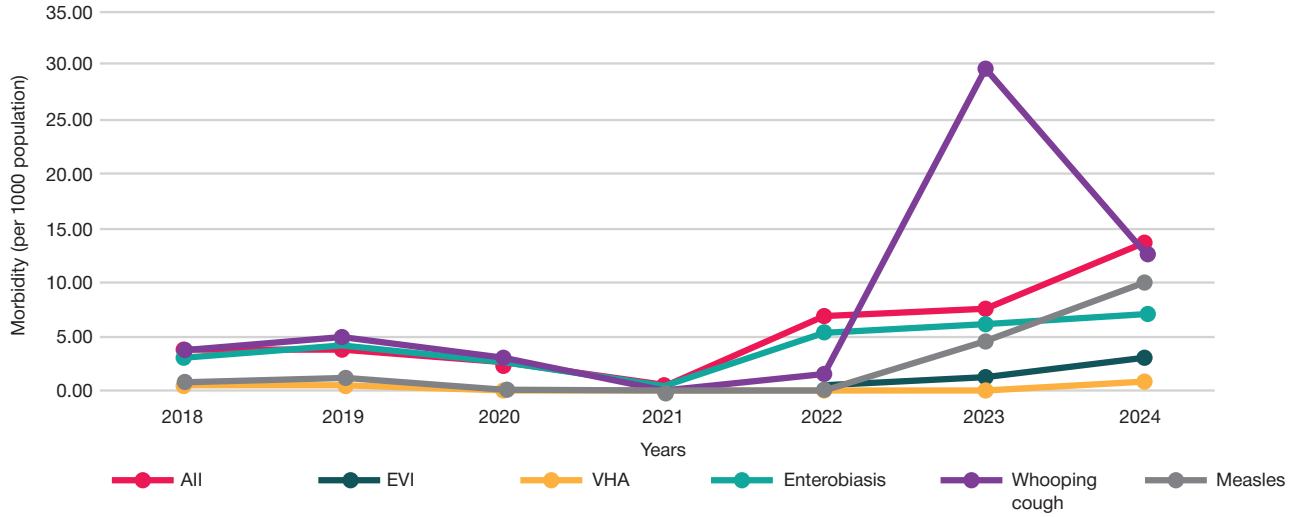

Fig. 4. Infectious morbidity rates in children aged 3–6 in the ZAO of Moscow for the years 2018–2024. Note: AII — acute intestinal infections; EVI — enterovirus infection; VHA — viral hepatitis A

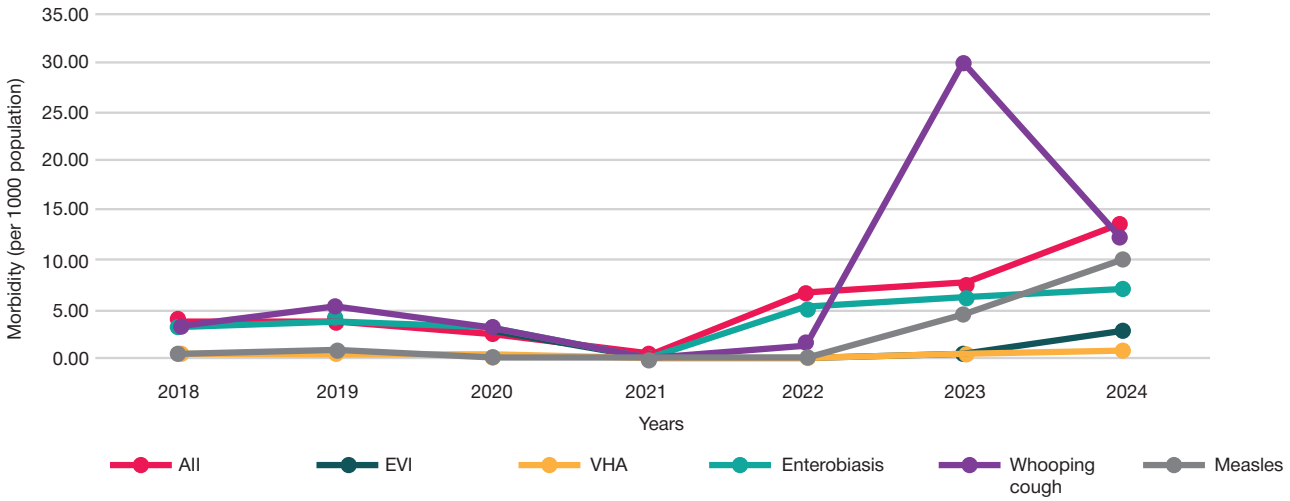

Fig. 5. Infectious morbidity rates in children aged 7–14 in the ZAO of Moscow for the years 2018–2024. Note: All — acute intestinal infections; EVI — enterovirus infection; VHA — viral hepatitis A

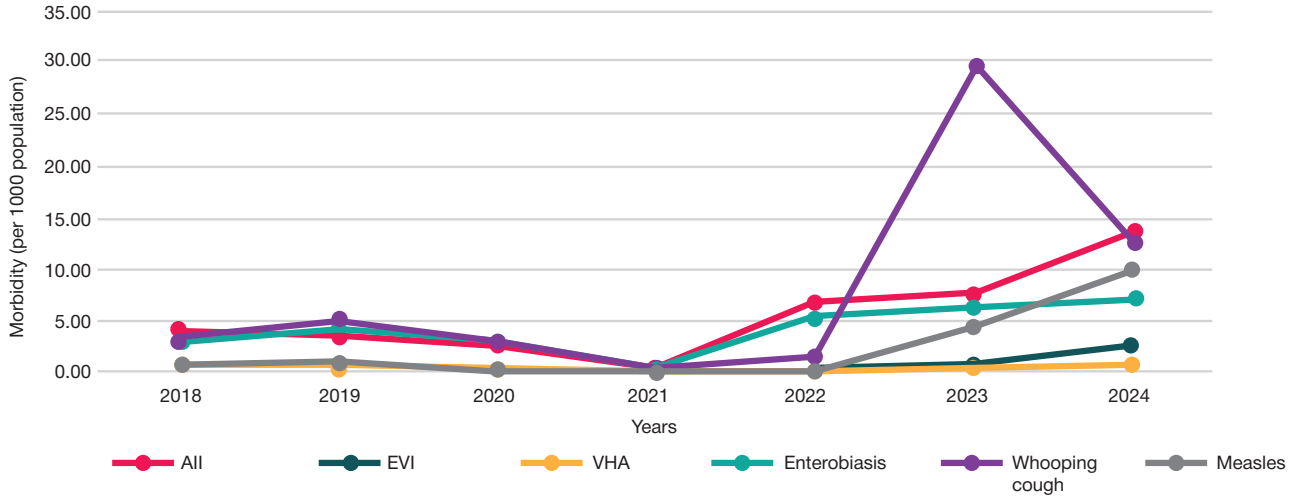

Fig. 6. Infectious morbidity rates in children aged 15–17 in the ZAO of Moscow for the years 2018–2024. Note: All — acute intestinal infections; EVI — enterovirus infection; VHA — viral hepatitis A

infections (whooping cough, measles). In the 1–2 year group, the incidence of viral acute intestinal infections (mainly of rotavirus and norovirus etiology) remains consistently high. An alarming increase in vaccine-preventable airborne infections (measles, whooping cough) and enterobiasis has been reported for preschool children (3–6 years old). In school students (7–14 years old), a multiple increase in the incidence of airborne infections (measles, whooping cough), AIIs and enterovirus infections, and enterobiasis has been reported. Adolescents (15–17 years old) demonstrate the dynamics similar to those of younger school students, with an increase in the incidence of almost all analyzed disease entities, including airborne, intestinal, and parasitic infections. The study confirmed the age-related heterogeneity of infection risk. The greatest risk is observed in infants (under the age of one year) and school students (7–14 years). The data obtained can provide the basis for the development of differentiated preventive programs targeting specific age groups and priority disease entities, designed to improve the hygiene education of children and their parents and reduce the incidence of infectious diseases.

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DYNAMICS OF MENTAL PERFORMANCE IN SCHOOLCHILDREN UNDER POOR INDOOR CLIMATE CONDITIONS AND ELEVATED CARBON DIOXIDE LEVELS

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One of the pressing current issues requiring investigation is the adverse effect of prolonged exposure of schoolchildren to substandard indoor climates and elevated CO_2 levels, which can impair their well-being, hinder cognitive performance, and disrupt the body's adaptive capabilities. This study aimed to assess the dynamics of mental performance of students depending on the said parameters, the indoor climate and CO_2 levels. The temperature, humidity, and CO_2 datapoints (n = 673) were recorded using an Engineering Technical Module in two rooms. Mental performance was assessed by the performance quotient and indicators of short-term memory and attention (n = 352); for this purpose, we used an NS-Psychotest hardware and software complex. In statistical processing, the threshold of significance was set at $p < 0.05$. We registered an increase of temperature up to 25.7 °C, a decrease of humidity to 31.3%, and a steady growth of the concentration of CO_2 from the normal 1000 ppm to substandard 2586 ppm. By the end of the day, the proportion of schoolchildren capable of high-level mental performance had dropped by 30%. We identified significant, moderately strong inverse correlations between performance level and CO_2 concentrations (r = –0.464, $p < 0.001$), as well as weak inverse correlations with temperature (r = –0.327, $p < 0.001$). A strong inverse relationship was found between fatigue and CO_2 levels (r = –0.599, $p < 0.001$); schoolchildren's functional state was poorest when the CO_2 concentration was highest. The study identified a correlation between the deterioration of air quality parameters and reduced mental performance among students, highlighting the necessity for monitoring and preventive interventions.

Keywords: educational institutions, schoolchildren, hygienic learning conditions, microclimate, carbon dioxide, mental performance, fatigue, health risks, prevention

Author contribution: Novikova II, Lobkis MA — concept and design of the study; Lobkis MA, Romanenko SP, Sorokina AV — collection and processing of the material; Lobkis MA, Romanenko SP — statistical processing of the material; Lobkis MA, Sorokina AV — article authoring; Novikova II, Romanenko SP — editing.

Compliance with ethical standards: the study design was previously reviewed by the Local Ethics Committee of the Novosibirsk Research Institute of Hygiene of Rospotrebnadzor (Minutes No. 2 of February 1, 2024). The parents/legal representatives have filled the informed consent forms for the children's participation in the study.

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Received: 25.06.2025 **Accepted:** 26.12.2025 **Published online:** 31.12.2025

DOI: 10.24075/rbh.2025.149

ДИНАМИКА УМСТВЕННОЙ РАБОТОСПОСОБНОСТИ ШКОЛЬНИКОВ В УСЛОВИЯХ НЕБЛАГОПРИЯТНЫХ ПОКАЗАТЕЛЕЙ МИКРОКЛИМАТА И УГЛЕКИСЛОГО ГАЗА В ПОМЕЩЕНИЯХ

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В настоящее время актуальным является изучение неблагоприятного воздействия длительного пребывания обучающихся в условиях, не отвечающих требованиям нормативов по показателям микроклимата и концентрации CO_2, способного вызывать нарушение самочувствия, снижение показателей умственной деятельности, нарушение адаптационных возможностей организма. Целью работы было оценить динамику умственной работоспособности обучающихся в зависимости от указанных параметров. Показатели температуры, влажности и CO_2 (n = 673) регистрировали с помощью «Инженерно-технического модуля» в двух классах. Умственную работоспособность оценивали по коэффициенту работоспособности, показателям кратковременной памяти и внимания (n = 352) с использованием аппаратно-программного комплекса «НС-ПсихоТест». Статистическую обработку данных выполняли при уровне значимости $p < 0,05$. Зарегистрированы повышенная температура (до 25,7 °C) и низкая влажность (до 31,3%), а также устойчивое повышение концентрации CO_2 по сравнению с нормой (1000 ppm) до 2586 ppm. Установлено снижение доли учащихся с высокой работоспособностью на 30% к концу дня. Выявлены значимые обратные корреляции умеренной силы между работоспособностью и концентрацией CO_2 (r = –0,464, $p < 0,001$), а также слабые — с температурой (r = –0,327, $p < 0,001$). Обнаружена сильная обратная связь между утомлением и уровнем CO_2 (r = –0,599, $p < 0,001$). Наиболее выраженное ухудшение функционального состояния наблюдалось в периоды максимальных концентраций CO_2. Исследование выявило взаимосвязь между ухудшением параметров воздушной среды и снижением умственной работоспособности школьников, что обосновывает необходимость мониторинга и профилактических мероприятий.

Ключевые слова: общеобразовательные организации, обучающиеся, гигиенические условия обучения, микроклимат, диоксид углерода, умственная работоспособность, утомление, риски здоровью, профилактика

Вклад авторов: И. И. Новикова, М. А. Лобкис — концепция и дизайн исследования; М. А. Лобкис, С. П. Романенко, А. В. Сорокина — сбор и обработка материала; М. А. Лобкис, С. П. Романенко — статистическая обработка материала; М. А. Лобкис, А. В. Сорокина — написание текста; И. И. Новикова, С. П. Романенко — научное редактирование.

Соблюдение этических стандартов: дизайн исследования предварительно прошел экспертизу в Локальном этическом комитете ФБУН «Новосибирский НИИ гигиены» Роспотребнадзора (протокол № 2 от 1 февраля 2024 г.). Получено предварительное письменное информированное согласие родителей/законных представителей на участие детей в исследовании.

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Статья получена: 25.06.2025 **Статья принята к печати:** 26.12.2025 **Опубликована онлайн:** 31.12.2025

DOI: 10.24075/rbh.2025.149

During the school years, the mental and physical health of students is influenced by various factors, including how well classroom conditions meet hygienic standards. Against the background of an increasing academic workload, a compromised environment depletes the body's reserves, leading to functional abnormalities and disorders of both mental and physical health [1, 2]. One of the most important tasks in creating favorable conditions for education is to monitor and improve classroom air quality, which depends in particular on microclimate parameters and carbon dioxide (CO_2) concentration [3].

Studies have shown that prolonged exposure to elevated concentrations of CO_2 (1000–1500 ppm or higher) has both immediate and delayed negative effects on students' well-being. Such exposure disrupts the metabolic processes of the circulatory, central, and respiratory systems, leading to deteriorated performance and mental activity, increased fatigue, lower resistance to infectious and non-infectious agents, and a higher incidence of upper respiratory tract diseases [4–7].

Children studying in classes with high concentrations of CO_2 often experience heavy breathing, shortness of breath, dry cough, and rhinitis. Students with asthma may have attacks [8]. Higher CO_2 levels in schools are associated with an increase in illness-related absences; respiratory infections and asthma are the main diseases in such conditions. An increase in the concentration of CO_2 in a classroom negatively affects the academic performance and general productivity of schoolchildren. It is considered a risk factor for chronic fatigue syndrome and higher incidence of upper respiratory tract diseases [9–11].

A study involving more than 400 schools in the United States found that an increase in classroom CO_2 concentration to 1,000 ppm was associated with a 10–20% drop in attendance, and that each additional 100 ppm of CO_2 corresponded to a further 0.2% decrease in yearly attendance [12]. Studies focusing on preschool establishments have shown that increasing the frequency of air exchange has a positive effect on kindergarten attendance: morbidity decreases by 12% with each additional hourly increase in the air exchange rate [13].

In Belarus, researchers reported that carbon dioxide concentrations above 1500 ppm in classrooms are associated with more complaints of rapid fatigue and headaches, affecting about one-third of primary school students [14, 15]. There is evidence of a 30.0% decrease in concentration of attention at CO_2 levels above 600–800 ppm; when these exceed 1500 ppm, about 80.0% of students experience fatigue [16]. Substandard microclimate indicators can worsen people's well-being by causing physiological changes in the functional state of organs and systems [17, 18]. In educational settings, failure to meet regulated indoor climate parameters can also disrupt children's adaptation processes [19].

Thus, numerous studies support the importance of examining how indoor air quality affects the functional state and health of individuals, particularly children, taking into account microclimate parameters and carbon dioxide levels.

It is important to note that in educational establishments, an increase in CO_2 concentration correlates with the accumulation of a wide range of other anthropotoxins released by humans as well as substances emitted by finishing materials, furniture, and educational supplies. Thus, CO_2 in this context can be considered as a convenient integral indicator (surrogate marker) of the overall level of anthropogenic load on the indoor air environment. Consequently, the observed effects on performance and well-being are highly likely caused by the combination of contaminants, and the concentration of CO_2 is an indirect indicator of this combination.

This study aimed to investigate variations in schoolchildren's mental performance across the school day, relative to classroom microclimate conditions and CO_2 concentration

METHODS

Hygienic, physiological, and analytical research methods were used in the work.

The indoor climate parameters were measured with the Engineering Technical Module (measuring instrument pattern approval certificate 89313-23) in the automatic continuous mode over the course of one week. The module recorded values of individual microclimate indicators (temperature, relative humidity) and carbon dioxide concentration around the clock, generated summary reports covering current and past data, and compared the measurements to the given regulated value ranges, visualizing the monitoring results.

The module worked for a week in two elementary school classrooms used by 3rd- and 4th-grade classes. The 4th-grade class studied during the first shift in Room 1, and the 3rd-grade class had the second shift in Room 2. The total number of observations was 673. The indoor climate was evaluated against the regulated parameters stipulated in SP 2.4.3648-20 "Sanitary and epidemiological requirements for educational organizations, recreational establishments for children and youth"; SanPiN 1.2.3685-21 "Hygienic standards and requirements for safety and (or) harmlessness to humans." As for carbon dioxide, its values were compared to those given in GOST 30494—2011 "Residential and public buildings. Indoor climate parameters"; GOST R EN 13779—2007 "Ventilation in non-residential buildings. Technical requirements for ventilation and air conditioning systems"; EN 13779:2004 "Ventilation for non-residential buildings — performance requirements for ventilation and room-conditioning systems." The rooms were similar in their architectural, planning, and sanitary specifications: each had an area of 54 m^2 and a ceiling height of 3.2 m. The design occupancy met sanitary standards and was set at 25 people, providing a minimum of 6.9 m^3 of air per student. The heating carrier (water) came from the centralized town system to the radiators in the rooms. The temperature of the carrier could not be adjusted during the school day. The ventilation was natural, enabled by window transoms and exhaust ducts, with no forced elements. In accordance with the relevant regulations, the teachers fully aired the rooms for five minutes during breaks according to the general school schedule; we did not monitor compliance with the established airing routine. Wet cleaning was performed twice a day — at the end of the first and second shifts. It is important to note how the classrooms were used differently: Room 1 was reserved for 4th-grade classes in the first shift, while Room 2, used by the 3rd grade in the second shift, served for part-time activities (up to 12 people) in the first shift.

The students' mental performance was assessed using indicators of the working capacity coefficient, short-term memory dynamics, attention span, concentration, and stability. The assessment was conducted with the NS-PsychoTest hardware and software complex, and measurements were taken three times a day — at the beginning, middle, and end of the school day — over the course of a week (total number of observations: 352).

The following techniques were used to measure mental performance:

1. Kraepelin tables [20], designed for assessment of the dynamics of mental performance and detection of fatigue, completed three times during the school day (n = 132). Each table consists

Table. Mean microclimate parameters and CO_2 concentration during the school day over a week

Indicators M ± SD	First shift (Room 1)		
	Lessons		
	1	2	3
Temperature, C°	22.2 ± 0.5	23.3 ± 0.4	23.3 ± 0.8
Relative humidity, %	46.5 ± 2.7	52.4 ± 4.3	50.5 ± 6.0
CO_2 concentration, ppm	1312.2 ± 485.4	2586 ± 543.7	2039 ± 823.8
Indicators M ± SD	Second shift (Room 2)		
	Lessons		
	1	2	3
Temperature, C°	25.7 ± 0.2	25.7 ± 0.9	25.7 ± 0.2
Relative humidity, %	31.3 ± 2.5	32.5 ± 5.0	33.5 ± 2.5
CO_2 concentration, ppm	1443.3 ± 482.7	2097.1 ± 425.1	2097.6 ± 500.6

of eight pairs of rows of single-digit numbers, with the numbers arranged vertically one above the other. The performance coefficient C_{per} is calculated as S2/S1, where S2 is the sum of correctly performed additions of the last four rows (S2), and S1 is the sum of correctly performed additions of the first four rows (S1).

2. Memory for numbers [21], designed to assess the dynamics of short-term memory, completed twice during the school day (n = 88). The mnemonic performance is evaluated by the number of correctly found numbers: 2 points — low efficiency, 3 points — satisfactory, 4 points — average, 5 points — high.

3. Munsterberg's method [22], designed to assess the attention concentration and stability, completed three times during the school day (n = 132). The testing involves finding words in rows random letters, duration — 2 minutes. The measured results are the number of incorrectly highlighted words and the number of missed words. The level of stability and concentration of attention can be low, below average, average, above average, and high.

Statistical data processing was performed using the methods of parametric and nonparametric analysis. The distribution of quantitative variables was assessed using the Shapiro–Wilk test when number of indicators was below 50 and the Kolmogorov–Smirnov test when it exceeded 50.

We used the standard methods of descriptive statistics: calculated means, standard deviations, medians, ranges (minimum and maximum), 25th–75th percentiles, and coefficients of variation.

For the comparative assessment of changes in quantitative indicators, we used the parametric Student's t-test for normally distributed data. In the case of a non-normal distribution, the Mann–Whitney test was applied for two independent groups, the Wilcoxon test for two dependent groups, and the Kruskal–Wallis test for several independent groups.

To study the relationship, we used the correlation analysis methods. The Pearson correlation coefficient was used to assess the strength of the relationship between quantitative indicators with a normal distribution, and the Spearman rank correlation — for variables with non-normal distributions. Correlation coefficients were interpreted using the Chaddock scale: weak (0.1–0.3), moderate (0.3–0.5), strong (0.5–0.7), high (0.7–0.9), very high (0.9–0.99). The significance of the relationship was assessed using the Student's t-test, and the relationship was considered significant at $p < 0.05$.

Statistical processing was performed in STATISTICA 10 (StatSoft; USA) and MS Office Excel 2016 (Microsoft; USA).

RESULTS

The assessment of the actual dynamics of temperature, relative humidity, and CO_2 concentration was performed to determine the cause-effect relationship of these parameters and the functional state of students. The recorded values of the indicators generally varied highly. During the first shift, the mean air temperature was within acceptable limits. In the second shift, we registered values exceeding the norm: the temperature in Room 2 was significantly higher than that recorded earlier in Room 1 through all three lessons ($p < 0.001$ for each comparison). The relative humidity in Room 1 was significantly higher than in Room 2 during all lessons ($p < 0.001$). The CO_2 concentration varied greatly during the school day in both classrooms, reaching values significantly exceeding those recommended in the hygienic standard (800–1000 ppm, GOST R EN 13779—2007 "Ventilation in non-residential buildings. Technical requirements for ventilation and air conditioning systems"). Significant differences in CO_2 concentration between shifts were observed only in the second lesson ($p = 0.049$); in the first and third lessons, the values of this parameter did not differ significantly ($p > 0.05$). The dynamics of indicators within each shift also deserves attention. In Room 1, the CO_2 concentration increased from the first to the second lesson (from an average of 1312 to 2586 ppm), and decreased by the third lesson (2039 ppm), remaining high. In Room 2, the CO_2 concentration increased from the first to the second lesson (from 1443 to 2097 ppm) and remained almost unchanged in the third lesson (2098 ppm). Thus, we identified stable differences in temperature and humidity between shifts, while the differences in CO_2 concentration were unsystematic (Table).

It should be noted that although the ventilation and heating systems are in working condition and hygienic requirements for classroom cleaning and airing are met, the microclimate parameters and carbon dioxide concentration indicate that the current preventive measures are not sufficiently effective. This highlights the need for new engineering solutions to ensure optimal air quality in classrooms.

Over the course the school day, the classroom microclimate indicators, including carbon dioxide concentration, generally increased from the 1st to the 6th lesson. This increase was associated with the growth of proportion of schoolchildren whose performance dropped significantly — by more than 30% ($p < 0.05$; Fig. 1A). "At the same time, we observed a more drastic drop in the share of well-performing students during the first shift — by more than 40% ($p < 0.01$ for the pairwise comparison of proportions between the 1st and 6th lessons). By the end of the school day (second shift), there were no schoolchildren showing a high level of performance, and the differences in the distribution of the performance indicators between the beginning and the end of the school day were significant ($p < 0.001$). These changes, together with the influence of the studied factors, may result from the natural buildup of fatigue by the end of the second shift (Fig. 1B).

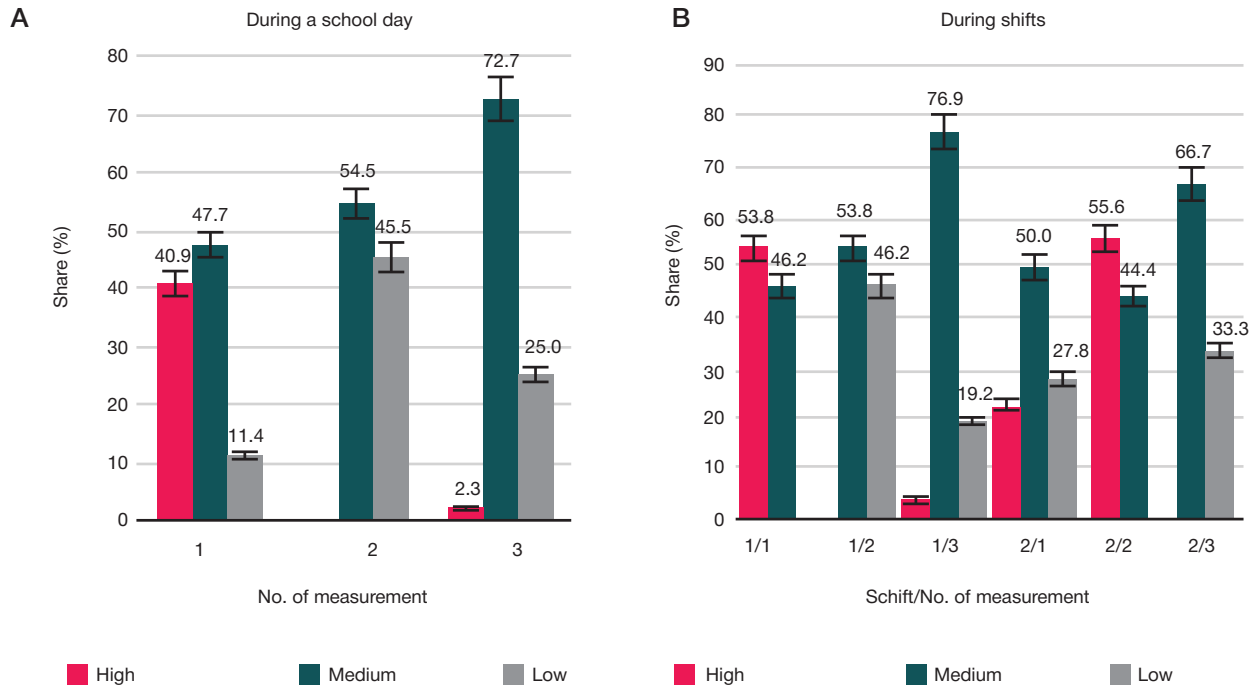

Fig. 1. Characteristics of schoolchildren by performance, %

The characteristic of the performance coefficient depending on the actual dynamics of the microclimate and carbon dioxide concentration is shown in Fig. 2. Using the Spearman's rank correlation coefficient, we found significant inverse moderately strong relationships between the performance coefficient and CO_2 concentration (r = –0.464, r^2 = –0.198, p = –0.0000), as well as weak ones between the performance coefficient and air temperature (r = –0.327, r^2 = –0.118, p = –0,000). As for humidity, it did not affect the said coefficient significantly (r = –0.056, r^2 = –0.003, p = –0.821).

The evaluation of the dependence of mnemonic processes on the dynamics of microclimate and carbon dioxide concentration (using Spearman's rank correlation coefficient) revealed significant inverse relationships of moderate strength between memory performance and CO_2 concentration (r = –0.500, r^2 = 0.254, p = 0.001), as well as between memory performance and air temperature (r = –0.384, r^2 = 0.141, p = 0.002). The relationship between memory performance and relative humidity was insignificant (r = –0.060,r^2 = –0.002, p = –0.577).

A comparative assessment of short-term memory showed that, over the study period, the proportion of students whose short-term memory remained highly effective by the end of the school day decreased from 22.7% to 9.1%, while the proportion of those who demonstrated low accuracy and poor short-term memory efficiency increased from 6.8% to 18.2% (Fig. 3A). This finding is relevant to both shifts: in the first shift,

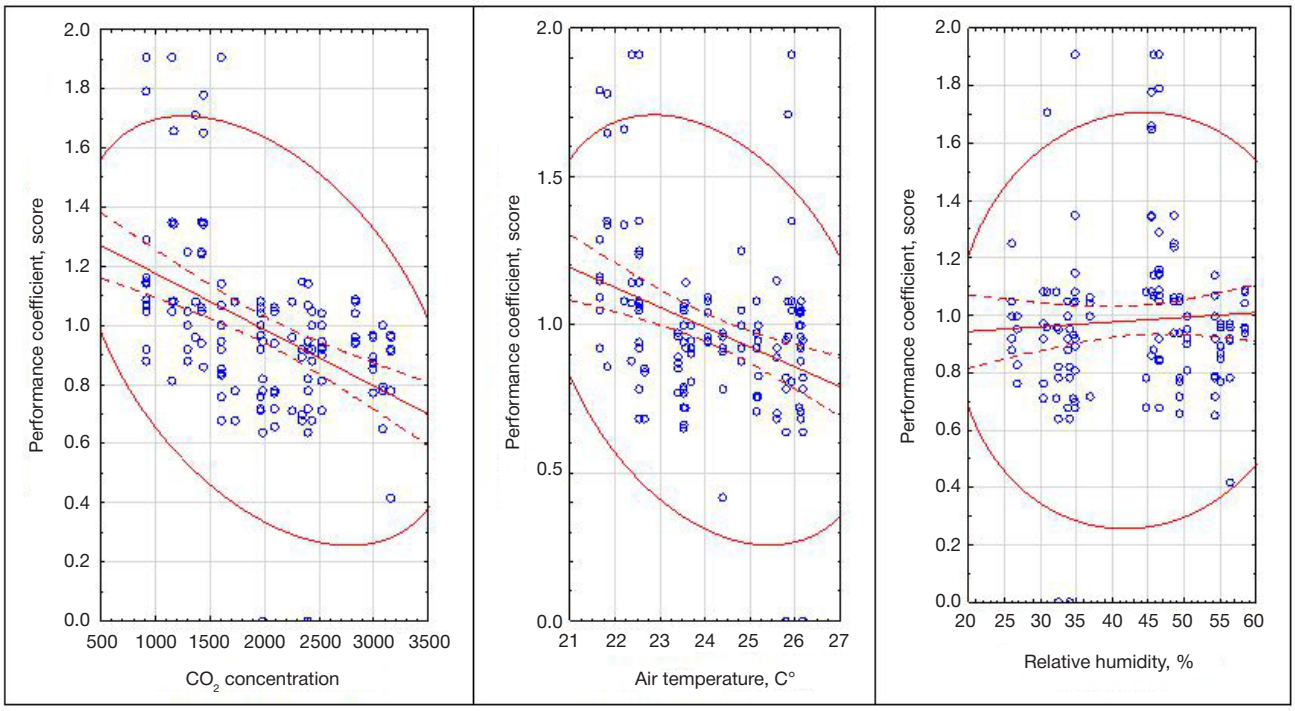

Fig. 2. Dispersion diagram of correlations between CO_2 concentration, temperature, relative humidity, and the performance coefficient

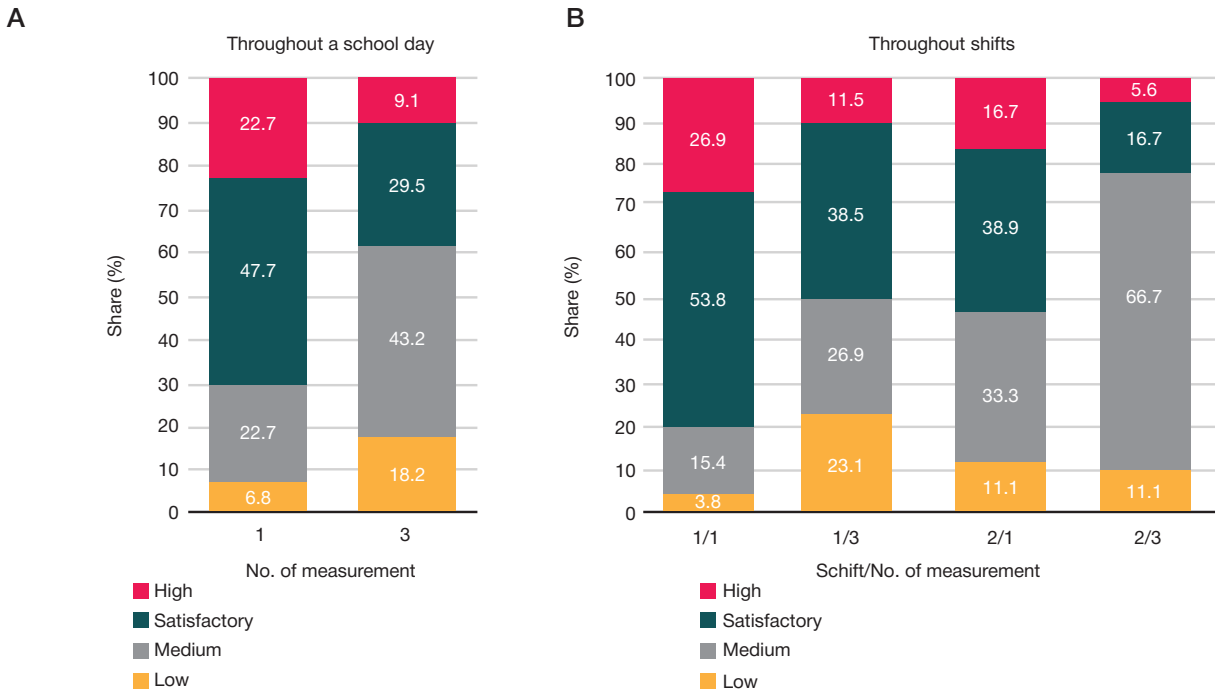

Fig. 3. Effectiveness of mnemonic processes among students throughout the school day, %

the considered indicator dropped by 15.4%, in the second shift — by 10.9% (Fig. 3B).

The share of students with low mnemonic efficiency is greatest at the highest carbon dioxide levels (Fig. 4).

Using the Munsterberg test [22], we assessed the selectivity and volume of attention in the dynamics of the school day. This test allows determining the degree of fatigue depending on the actual indicators of the microclimate and CO_2 concentration.

The results of the test, which reflect the dependence of the number of correct answers on the parameters of the microclimate and CO_2 concentration in the classrooms, are shown in Fig. 5.

In the dynamics of the school day, the assessment of fatigue levels based on actual microclimate indicators and carbon dioxide concentration revealed a strong inverse correlation between CO_2 concentration and the number of correct answers, both over the entire monitoring period and across study shifts (r = –0.599, r^2 = 0.359, $p < 0.0001$) There was also a weak significant inverse relationship between fatigue indicators and air temperature (r = –0.303, r^2 = –0.092, p = –0.0004), as well as relative humidity (r = –0.244, r^2 = –0.059, p = –0.005).

The largest proportion of respondents with the highest levels of fatigue was registered during periods when the optimal concentrations of carbon dioxide in the classroom air were exceeded (Fig. 6).

The distribution of students by attention span and selectivity also indicates that fatigue becomes more prevalent as the school day progresses. Over the entire observation period, the share of children with high fatigue levels increased by 70.4%: from 2.3% at the beginning to 72.7% by the end of lessons. Specifically, in the first shift, the proportion rose from 3.8% to 65.4%, and in the second shift — from 0% to 77.8%. In the background of this process, there is a progressive deterioration in the parameters of the air environment: carbon dioxide concentration, elevated from the outset (Table), increased by 1.5–2 times by the middle of the school day, significantly exceeding hygiene standards. In addition, during the second shift (Room 2), the air temperature was consistently above the permissible values, and the relative humidity decreased.

DISCUSSION

The importance of maintaining good air quality in classrooms and other educational spaces is beyond doubt. Back in the 1980s, Russian scientists observed a direct relationship between air quality and the well-being, performance, and other functional indicators of students, as well as significant variability in the indoor microclimate under conditions of insufficient or imperfect air exchange [23, 24]. According to current interstate standards (GOST 30494—2011 "Residential and public buildings. Indoor climate parameters"; GOST R EN 13779—2007 "Ventilation in non-residential buildings. Technical requirements for ventilation and air conditioning systems"), carbon dioxide concentration is the main indicator of indoor air quality, serving both as an independent factor and as an integral marker of human-related air pollution.

In this study, assessing the relationship between the parameters of the microclimate, CO_2 concentration, and mental performance

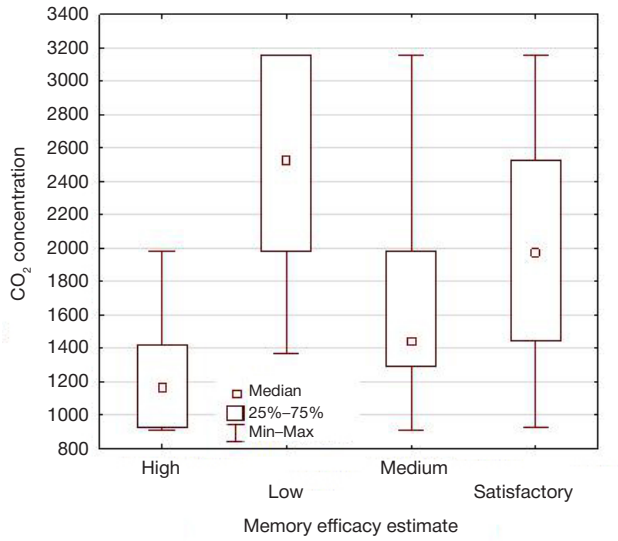

Fig. 4. Distribution of students' short-term memory efficiency depending on the actual carbon dioxide concentrations over the entire monitoring period

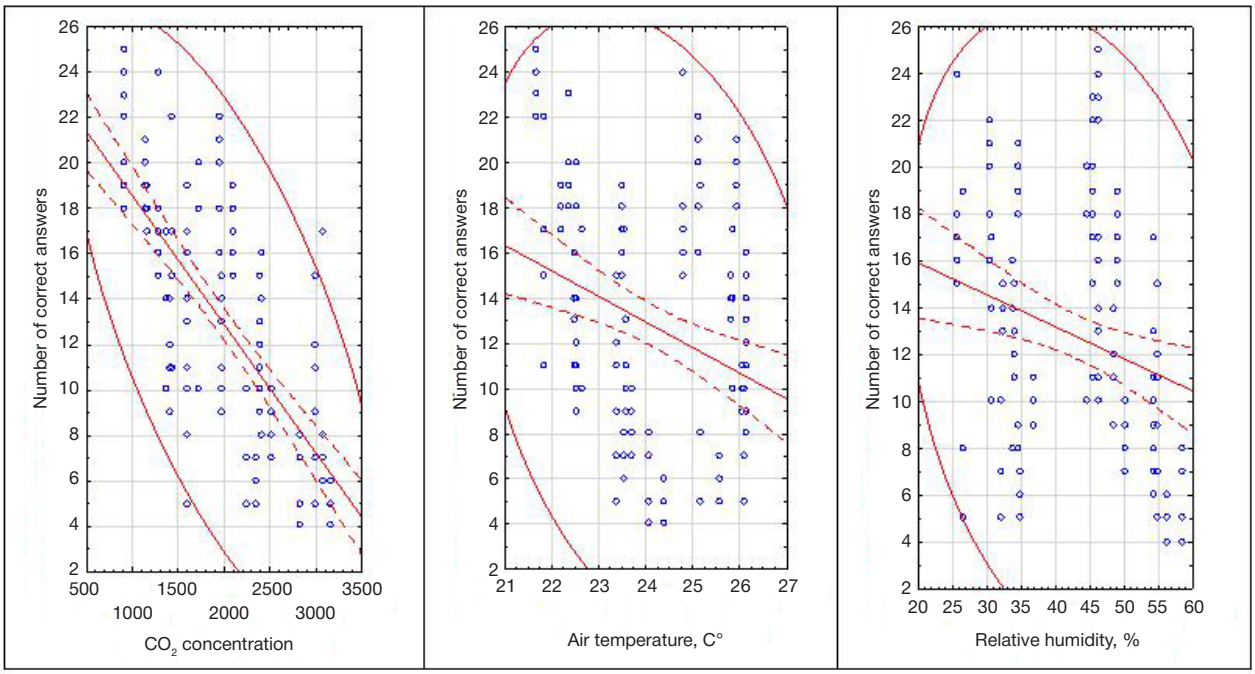

Fig. 5. Dispersion diagram of correlations between microclimate indicators and CO_2 concentration and the number of correct answers

of students, we registered a progressive deterioration in their functional state during the day. In Room 1, the number of students capable of high performance by the end of the first shift decreased by 30%, and in Room 2, there were no such students by the end of the second shift. The lack of high-performing schoolchildren by the end of the second shift deserves a special mention. There was a combination of factors behind this phenomenon: consistently increased air temperature throughout the day (exceeding the regulatory values) and a significant increase in the initially high concentration of CO_2. Such a combination could have a negative effect.

Correlation analysis confirmed significant inverse relationships, moderately strong and weak, between performance indicators, mnemonic processes, fatigue, and microclimate parameters (CO_2 concentration and air temperature). It is important to note that although the observed correlations are consistent with the hypothesis of the influence of environmental factors, they do not allow an unambiguous declaration of cause-and-effect relationships. The data obtained indicate that a decline in performance and deterioration of cognitive functions (such as memory and concentration) over the course of the school day occur in parallel with a progressive deterioration in the parameters of the air environment. This is consistent with literature data indicating a link between weakening cognitive capabilities and elevated CO_2 concentrations [25], as well as unfavorable microclimate parameters [26–29].

However, it is necessary to take into account the complex nature of the impact. The learning process itself is a burden, which naturally leads to fatigue. In the context of this observational study, it is impossible to fully isolate the contribution of the actual educational load and the contribution of the microclimate parameters to the observed deterioration of the functional state. Therefore, a more accurate conclusion is that when the learning process takes place under unfavorable air and thermal conditions (such as combined anthropogenic air pollution, high temperature, and low humidity), the development of fatigue and the deterioration of cognitive functions in students are more pronounced. The revealed relationships indicate the potential role of these environmental factors as aggravating components in the overall picture of learning fatigue.

Limitations and prospects of the study

The limitations of the study include its observational design, which does not allow full control of all related factors (person-specific variability of fatigue, pedagogical techniques, etc.), as well as measuring CO_2 concentration as the main, but not the only, marker of air quality. Further controlled intervention studies are needed to more accurately establish cause-and-effect relationships and assess the contribution of each factor. Such a study could include, for example, targeted adjustment of ventilation parameters and monitoring of a wider range of indoor air contaminants. The results of this work justify the need for continuous monitoring and the development of preventive measures to improve classroom air quality as an essential element of a healthy educational environment.

CONCLUSIONS

Continuous monitoring of temperature, relative humidity, and carbon dioxide concentration in educational facilities

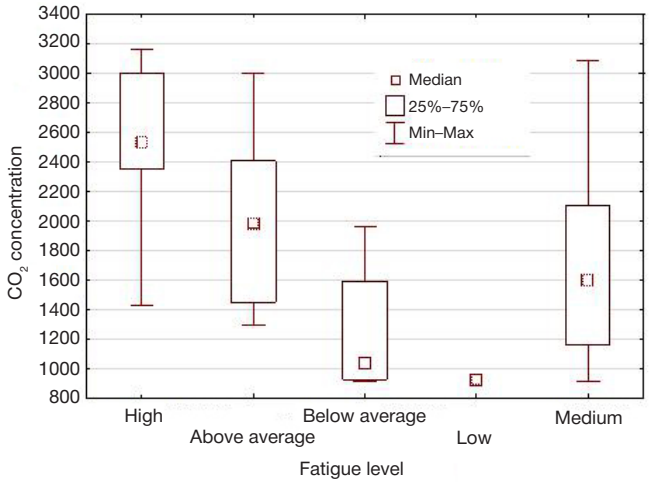

Fig. 6. Distribution of students' fatigue levels depending on the actual carbon dioxide concentrations over the entire monitoring period

revealed significant deviations from the regulated values of these parameters over the course of the school day. Room 2 (second shift) had a higher temperature because it was heated continuously throughout the day, used for part-time activities in the morning, and exposed to sunlight in the afternoon. In contrast, Room 1, which was occupied only during the first shift, lacked these sources of heat and prolonged exposure. The lower relative humidity in Room 2 is consistent with the hypothesis of increased temperature and possible insufficient ventilation efficiency. High and comparable levels of carbon dioxide concentration in both classrooms, reaching values significantly exceeding the hygienic standard, indicate that the natural ventilation, managed by a pattern, is insufficient to ensure the necessary air exchange given the actual occupancy of classrooms. The increase in CO_2 concentration by the second or third lesson reflects a typical accumulation of anthropogenic pollutants, and the absence of a systematic difference between classrooms suggests that the ventilation regime in place is ineffective at maintaining acceptable CO_2 levels, regardless of the time of classes. Thus, the presented parameters of the microclimate and carbon dioxide were formed in the conditions of typical classrooms with natural ventilation and a standard but insufficiently effective air exchange regime, and the differences in temperature and humidity are primarily related to the different times of use of classrooms during the day and the resulting differences in thermal balance. The correlation analysis confirmed that variations in classroom microclimate and carbon dioxide concentration were associated with changes in students' cognitive performance indicators. We have shown that elevated indoor carbon dioxide concentrations can reduce the effectiveness of mental performance, including shortterm memory, attention span, and concentration, and can significantly increase the proportion of students experiencing fatigue.

The results of this study make it possible to identify causal relationships within the system linking qualitative and quantitative indicators of air quality in educational institutions to the actual functional state of students. These relationships form the basis for developing a risk assessment system and a program to prevent adverse reactions in students' functional body systems in general education settings.

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