

RUSSIAN BULLETIN OF HYGIENE

SCIENTIFIC MEDICAL JOURNAL

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ADDRESS Ostrovityanov St. 1, Moscow, 119997, Russia

Indexed in RSCI. IF 2018: 0,5

Open access to archive



Issue DOI: 10.24075/rbh.2026-03

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; address: Ostrovityanov Street 1, Moscow 119997 Russia

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Approved for print 30.09.2026
Circulation: 100 copies. Printed by Print.Formula
www.print-formula.ru

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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.2026-03

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);

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Подписано в печать 30.09.2026

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

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FUNCTIONAL INDICATORS AND PHYSICAL FITNESS IN COMPREHENSIVE ASSESSMENT OF THE HEALTH OF CHILDREN WITH DISABILITIES OR SPECIAL HEALTH NEEDS

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In the context of declining birth rates, maintaining the health of children with disabilities and special health needs (SHN) is one of the state's tasks. A comprehensive assessment of children's health is essential for solving this problem. The study aimed to justify the inclusion of quantitative indicators of functional state, physical development and physical fitness in the comprehensive assessment of the health of children with disabilities and SHN. A cross-sectional study was conducted in September 2025 at the boarding school for disabled children and children with SHN ($n = 69$) and the ordinary school ($n = 69$). Students aged 7–17 years were matched by gender, age, and body length. During the study we assessed physical development, psycho-functional state, physical fitness, and nutrition. The cluster analysis (k-means) was performed based on 11 indicators in a combined sample ($n = 138$). As a result, two clusters were allocated: "dysfunctional" (64 children, among them 35.9% from the ordinary school) with poor adaptation, excess body weight, high fat consumption; "functional" (74 children, among them 37.8% from the boarding school) with good adaptation, normal body weight, but low caloric intake. Contradictions have been identified between health groups and medical groups for physical education. The data obtained indicate that children with disabilities have various psycho-functional states that change during their stay in an educational organization, comparable in some cases to those of children from the ordinary school. It is recommended to supplement the comprehensive health assessment of children with disabilities and children with SHN by defining quantitative indicators of physical development, body's functional state, and data on the children's physical fitness. Furthermore, the child's lifestyle, typical for children of his/her age, should be taken into account.

Keywords: comprehensive health assessment, health groups, medical groups for physical education, functional state, disabled children, children with special health needs, schoolchildren, cluster analysis

Author contribution: Gudinova ZhV — research supervision, study concept, development of methodology, data analysis and systematization, critical revision and editing of the manuscript, drawing conclusions; Rybkin AA — collection, analysis and generalization of literature data, data collection, application of statistical and mathematical methods for data analysis, interpretation of the study results, manuscript writing, graphics; Demakova LV — collection, analysis and generalization of literature data.

Compliance with ethical standards: the study was approved by the Ethics Committee of the Omsk State Medical University (Minutes No. 10 of September 19, 2023, No. 13 of October 22, 2025). Parents (guardians) of the participants submitted written informed consent forms.

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Received: 07.05.2026 **Accepted:** 09.06.2026 **Published online:** 24.08.2026

DOI: 10.24075/rbh.2026.168

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ФУНКЦИОНАЛЬНЫЕ ПОКАЗАТЕЛИ И ФИЗИЧЕСКАЯ ПОДГОТОВЛЕННОСТЬ В КОМПЛЕКСНОЙ ОЦЕНКЕ ЗДОРОВЬЯ ДЕТЕЙ-ИНВАЛИДОВ И С ОГРАНИЧЕННЫМИ ВОЗМОЖНОСТЯМИ ЗДОРОВЬЯ

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В условиях спада рождаемости сохранение здоровья детей-инвалидов и с ограниченными возможностями здоровья (ОВЗ) является одной из государственных задач. Значимой для решения этой задачи является комплексная оценка здоровья детей. Целью исследования было обосновать включение количественных показателей функционального состояния, физического развития и физической подготовки в комплексную оценку здоровья детей с инвалидностью и ОВЗ. Поперечное исследование проведено в сентябре 2025 г. на базе школы-интерната для детей-инвалидов и с ОВЗ ($n = 69$) и обычной школы ($n = 69$). Учащиеся в возрасте 7–17 лет были подобраны по полу, возрасту и длине тела. В ходе исследования оценивали физическое развитие, психофункциональное состояние, физическую подготовленность и питание. Выполнен кластерный анализ (k-средних) по 11 показателям на объединенной выборке ($n = 138$). В результате выделены два кластера: «неблагополучный» (64 ребенка, из них 35,9% из обычной школы) с плохой адаптацией, избытком массы тела, высоким потреблением жиров; «благополучный» (74 ребенка, из них 37,8% из школы-интерната) с хорошей адаптацией, нормальной массой тела, но низкой калорийностью рациона. Выявлены противоречия между группами здоровья и медицинскими группами для занятия физическим воспитанием. Полученные данные свидетельствуют о том, что дети-инвалиды имеют различные изменяющиеся в процессе пребывания в образовательной организации психофункциональные состояния, сопоставимые в ряде случаев с таковыми у детей из обычной школы. Рекомендовано дополнить комплексную оценку здоровья детей-инвалидов и детей с ОВЗ определением количественных показателей физического развития, функционального состояния организма, данными по физической подготовленности детей. Помимо этого следует учитывать образ жизни ребенка, свойственный детям его возраста.

Ключевые слова: комплексная оценка здоровья, группы здоровья, медицинские группы физического воспитания, функциональное состояние, дети-инвалиды, дети с ограниченными возможностями здоровья, школьники, кластерный анализ

Вклад авторов: Ж. В. Гудинава — научное руководство, концепция исследования, развитие методологии, анализ и систематизация данных, критический пересмотр и редактирование текста рукописи, формулировка выводов; А. А. Рыбкин — сбор, анализ и обобщение данных литературы, сбор данных, применение статистических и математических методов для анализа данных, интерпретация результатов исследования; написание текста рукописи, работа с графическим материалом; Л. В. Демакова — сбор, анализ и обобщение данных литературы.

Соблюдение этических стандартов: исследование одобрено этическим комитетом ФГБОУ ВО ОмГМУ Минздрава России (протоколы № 10 от 19 сентября 2023 г., № 13 от 22 октября 2025 г.). Получены письменные информированные согласия родителей (опекунов).

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Статья получена: 07.05.2026 **Статья принята к печати:** 09.06.2026 **Опубликована онлайн:** 24.08.2026

DOI: 10.24075/rbh.2026.168

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In the context of declining birth rates, maintaining the health of every child, including children with disabilities and children with special health needs (SHN), is an important state task [1–5]. A major role in solving this problem is played by a comprehensive assessment of children's health, the basis of which, based on well-known methodology and techniques, was provided back in 1965 by S.M. Grombach [6], carried out in our country for a long time and currently regulated by the regulatory documents of the Ministry of Health of the Russian Federation [7]. However, in our opinion, regarding children with disabilities and children with SHN, there are still certain methodological difficulties in the comprehensive assessment of health, including in determining the health group (HG) and medical groups (MG) for physical education (PE) classes [8].

To clarify the comprehensive assessment of the health of children with disabilities and SHN, it is proposed to define additional informative health parameters: children's functional status, physical development, and the main indicators of their physical fitness. The indicators were selected considering the specifics of the educational environment of boarding schools (possible stress — illness, being at school 24/7, separation from family), accessibility and ease of use of these methods in the context of the educational institution by a doctor and a PE teacher at school. It is also important that all the indicators are quantitative, which always facilitates the assessment of the state, and also increases the possibility of using indicators during statistical analysis of data.

The study aimed to justify the inclusion of quantitative indicators of functional state, physical development, and physical fitness in the comprehensive assessment of the health of children with disabilities and SHN.

METHODS

The cross-sectional study was conducted in September 2025 at the Municipal Autonomous Educational Institution (MAOU) "Ishim Boarding School" for children with SHN and disabilities (hereinafter, boarding school) and the secondary comprehensive school No. 4, Ishim (hereinafter, control school). The study involved 138 children aged 7 to 17 years: 69 from the boarding school (the sample was limited to the population of schoolchildren, who studied at the boarding school in the academic years 2023–2025) and 69 from the control school. Children who attended the boarding school had 2–8 established diagnoses. The two leading disorders that all children had were disorders of the nervous system and sensory organs (hearing loss), as well as mental disorders. Children from the control school were selected by pairwise comparison with the index group by gender, age, and body length. Inclusion criteria: age 7–17 years, studying at the MAOU "Ishim Boarding School" or the secondary comprehensive school No. 4, Ishim, availability of the parents' (legal representatives') informed consent, for boarding school — "disabled child" or "child with SHN" status, for control school — no such status. Exclusion criteria: failure to meet any of the inclusion criteria, no informed consent, attending any other educational institution, for boarding school — no "disabled child" or "child with SHN" status, for control school — "disabled child" or "child with SHN" status.

Physical development was assessed based on the anthropometric measurements performed by the medical specialist at school in accordance with the body mass index (BMI) estimates and the World Health Organization (WHO) tables [9]. The index method was selected due to the need for a quantitative indicator for subsequent statistical processing of data (cluster analysis).

To assess the children's body psychofunctional state, the estimated criteria based on anthropometric (body length, body weight) and functional measurements (heart rate, blood pressure, pulse blood pressure) performed by the medical specialist at school were selected. The following were calculated: adaptive potential of the cardiovascular system according to R.M. Baevsky (AP) [10]; stress level according to Yu.R. Shejkh-Zade [11]; maximum oxygen consumption (MOC) according to the method by S.A. Dushanin [12].

Physical fitness was assessed based on the questionnaire survey results and excerpts from the PE teacher's journal, as well as based on three indicators included in GTO standards: two footed standing long jump, cm — speed-strength capabilities; standing forward bend on a gymnastic bench (for healthy schoolchildren) and seated forward bend on the floor with both legs straight (for children with health problems [13]), cm — flexibility; 30 m and 60 m run — speed capabilities. All the tests were conducted by the PE teacher at school during classes and estimated for each child as a percentage of the "silver" GTO standard [13, 14].

The hygienic assessment of nutrition is based on the analysis of menu layouts, diet control sheets, and technical cards. The children's actual nutrition was assessed by the questionnaire survey (34 questions, including a table of the frequency of food and dish consumption throughout the month, developed by the researchers of the Federal Research Center of Nutrition, Biotechnology, and Food Safety) and the 24-h dietary recall method. The data on nutrition were processed using the Diet Calculation Module software (Institute of Physiology of the Komi Scientific Center of the Ural Branch of the Russian Academy of Sciences, Boyko ER, Eseva TV, Evdokimov AV; Russia). The standards established by sanitary legislation were taken as standard values [15].

Statistical processing of the research results was performed by the descriptive statistics methods, cluster analysis (k-means) in the Statistica 6.0 software package (StatSoft; USA); the differences were considered significant at $p < 0.05$ [16]. Clustering was performed on a combined sample of children (boarding school and control school, $n = 138$). All indicators were standardized according to the cluster analysis method in the corresponding option of the Statistica 6.0 software package (StatSoft; USA) based on the following characteristics:

- MOC: the higher, the better;
- AP: the higher, the poorer adaptation;
- stress level: the higher, the worse, the more likely stress;
- GTO test "Standing long jump": the higher the better (jump range);
- GTO test "Flexibility": the higher, the more flexible;
- GTO test "30/60 m run": the higher, the worse (slower running speed);
- BMI;
- caloric content, percentage of normal consumption;
- proteins, percentage of normal consumption;
- fat, percentage of normal consumption;
- carbohydrates, percentage of normal consumption.

RESULTS

Based on the questionnaire survey results and excerpts from the boarding school PE teacher's journal it was determined that 100% of children with disabilities and SHN study at the boarding school. Among them 46.4% attend sports sections (and 4.3% attend sports sections with high-intensity training twice a week or more often), 23.2% have passed

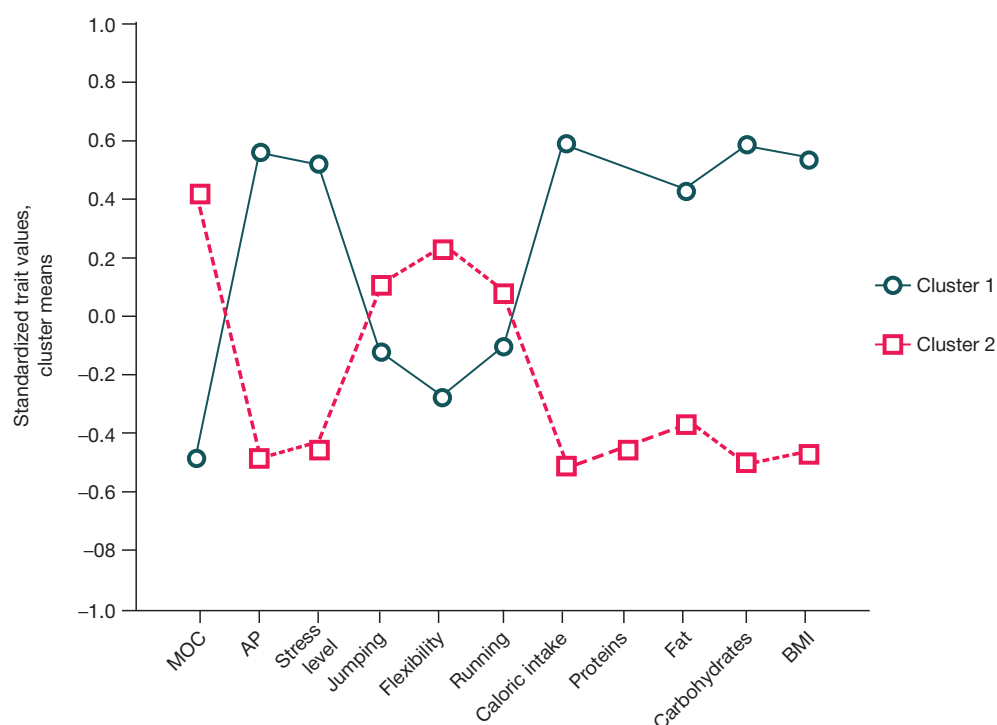


Fig. Clustering of mean values of the functional state and physical fitness indicators

the GTO tests and received the "silver" badge (standards adapted for disabled children).

Catering in both schools is generally compliant with hygienic standards [15]. However, the children's actual diet is unbalanced and non-compliant with hygienic standards: In both schools, children aged 7–11 years had adequate energy intake and protein intake, while fat consumption was excessive and carbohydrate consumption was insufficient (by 14–16%). The energy value of the diet of adolescents at the boarding school was normal, while in the control school the energy value of the diet was insufficient — by 6.8% lower compared to the standard [15]. In the control school, the adolescents' consumption of proteins and carbohydrates was 12.8 and 23.1% lower, respectively, and that of fat was 25.4% higher. Furthermore, an imbalance in the consumption of proteins, fats, and carbohydrates (hereinafter, PFC) was reported for both groups: children from the boarding school — 1 : 1.2 : 3.8; children from the control school — 1 : 1.4 : 3.8; adolescents from the boarding school — 1 : 1.3 : 4.0; adolescents from the control school — 1 : 1.5 : 3.8.

The clustering results are shown in the Figure and in the Table. As can be seen from the Figure and Table, as a result of cluster analysis, the cohort of children was divided into two clusters that differed significantly in all 11 classification characteristics.

Cluster 1, "dysfunctional", is characterized by an unsatisfactory state of body adaptation based on all indicators (MOC, AP according to Baevsky, stress level according to Sheikh-Zade), overweight (based on BMI), lower flexibility indicators, excess caloric intake due to high fat consumption (129% of normal) (Fig., Table). This cluster consists of 64 children, among them 64.1% are schoolchildren from the boarding school, 35.9% are children from the control group.

More than half of the children in this cluster are children with HG V, there are 7.8% of children with HG III and 7.8% with HG I F3, 25.0% of children with HG II. As for MG for PE, more than a half of children belonging to the preparatory MG (56.3%), about a third of children belong to the main MG, and a 12.4% belong to the special group (two schoolchildren

from the control school out of two). As for age, these children are older — half of them are high school students (Table).

As stated above, 35.9% of the cluster (23 children) are children from the control school (healthy). A total of 60.9% of these children are overweight (up to morbid obesity), 34.8% have tension of adaptation mechanisms, and 4.3% have stress. GTO badges were received by 100% of these children (among them 39.1% received a "golden" badge). A total of 21.7% of children from the control groups included in this cluster had HG I, 69.6% had HG II, and 8.7% had HG III. Most children (87.0%) belonged to the main MG, 4.3% to the preparatory one, and 8.7% to the special MG (all were children with HG III). Exceeding the actual daily caloric intake was reported for 78.3% of these schoolchildren. PFC ratio: 1 : 1.5 : 3.9 (Table).

Cluster 2, "functional", is characterized by good adaptation, low stress, normal body weight, good flexibility indicators, combined with a low calorie diet due to low protein and carbohydrate intake (70–77% of normal). This cluster includes 74 children, among them 62.2% were schoolchildren from the control school and 37.8% were children from the boarding school (Fig., Table).

In this cluster, 48.7% of children had HG I and II, and 22.9% of children had HG III. However, 28.4% of this cluster are children with HG V. As for MG for PE classes, a half of children belong to the preparatory MG (50.0%), about a half (47.3%) of children belong to the main group, but there are children belonging to the special group (two children, among them one from the boarding school). One child from the control school was exempted from PE classes (Table).

As stated above, 37.8% (28 children) of this cluster are children from the boarding school (disabled and with SHN). The majority (92.9%) of them have normal body weight (with the exception of one child with underweight and one child with grade 2 obesity). A total of 96.4% of these children have satisfactory adaptation, 78.6% have no stress and have different MOC values (low to high). More than half of these children (57.1%) specified in the questionnaire that they were not engaged in sports, but 89.3% of children received

Table. Comparative characteristics of clusters, mean values

Indicators	Cluster 1	Cluster 2	<i>p</i>
Number of children per cluster, abs.	64	74	
Fraction of schoolchildren studying at the boarding school, %	64.1	37.8	0.002
Fraction of schoolchildren of the control group, %	35.9	62.2	0.002
Health group (HG), %			
– HG I	7.8	17.6	0.088
– HG II	25.0	31.1	0.428
– HG III	7.8	22.9	0.016
– HG IV	0.0	0.0	1.000
– HG V	59.4	28.4	0.000
Medical group for physical education (MG), %			
– main	31.3	47.3	0.056
– preparatory	56.3	50.0	0.460
– special	12.4	2.7	0.028
Indicators of health and adaptation, mean values			
BMI, kg/m ²	23.03	18.35	0.000
MOC, mL/min/kg	56.9	69.7	0.000
AP according to Baevsky (AU)	02.08	1.89	0.000
Stress level according to Sheikh-Zade (AU)	1.11	0.90	0.000
Jumping, % of normal	105	110	0.183
Flexibility, % of normal	102	160	0.002
Running, % of normal	85	91	0.263
Caloric content, % of normal	107	80	0.000
Proteins, % of normal	102	77	0.000
Fat, % of normal	129	99	0.000
Carbohydrates, % of normal	97	70	0.000

GTO badges (of which 50.0% received the “golden” badge). However, the majority of them (75.0% of the total number of children with disabilities and SHN included in the cluster) have HG V, while the rest (25.0%) have HG III. The overwhelming majority (89.3%) of children with disabilities and SHN included in this cluster belong to the preparatory MG for PE classes, among them the majority are primary school students (64.3%). These children have nervous system disorders (G93.8), bilateral sensorineural hearing loss (H90.3), mental disorders (F), eye diseases (myopia, astigmatism) in their medical history. The actual daily caloric intake of these children is insufficient — on average, it is 90.8% of normal. PFC ratio: 1 : 1.3 : 3.6 (Table).

DISCUSSION

The study showed that children and adolescents in boarding schools for children with disabilities have various psycho-functional states that change during their stay in the educational institution, which requires regular assessment of indicators for the objective preparation of individual rehabilitation and habilitation programs, supplemented by recommendations on nutrition and physical education of children, to determine the HG, the MG, as well as to create appropriate conditions for the realization of these programs and the implementation of recommendations.

Among children with disabilities, a fairly large category of those included in the “functional” cluster 2 was identified (28 people out of 69 or 37.8%), whose functional characteristics were close to those of their healthy peers. At the same time,

quite a lot of conditionally healthy children from the control group (23 out of 69 or 35.9%), in terms of their functional indicators, approached those of disabled children with multiple diagnoses and limitations in life activities. This fact can be associated with excess body weight, which is consistent with the data of other authors [17, 18]. In addition, it was noted that the health indicators of children with disabilities studying at the boarding school deteriorated with age, which is consistent with the data provided by other authors [19].

In our previous papers [8], we noted a number of problems and inconsistencies that, in our opinion, exist in the comprehensive assessment of the health of children with disabilities.

Firstly, in no case were students in either the boarding school or the control school diagnosed with HG IV, which is generally assigned extremely rarely in the Tyumen Region [20–22]. Secondly, certain inconsistencies have been noted which, in our opinion, are present in the results of the comprehensive assessment of children's health, specifically: the “functional” cluster included 37.8% of children with HG III and even V, while the “dysfunctional” one included 35.9% of children with HG I and II. The “functional” cluster included 2.7% of children belonging to the special MG for PE classes, while, the “dysfunctional” one included 31.3% of children belonging to the main MG. Furthermore, children with HG V lead a completely normal life for children of this age — they attend school and sports sections, get from home to school and back on their own, and participate in sports competitions for people with disabilities. In our opinion, such distribution of children based on MG for PE classes creates the risk of decreased

effectiveness of physical education for healthier children, and, on the contrary, the risk of developing severe clinical situations during PE classes for sicker children.

Considering the results of the study, it is also clear that some children with disabilities do not have such severe limitations in their life activities that they can be classified as HG V according to the requirements of the regulatory document [23]. And if they are still assigned to group V (in cluster 1 there are 26.1% of such children (Table)), then why are not all of them assigned to the special MG for PE classes (there are only 2.7% of such children (Table))?

In our opinion, in this case, the boarding school doctor experiences methodological difficulties in determining the HG severity: if the doctor can distinguish between HG III and V, then he/she cannot distinguish between HG IV and V, and therefore assigns a more severe group. There are difficulties in distinguishing between "limitations on the opportunity to study or work" (formulation of the HG IV) and "significant limitations on the opportunity to study or work" (formulation of HG V) [7, Appendix 2]. Furthermore, in the formulations of the MG for physical education classes, there is no concept of "limitations of opportunities", but only "limitation of physical activity" [7, Appendix 3], which is not the same thing.

Thus, there is a need for methodological clarifications regarding the comprehensive health assessment. Perhaps, children who lead a normal life for children of their age (those studying at school, even a specialized one, independently attending school, sports sections) should be assigned HG I through IV, and HG V should be assigned to children with severe disorders who need to be educated at home, with significant limitations in learning opportunities and disruptions of the life style that normal for children. That is, the key point in this case should be the child's lifestyle or social and environmental rehabilitation, as specified in the International Classification of Functioning, Disability and Health (ICF) [24]. To resolve these issues, it is obvious that there is a need to harmonize the conceptual apparatus of the Ministry of Health

of the Russian Federation [7] with that of the Medical and Social Expertise Service [7], as was mentioned earlier [8], and to apply quantitative methods for assessing the body's functional state and physical development (as one of the criteria for the comprehensive assessment of health, [7]), as well as indicators of children's physical fitness of as the resulting criteria of human health.

CONCLUSIONS

The child's functional well-being is determined not so much by diagnoses, disability status, or health group (HG), but by his/her actual adaptive reserves, body weight, and physical fitness level.

Among children with disabilities, there is a group of children ($n = 28$, 37.8%) whose functional indicators are close to those of their healthy peers, and among conditionally healthy children, a hidden group at risk was identified ($n = 23$), whose psychofunctional indicators and physical fitness were close to those of children with disabilities. Children in this hidden group at risk are overweight.

In both groups, there were no children with HG IV, as well as contradictions between the definition of the HG and the medical group for PE classes, which, in our opinion, indicates the need to harmonize methodological approaches to defining these groups, including with respect to the use of concepts of limitations in learning or work opportunities.

It is recommended to supplement a comprehensive assessment of the health of children with disabilities and those with special health needs with indicators of body mass index and functional state (assessment of adaptive potential according to R.M. Baevsky, stress level according to Yu.R. Shejkh-Zade, maximum oxygen consumption according to the method by S.A. Dushanin), physical fitness (standing long jump, flexibility, 30/60 m run). Furthermore, it is recommended to consider the child's lifestyle, typical for children of his/her age (facts of attending the educational institution, sports sections, etc.).

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TEN-YEAR TRENDS IN SCHOOL-RELATED MORBIDITY AMONG CHILDREN AND ADOLESCENTS IN RUSSIA

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The effects of educational environment factors and processes on the increasing incidence of certain functional disorders and chronic diseases, which can collectively be referred to as school-related diseases, is a relevant issue of childhood and adolescence hygiene. Seeking to prioritize preventive effort directions, this study aimed to analyze trends in overall and primary morbidity from these diseases among Russian children and adolescents from 2015 to 2024. The data collected for the descriptive analysis covered children (0–14 years old) and older adolescents (15–17 years old); they were officially reported by the Central Research Institute for Organization and Informatization of Healthcare. We assessed the dynamics of morbidity at the level of classes of diseases and certain disease entities, and calculated the disease chronization indices (DCIs). The data were systematized and analyzed in Microsoft Office Excel 2020. The study suggests criteria for classifying certain health disorders as school-related. We identified persistent morbidity trends (noticeable throughout the study period) for individual ICD-10 classes, and observed high DCI values for diseases of the eye, the musculoskeletal system, and mental disorders. These findings may be associated with increased psycho-emotional stress, educational and visual demands, and insufficient physical activity. The analysis of morbidity trends identified the following priority areas for preventive work: promoting physical activity among schoolchildren, reducing psycho-emotional stress associated with examinations in grades 9 and 11, teaching students how to arrange their educational and leisure activities, promoting healthy nutrition, and increasing sleep duration.

Keywords: preventive medicine, children and adolescents, school-related diseases, overall and primary morbidity, disease chronization index

Author contribution: Rapoport IK, Kuchma VR — study concept and design, article editing; Rapoport IK — data collection and article authoring; V Chubarovskiy VV — data collection and article editing; Sokolova SB — data collection, statistical analysis of results, and article editing; all authors — approval of the final version of the article, responsibility for the integrity of all parts of the article.

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Received: 03.04.2026 **Accepted:** 16.05.2026 **Published online:** 30.08.2026

DOI: 10.24075/rbh.2026.169

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ДЕСЯТИЛЕТНЯЯ ДИНАМИКА ЗАБОЛЕВАЕМОСТИ ДЕТЕЙ И ПОДРОСТКОВ РОССИИ ШКОЛЬНО-ОБУСЛОВЛЕННЫМИ БОЛЕЗНЯМИ

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Актуальной проблемой гигиены детей и подростков является влияние факторов учебной среды и напряженного образовательного процесса на рост заболеваемости некоторыми функциональными нарушениями и хроническими болезнями, которые условно можно отнести к «школьно-обусловленным нарушениям здоровья». Цель исследования — проанализировать динамику общей и первичной заболеваемости детей и подростков России школьно-обусловленными болезнями за 2015–2024 гг. для обоснования приоритетных направлений профилактической работы. Выполнен дескриптивный анализ общей и первичной заболеваемости детей (0–14 лет) и старших подростков (15–17 лет) школьно-обусловленными болезнями на основании данных, опубликованных в официальных статистических сборниках ФГБУ «ЦНИИОИЗ» МЗ РФ. Определены динамика заболеваемости по классам болезней и отдельным нозологиям и показатели хронизации заболеваний. Систематизация информации и статистический анализ проведены в электронных таблицах Microsoft Office Excel 2020. Представлено обоснование критериев отнесения определенных нарушений здоровья к «школьно-обусловленным». Выявлены устойчивые неблагоприятные тенденции динамики заболеваемости по отдельным классам МКБ-10, наблюдавшиеся в течение 10 лет в детско-подростковой популяции, и высокие значения показателя хронизации заболеваний по классам болезней глаза, костно-мышечной системы, психическим расстройствам, что может быть связано с увеличением психоэмоционального напряжения, учебной и зрительной нагрузки, гиподинамией. Анализ динамики заболеваемости показал, что приоритетными направлениями профилактической работы должны стать увеличение двигательной активности, снижение психоэмоционального напряжения при подготовке к экзаменам в 9 и 11 классах, обучение школьников рациональной организации учебной и досуговой деятельности, здоровое питание и увеличение времени сна.

Ключевые слова: профилактическая медицина, дети и подростки, школьно-обусловленные болезни, общая и первичная заболеваемость, показатель хронизации

Вклад авторов: И. К. Рапопорт, В. Р. Кучма — концепция и дизайн исследования, редактирование статьи; И. К. Рапопорт — сбор материала и написание текста статьи; В. В. Чубаровский — сбор материала и редактирование статьи; С. Б. Соколова — сбор материала, статистическая обработка результатов и редактирование статьи; все авторы — утверждение окончательного варианта статьи, ответственность за целостность всех частей статьи.

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Статья получена: 03.04.2026 **Статья принята к печати:** 16.05.2026 **Опубликована онлайн:** 30.08.2026

DOI: 10.24075/rbh.2026.169

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Numerous Russian and foreign studies conducted in isolated school cohorts suggest that educational environment, excessive workload, high academic performance requirements, pre-exam stress, digitalization of education, disrupted daily routine and nutrition patterns, low physical activity, and poor sleep significantly contribute to the deterioration of the health of schoolchildren [1–7]. The prevalence of certain functional disorders and chronic diseases that can be conditionally labeled "school-related health disorders" is growing in this population [8, 9]. Such disorders include both functional disruptions associated with uneven development of organs and body systems (typically transient course and not requiring medical attention), and diseases with a more severe chronic course that necessitate intervention. There is a certain connection between hereditary background and school-related health disorders; they may have different etiology and pathogenesis, but generally meet the following criteria:

- such disorders occur in 5% or more of schoolchildren;
- the severity of pathological processes and the prevalence of disorders increase from junior high school to high school.

School-related health disorders reduce the quality of life of schoolchildren and have social consequences, such as restrictions on service in the armed forces and limited choice of professions.

Functional disorders, such as neurotic reactions, postural disorders, and spasm of accommodation, are virtually excluded from the official statistics. Their prevalence can be established only in the context of a research that includes a thorough medical examination of children [10].

Official statistics document school-related diseases that are predominantly chronic. They are recorded using Form No. 12 "Number of Cases on the Medical Organization's Service Area" at first diagnosis and considered in the primary incidence analysis, and exacerbations, which are also recorded, are added to the dataset for overall prevalence analysis [1, 8, 9].

The grounds for classifying certain diseases as school-related are the links between the development of pathologies, educational environment, and behavioral health risk factors.

- myopia. Its pathogenesis is largely associated with high visual strain (including screen use), insufficient physical activity, and prolonged sitting in a static position; in the ICD-10 classification, myopia belongs to Chapter VII (H), "Diseases of the eye and adnexa" [11–13];

- neuroses, somatoform dysfunction of the autonomic nervous system, tension type headache. These conditions are caused by chronic neuro-emotional and examination-related stress, overwork, insufficient sleep, didactogenic influences, and school-related phobias; in ICD-10, they are assigned to Chapter V (F), "Mental and behavioural disorders," and Chapter VI (G), "Diseases of the nervous system" [1, 14–18];

- diseases of the circulatory system involving high blood pressure. Such diseases are associated with neuro-emotional and examination-related stress, overwork, insufficient sleep; they belong to Chapter IX (I), "Diseases of the circulatory system" [8, 16, 18];

- obesity (simple, constitutionally exogenous). This disease, often concomitant with disrupted carbohydrate metabolism, is caused by insufficient physical activity and poor nutrition (excessive calorific value); in ICD-10, it is described in Chapter IV (E), "Diseases of the endocrine system, eating disorders and metabolic disorders" [19, 20];

- chronic gastritis and duodenitis. Although these diseases have a helicobacterial etiology, they are also, in part, complex psychosomatic disorders linked to psychological stress, poor nutrition, and irregular daily routines; they belong to Chapter XI (K), "Diseases of the digestive system" [21, 22];

- deforming dorsopathies (including grade I–II scoliosis). The development of these pathologies is associated with insufficient physical activity, prolonged sitting in a static position, functionally incorrect posture at the workplace, and furniture mismatching height; they are classified in Chapter XIII (M), "Diseases of the musculoskeletal system and connective tissue" [23, 24].

- menstrual disorders in girls. Psychosomatic by nature, these disorders are associated with great nervous and emotional stress, stress caused by frequent tests, exam preparation, etc.; in ICD-10, they belong to Chapter XIV (N), "Diseases of the genitourinary system" [25, 26].

The dynamics of the overall and primary morbidity of the above-mentioned pathologies and classes of diseases to which they belong reflect the main trends in the changing health status of modern children and older adolescents.

This study aimed to prioritize prevention directions by analyzing the trends in overall and primary morbidity of Russian children (0–14 years old) and adolescents (15–17 years old) with school-related diseases in 2015–2024.

METHODS

For the analysis, we used data on the prevalence of school-related diseases and their primary morbidity among children (0–14 years old) and older adolescents (15–17 years old). The timeframe was 2015–2024; the data was collected from the official statistical publications of the Central Research Institute for Organization and Informatization of Healthcare [27]. In Russian medical practice, researchers calculate relative values per 100,000 population within the respective age cohort, using the procentimille (‰) indicator. The overall and primary morbidity for menstrual disorders is calculated for the number of girls under 15 and under 18, respectively.

Overall and primary morbidity data were analyzed using descriptive methods, and the percent change in morbidity rates in 2024 versus 2015, as well as the disease chronization index (DCI), were calculated. DCI, the ratio of overall morbidity to primary morbidity, was determined for 2015 and 2024. The index and the criteria underlying it have been proposed by public health experts [28]. DCI under 2 is considered "insignificant," from 2 to 4 — "significant," above 4 — "high."

MS Office Excel 2020 spreadsheets (Microsoft; USA) were used for accumulation, systematization of information and descriptive analysis.

An expert-analytical approach was applied to review data on the relationship between educational environment factors and schoolchildren's lifestyle, on the one hand, and the dynamics of school-related disease incidence and pathologies' chronization, on the other. The objective was to substantiate a package of preventive measures.

The article examines the dynamics of overall and primary morbidity among children and adolescents, focusing only on ICD-10 chapters and individual nosologies that can be conditionally regarded as school-related diseases.

RESULTS

During the ten-year period under consideration, **overall morbidity among children aged 0–14 years increased slightly by 0.3% — from 223920.7 ‰ to 224565.2 ‰** (Table 1).

Overall, within the ten years under consideration, the overall morbidity has grown for diseases of the endocrine system and metabolic disorders — by 37.1%, from 3944.2 ‰ to 5407.4 ‰ ; in particular, the number of obesity cases

Table 1. Morbidity due to school-related diseases among children aged 0–14 years: trends in incidence and chronization, 2015–2024

Classes of diseases according to ICD-10	Morbidity (per 100,000 children of the considered age)			Incidence trends, 2024 vs. 2015 (%)	Chronization	
	Type of morbidity	2015	2024		2015	2024
All diseases	Overall	223 920.7	224 565.2	+0.3	1.25	1.31
	Primary	179 741.3	171 683.9	–4.5		
Diseases of the endocrine system, metabolic disorders	Overall	3944.2	5407.4	+37.1	2.62	3.53
	Primary	1504.6	1533.3	+1.9		
including obesity	Overall	1217.6	1780.6	+46.2	3.19	3.99
	Primary	382.0	445.9	+16.7		
Mental disorders and behavioral disorders	Overall	2940.2	2853.7	–2.9	5.33	5.42
	Primary	552.0	526.1	–4.7		
Nervous system diseases	Overall	9115.3	9328.8	+2.3	2.4	3.11
	Primary	3802.9	3002.8	–21.0		
Diseases of the eye and adnexa	Overall	12074.1	13402.8	+11	2.02	3.07
	Primary	5981.9	4359.7	–27.1		
including myopia	Overall	3547.9	4712.0	+32.8	3.56	4.31
	Primary	997.6	1093.9	+9.7		
Diseases of the circulatory system	Overall	1980.3	1847.0	–6.7	2.71	3.72
	Primary	730.9	496.8	–32.0		
including diseases involving high blood pressure	Overall	60.8	46.6	–23.4	2.87	3.11
	Primary	21.2	15.0	–29.2		
Diseases of the digestive system	Overall	13272.7	11039.5	–16.8	1.81	2.52
	Primary	7322.3	4385.5	–40.1		
including gastritis and duodenitis	Overall	1919.2	1309.4	–31.8	2.64	3.33
	Primary	725.8	392.9	–45.9		
Diseases of the musculoskeletal system and connective tissue	Overall	7581.3	8777.8	+15.8	2.26	3.57
	Primary	3356.3	2458.5	–26.7		
including deforming dorsopathy	Overall	2236.1	2183.3	–2.4	2.62	3.53
	Primary	852.8	619.1	–27.4		
Diseases of the genitourinary system	Overall	5443.1	4732.0	–13.1	1.9	2.04
	Primary	2863.8	2323.6	–18.9		
including menstrual disorders	Overall	1592.0	1967.6	+23.6	1.51	1.56
	Primary	1055.8	1259.7	+ 19.3		

has increased by 46.2%, from 1217.6⁰/₀₀₀₀ to 1780.6⁰/₀₀₀₀. The overall incidence of diseases of the nervous system has grown slightly by 2.3%, from 9115.3⁰/₀₀₀₀ to 9328.8⁰/₀₀₀₀. The overall morbidity from diseases of the eye and adnexa rose significantly by 11.0% (from 12074.1⁰/₀₀₀₀ to 13402.8⁰/₀₀₀₀), including a 32.8% increase in myopia (from 3547.9⁰/₀₀₀₀ to 4712.0⁰/₀₀₀₀). Morbidity from diseases of the musculoskeletal system and connective tissue increased by 15.8%, from 7581.3⁰/₀₀₀₀ to 8777.8⁰/₀₀₀₀. The overall morbidity from diseases of genitourinary system decreased, but the incidence of menstrual disorders has grown by 23.6%, from 1592.5⁰/₀₀₀₀ to 1967.6⁰/₀₀₀₀.

We registered a *downward morbidity trend* for the following classes of diseases: mental disorders and behavioral disorders — 2.9% (from 2940.2⁰/₀₀₀₀ to 2853.7⁰/₀₀₀₀); diseases of the circulatory system — 6.7% (from 1980.3⁰/₀₀₀₀ to 1847.0⁰/₀₀₀₀), including those that involve elevated blood pressure — 23.4% (from 60.8⁰/₀₀₀₀ to 46.6⁰/₀₀₀₀); diseases of the digestive system — 16.8% (from 13272.7⁰/₀₀₀₀ to 11039.5⁰/₀₀₀₀), including gastritis and duodenitis — 31.8% (from 1919.2⁰/₀₀₀₀ to 1309.4⁰/₀₀₀₀); diseases of the genitourinary system — 13.1% (from 5443.1⁰/₀₀₀₀ to 4732.0⁰/₀₀₀₀), with increasing prevalence of menstrual disorders in girls.

In addition, there was a slight decrease in the overall incidence of deforming dorsopathies — by 2.4% (from 2236.1⁰/₀₀₀₀ to 2183.3⁰/₀₀₀₀), although the overall prevalence of diseases of the musculoskeletal system among children increased.

Over the considered ten-year period, the **primary incidence among children decreased by 4.5%**, from 179741.3⁰/₀₀₀₀ to 171683.9⁰/₀₀₀₀ (Table 1).

We have registered a *decline of primary incidence among children* for the following classes: mental disorders and behavioral disorders, dropped by 4.7%, from 552.0⁰/₀₀₀₀ to 526.1⁰/₀₀₀₀; diseases of the nervous system, by 21.0%, from 3802.9⁰/₀₀₀₀ to 3002.8⁰/₀₀₀₀; eye diseases, by 27.1%, from 5981.9⁰/₀₀₀₀ to 4359.7⁰/₀₀₀₀, however, primary incidence of myopia has increased. Other disorders that have decreased over the considered period are: diseases of the circulatory system — by 32.0% (from 730.9⁰/₀₀₀₀ to 496.8⁰/₀₀₀₀), including diseases involving elevated blood pressure — by 29.2% (from 21.2⁰/₀₀₀₀ to 15.0⁰/₀₀₀₀); diseases of the digestive system — by 40.1% (from 7322.3⁰/₀₀₀₀ to 4385.5⁰/₀₀₀₀), including gastritis and duodenitis — by 45.9% (from 725.8⁰/₀₀₀₀ to 392.9⁰/₀₀₀₀); diseases of the musculoskeletal system — by 26.7% (from 3356.3⁰/₀₀₀₀ to 2458.5⁰/₀₀₀₀), including deforming dorsopathies — by 27.4% (from 852.8⁰/₀₀₀₀ to 619.1⁰/₀₀₀₀); diseases of the genitourinary

Table 2. Morbidity due to school-related diseases among adolescents aged 15–17 years: trends in incidence and chronification, 2015–2024

Classes of diseases according to ICD-10	Morbidity (per 100,000 children of the considered age)			Incidence trends, 2024 vs. 2015 (%)	Chronization	
	Type of morbidity	2015	2024		2015	2024
All diseases	Overall	224 725.9	234 669.9	+4.4	1.62	1.61
	Primary	138 509.7	145 437.3	+5.0		
Diseases of the endocrine system, metabolic disorders	Overall	9898.4	11914.6	+20.4	3.46	3.86
	Primary	2864.4	3087.2	+7.8		
including obesity	Overall	2935.0	3799.1	+29.4	3.97	4.47
	Primary	738.8	850.7	+15.0		
Mental disorders and behavioral disorders	Overall	6303.6	5394.2	–14.4	5.78	7.46
	Primary	1089.8	723.4	–33.6		
Nervous system diseases	Overall	12542.5	12299.6	–1.9	3.16	3.24
	Primary	3969.8	3799.3	–4.3		
Diseases of the eye and adnexa	Overall	21622.6	24466.8	+13.2	3.36	4.39
	Primary	6437.7	5578.6	–13.3		
including myopia	Overall	11689.4	14431.2	+23.5	5.37	5.93
	Primary	2177.8	2432.5	+11.7		
Diseases of the circulatory system	Overall	5477.0	4905.3	–10.4	3.31	3.35
	Primary	1655.0	1463.3	–11.6		
including diseases involving high blood pressure	Overall	596.5	481.1	–19.3	3.51	3.28
	Primary	169.9	146.9	–13.5		
Diseases of the digestive system	Overall	19117.8	14352	–24.9	2.59	2.81
	Primary	7374.9	5110.5	–30.7		
including gastritis and duodenitis	Overall	6239.9	4151.7	–33.5	3.78	3.73
	Primary	1649.9	1112.2	–32.6		
Diseases of the musculoskeletal system and connective tissue	Overall	17392.9	19547.7	+12.4	2.93	3.81
	Primary	5936.6	5127.8	–13.6		
including deforming dorsopathy	Overall	7239.3	7446.1	+2.9	3.38	3.94
	Primary	2144.6	1891.0	–11.8		
Diseases of the genitourinary system	Overall	11342.4	10008.9	–11.8	1.91	1.97
	Primary	5952.8	5079.4	–14.7		
including menstrual disorders	Overall	5416.6	7029.6	+29.8	1.61	1.77
	Primary	3373.9	3981.7	+18.0		

system — by 18.9% (from 2863.8⁰/₀₀₀₀ to 2323.6⁰/₀₀₀₀), with the increase in the frequency of menstrual disorders.

Within the same period, we recorded an *increase in the primary morbidity* with the diseases of the endocrine system and metabolic disorders — by 1.9% (from 1504.6⁰/₀₀₀₀ to 1533.3⁰/₀₀₀₀).

A noteworthy development is the increase of primary incidence of the diseases conventionally considered school-related, including obesity, which has grown by 16.7% (from 382.0⁰/₀₀₀₀ to 445.9⁰/₀₀₀₀), myopia — by 9.7% (from 997.6⁰/₀₀₀₀ to 1093.9⁰/₀₀₀₀), and menstrual disorders — by 19.3% (from 1055.8⁰/₀₀₀₀ to 1259.7⁰/₀₀₀₀).

The **overall morbidity among adolescents** aged 15 through 17 years has **increased by 4.4%**, from 224725.9⁰/₀₀₀₀ to 234669.9⁰/₀₀₀₀ (Table 2).

We have registered an *increase of the overall morbidity* from the following classes: diseases of the endocrine system and metabolic disorders — by 20.4% (from 9898.4⁰/₀₀₀₀ to 11914.6⁰/₀₀₀₀), including obesity — by 29.4% (from 2935.0⁰/₀₀₀₀ to 3799.1⁰/₀₀₀₀); diseases of the eye and adnexa — by 13.2% (from 21622.6⁰/₀₀₀₀ to 24466.8⁰/₀₀₀₀), including myopia — by 23.5% (from 11689.4⁰/₀₀₀₀ to 14431.2⁰/₀₀₀₀);

diseases of the musculoskeletal system and connective tissue — by 12.4% (from 17392.9⁰/₀₀₀₀ to 19547.7⁰/₀₀₀₀), with the incidence of deforming dorsopathies growing by 2.9% (from 7239.3⁰/₀₀₀₀ to 7446.1⁰/₀₀₀₀). The overall incidence of menstrual cycle disorders has increased by 29.8% (from 5416.6⁰/₀₀₀₀ to 7029.6⁰/₀₀₀₀).

The *overall morbidity* from the following classes of diseases has *decreased* in adolescents: mental, behavioral and neurodevelopmental disorders — by 14.4% (from 6303.6⁰/₀₀₀₀ to 5394.2⁰/₀₀₀₀); diseases of the nervous system — by 1.9% (from 12542.5⁰/₀₀₀₀ to 12299.6⁰/₀₀₀₀); diseases of the circulatory system — by 10.4% (from 5477.0⁰/₀₀₀₀ to 4905.3⁰/₀₀₀₀), including diseases involving elevated blood pressure — by 19.3% (from 596.5⁰/₀₀₀₀ to 481.1⁰/₀₀₀₀); diseases of the digestive system — 24.9% (from 19117.8⁰/₀₀₀₀ to 14352.0⁰/₀₀₀₀), including a marked decrease in the prevalence of gastritis and duodenitis — by 33.5% (from 6239.9⁰/₀₀₀₀ to 4151.7⁰/₀₀₀₀); diseases of the genitourinary system — by 11.8% (from 11342.4⁰/₀₀₀₀ to 10008.9⁰/₀₀₀₀), with an increase in the prevalence of menstrual disorders.

In 2015–2024, the **primary morbidity of adolescents** from all the considered diseases combined **increased by 5.0%**, from

138509.7⁰/₀₀₀₀ to 145437.3⁰/₀₀₀₀, mainly due to a significant increase (by 22.9%) in the primary incidence of respiratory diseases.

There was a marked growth of primary morbidity of adolescents from the diseases of the endocrine system and metabolic disorders — by 7.8%, from 2864.4⁰/₀₀₀₀ to 3087.2⁰/₀₀₀₀, including obesity — by 15.1%, from 738.8⁰/₀₀₀₀ to 850.7⁰/₀₀₀₀. The primary incidence of myopia has increased by 11.7%, from 2177.8⁰/₀₀₀₀ to 2432.5⁰/₀₀₀₀, although overall incidence of eye diseases has dropped. The primary morbidity from menstrual disorders has increased by 18.0% (from 33737.9⁰/₀₀₀₀ to 3981.7⁰/₀₀₀₀), while the general indicator of the diseases of the genitourinary system has decreased.

We have registered a *decline in primary morbidity of adolescents* from the following classes: mental disorders — by 33.6% (from 1089.8⁰/₀₀₀₀ to 723.4⁰/₀₀₀₀); diseases of the nervous system — by 4.3% (3969.8⁰/₀₀₀₀ to 3799.3⁰/₀₀₀₀); eye diseases — by 13.3% (from 6437.7⁰/₀₀₀₀ to 5578.6⁰/₀₀₀₀); diseases of the circulatory system — by 11.65% (from 1655.0⁰/₀₀₀₀ to 1463.3⁰/₀₀₀₀), including diseases involving elevated blood pressure — by 13.5% (from 169.9⁰/₀₀₀₀ to 146.9⁰/₀₀₀₀); diseases of the digestive system — by 30.7% (from 7374.9⁰/₀₀₀₀ to 5110.5⁰/₀₀₀₀), including gastritis and duodenitis — by 32.6% (from 1649.9⁰/₀₀₀₀ to 1112.2⁰/₀₀₀₀); diseases of the musculoskeletal system — by 13.6% (from 5936.6⁰/₀₀₀₀ to 5127.8⁰/₀₀₀₀), including deforming dorsopathies — by 11.8% (from 2144.6⁰/₀₀₀₀ to 1891.0⁰/₀₀₀₀).

We conducted a comparative analysis of **DCIs** in the child and adolescent subpopulations in 2015 and 2024 (Tables 1 and 2). It was found that in the children's subpopulation, the DCI for all diseases has remained almost unchanged over the decade: in 2015 it was 1.25, in 2024 — 1.31; in the subpopulation of adolescents, the DCI was higher, but it has also not changed considerably: 1.62 in 2015, 1.61 in 2024.

Significant chronization of diseases in children (2.00 < DCI < 4.00) was detected in 2015 and in 2024 for most classes of diseases that include school-related varieties: diseases of the endocrine system and metabolic disorders — DCI 2.62 and 3.53, respectively; obesity — 3.19 and 3.99; diseases of the nervous system — 2.40 and 3.11; eye diseases — 2.02 and 3.07, including myopia — 3.56 in 2015; diseases of the circulatory system — 2.71 and 3.72, including diseases involving high blood pressure — 2.87 and 3.11; diseases of the digestive system — 1.81, a minor DCI in 2015, and 2.52, a significant DCI in 2024, including gastritis and duodenitis — 2.64 and 3.33; diseases of the musculoskeletal system — 2.26 and 3.57, including deforming dorsopathies — 2.62 and 3.53.

Significant chronization of diseases in adolescents (2.00 < DCI < 4.00) was detected in 2015 and 2024, also for most classes of diseases that include school-related varieties: diseases of the endocrine system (3.46 and 3.86, respectively); diseases of the nervous system (3.16 and 3.24); diseases of the eye and adnexa (3.36 — significant DCI in 2015 and 4.39 — high DCI in 2024); diseases of the circulatory system (3.31 and 3.35), including diseases involving high blood pressure (3.51 and 3.28); diseases of the digestive system (2.59 and 2.81), including gastritis and duodenitis (3.78 and 3.73); diseases of the musculoskeletal system (2.93 and 3.81), including deforming dorsopathies (3.38 and 3.94).

In both children and adolescents, we registered *high chronization* (DCI > 4) of mental disorders in 2015 and 2024: 5.33 and 5.42, and 5.78 and 7.46, respectively. Adolescents also exhibited high chronization of obesity in 2024 (4.47) and myopia in 2015 and 2024 (5.37 and 5.93, respectively). Among children, myopia's DCI was high in 2024: 4.31.

In 2015 and 2024, the chronization was *insignificant* (DCI < 2.00) only for the diseases of the genitourinary system — both in children (1.90 and 2.04) and in adolescents (1.91 and 1.97) — and menstrual disorders — DCI 1.51 and 1.56 among girls under 15, and 1.61 and 1.77, respectively, among girls aged 15–18 years. This trend suggests that the mentioned disorders are transient in most cases, triggered by lasting stress associated with exams.

A comparison of DCI for children and adolescents revealed that generally in these populations the chronization of the diseases was higher in 2024 than in 2015.

Older adolescents exhibited higher chronization values than children. We registered a very high DCI (up to 7.46 in 2024) for mental disorders in the population of adolescents. Other reasons for concern are the ever-increasing obesity and myopia chronization values among both children and adolescents. By the late stages of adolescence, schoolchildren carry an accumulated burden on chronic diseases, which affects the overall morbidity among them.

Preventive efforts in schools should be aimed at arresting the development of school-related diseases that tend to become chronic.

DISCUSSION

Until 2025, it was not possible to study the dynamics of the incidence of a number of diseases that may be associated with the influence of factors of the educational process and lifestyle of schoolchildren. Order of the Federal State Statistics Service No. 543 of November 13, 2024, which entered into force on January 1, 2025, approved changes to the reporting Form No. 12: addition of "Section 3.2. Students in educational organizations (ages 3 through 17 years): preschoolers and schoolchildren" and new lines enabling registration of almost all school-related diseases [29]. The information collected from 2025 will allow for a deeper and more differentiated analysis of morbidity in four age groups: preschoolers 3–6 years old, younger schoolchildren 7–10 years old, middle school students 11–14 years old (grades 5–8), and school students 15–17 years old (grades 9–11).

To obtain the most complete picture of the health status of children and adolescents, it is necessary to combine data on their treatment in medical organizations with information from preventive medical examinations (including detected pathological lesions), while maintaining individual (per capita) records of all identified health disorders for each child. This approach will yield information on the true (exhaustive) morbidity of children and adolescents.

Analyzing how students' true morbidity correlates with conditions and organizational features of upbringing and education in specific institutions, as well as with behavioral risk factors, will help quantify the contribution of these factors to the most common diseases among preschoolers and schoolchildren. The effectiveness of preventive interventions will be assessed by the degree to which they prevent the impact of adverse factors on the health of children and adolescents, including the onset of functional disorders, progression to chronic disease, and overall disease progression. [8, 9, 15, 21].

CONCLUSIONS

The expert-analytical study identified persistently unfavorable trends in overall morbidity among children and adolescents over the 2015–2024 decade. The indicators increased for the following classes of diseases: diseases of the eye

and adnexa, including myopia; diseases of the endocrine system and metabolic disorders, including obesity; diseases of the musculoskeletal system.

A comparison of data on chronization of diseases in children and adolescents in 2024 and 2015 showed more chronic cases in 2024 than in 2015, with the chronization rates higher in older adolescents than in children aged 0–14 years. Notably high values of the chronization index are observed for eye diseases, diseases of the musculoskeletal system, and especially mental disorders. Increasing chronization of mental disorders, eye diseases (myopia), and diseases of the musculoskeletal system may be associated with a stronger psychoemotional stress, academic and visual load, insufficient sleep and physical activity.

Based on the study data, preventive efforts should focus on reducing the psychoemotional stress among adolescents preparing for exams in grades 9 and 11; promoting physical activity in the considered populations (at least an hour a day); teaching all schoolchildren the rational organization of educational and leisure activities implying smaller visual load; ensuring a healthy diet and increasing the duration of night sleep.

To further study the health status of children and adolescents and associated health risk factors, a unified Russian database is needed. This database should contain a complete record of all healthcare encounters by each minor with any medical organization, as well as information on health disorders (both functional disorders and chronic diseases) detected during preventive medical examinations.

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KEY OCCUPATIONAL HAZARDS ASSOCIATED WITH THE WATER FILLING OF PASSENGER RAIL CARS

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Outfitter is one of the most important specializations among the many professions in the railway industry. Among other duties, outfitters fill the water supply systems of passenger cars, a process associated with exposure to the combined effects of a complex of hazardous industrial factors, such as heavy physical labor, an adverse microclimate, high noise levels, low lighting, and bacterial contamination of the skin of the hands and overalls. This study aimed to investigate the specifics of the working conditions of outfitters and the morbidity with temporary disability among them in order to develop preventive measures. We used the "snapshot of the working day" method, measured harmful physical factors and bacterial load. By the severity of labor, the work of the outfitters was established to belong to class 3.2 (R 2.2.2006-05). During nighttime hours, the intensity of artificial lighting in outdoor areas and on station tracks ranged from 6 to 8 lux, whereas the normative value was ≥ 10 lux; this corresponded to class 3.1. The equivalent sound level at the outfitters' workplaces was 88 dBA, which is 8 dBA higher than the maximum permissible level, which corresponded to class 3.2. By the biological factor, the working conditions belonged to class 3.2, and by the hygienic indicators — to class 3.3. Analysis of three-year average morbidity with temporary disability data indicates that specific occupational hazards increase morbidity: disability rates among outfitters were significantly higher than in the railway transport industry overall (by 27.8% in cases and 29.0% in disability days). The study enabled the development of a number of preventive measures.

Keywords: outfitters filling water tanks in passenger cars, working conditions, microclimate, noise, lighting conditions, bacterial contamination, morbidity with temporary disability, preventive recommendations

Author contribution: Kaptsov VA — study conceptualization, methodology, approval of the final version of the article; Ovechkina ZhV — data collection and processing, article authoring; Korolik W — literature review, selection and analysis of studies, analysis of the regulatory and procedural guidelines; Kozyreva FU — data analysis, article editing; Tikhonova YuL — statistical data processing, text editing; all authors — approval of the final version of the article, responsibility for the integrity of all sections of the article.

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Received: 22.03.2026 **Accepted:** 06.08.2026 **Published online:** 06.09.2026

DOI: 10.24075/rbh.2026.170

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ВЕДУЩИЕ ПРОИЗВОДСТВЕННЫЕ ФАКТОРЫ ПРИ ЗАПРАВКЕ ПАССАЖИРСКИХ ВАГОНОВ ВОДОЙ

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Среди многочисленных профессий железнодорожной отрасли важное место занимают экипировщики, заправляющие водой систему водоснабжения пассажирских вагонов, которые подвергаются сочетанному воздействию комплекса вредных производственных факторов, таких как тяжелый физический труд, неблагоприятный микроклимат, высокий уровень шума, низкая освещенность, бактериальная обсемененность кожных покровов рук и спецодежды. Целью исследования было изучить специфику условий труда экипировщиков и заболеваемость с временной утратой трудоспособности (ЗВУТ) для разработки профилактических мероприятий. В ходе исследования использовали метод «фотография рабочего дня», измерение вредных физических факторов, бактериологические методы. Установлено, что условия труда экипировщиков по показателю «тяжесть трудового процесса» относились к классу 3.2 (Р 2.2.2006-05). На открытых территориях и станционных путях в темное время суток уровень искусственной освещенности находился в пределах 6–8 лк при норме не менее 10 лк, что соответствовало классу 3.1. Эквивалентный уровень звука на рабочих местах экипировщиков составлял 88 дБА, что на 8 дБА выше предельно-допустимого уровня, и относился к классу 3.2. Оценка условий труда по биологическому фактору соответствовала классу 3.2, а общая оценка условий труда — классу 3.3. Воздействие вредных факторов труда может приводить к росту заболеваемости, что подтверждают результаты анализа среднегодовых показателей ЗВУТ экипировщиков за трехлетний период, которые значительно превышают общеотраслевые показатели для работающих на железнодорожном транспорте (по случаям на 27,8%, по дням нетрудоспособности на 29,0%). Выполненные исследования позволили разработать ряд профилактических мероприятий.

Ключевые слова: экипировщики по заправке пассажирских вагонов водой, условия труда, микроклимат, шум, освещенность, бактериальная обсемененность, заболеваемость с временной утратой трудоспособности, ЗВУТ, профилактические рекомендации

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Статья получена: 22.03.2026 **Статья принята к печати:** 06.08.2026 **Опубликована онлайн:** 06.09.2026

DOI: 10.24075/rbh.2026.170

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There is no doubt that railroad transport is one of the key drivers of the industrial and economic development of the Russian Federation. This mode of transportation connects regions of the country and promotes trade, production, and tourism. One of the key advantages of railroad transport is its capability to carry large volumes of cargo over long distances. Train tracks and cars are extremely durable, which makes railroads ideal for transportation of heavy and bulky items, including coal, ore, oil, and construction materials. Railroads interconnect industrial facilities located in different regions of the country. The extensive network of tracks allows bringing cargo to the farthest corners of the nation. It underpins the development of industrial clusters and enables creation of jobs, which, in turn, stimulates economic growth and improves the quality of life of the population. Railroads also play an important role in the tourist industry, comfortably and conveniently moving people between cities and sights. Trains allow tourists to quickly and easily reach popular resorts and cultural landmarks, which eventually translates into profits for the state. In addition, railroad transport is a more environmentally friendly mode of cargo moving than motorways: locomotive engines run on electricity, and hence emit no harmful substances into the atmosphere, thus contributing to the improvement of the environmental conditions and health of the population [1–4].

Labor conditions on the railroad are specific and heavy: there is a considerable number of occupational hazards the workers are exposed to [5–14], including round-the-clock operation, moving trains, insufficiency of mechanical aides and automated routines, poor lighting in the working areas, loud noise, shock hazard, psychoemotional stress.

The aforementioned factors underpin the urgency of investigation of the conditions of labor of outfitters who fill long-distance cars with drinking water, as the ceaseless movement of trains, passenger safety and comfort largely depend on their work.

Drinking water plays a key role in human life; in the context of traveling by railroad, it is used for both subsistence and sanitary purposes [15–17]. In the passenger car replenishment systems installed at stations, violations of the rules of storage and use of filling hoses and contamination of tanks and piping can result in the pollution of the supplied water. The problem becomes especially urgent in summer, when high temperatures promote growth of the colonies of microorganisms.

Outfitters work outdoors in adverse conditions: poor lighting at night, high noise levels, and a heavy bacterial load. Their work is physically demanding, involving the manual handling of filling hoses and many other strength-intensive tasks.

Among the numerous jobs in the railroad industry, that of outfitters filling passenger cars with water remains largely unstudied by scholars. A comprehensive analysis of the specifics of work of the considered professional category and its overall operational importance necessitated field studies aimed at investigation of occupational hazards and factors.

This study aimed to investigate the specifics of the working conditions of outfitters and the incidence of temporary disability among them in order to develop preventive measures.

METHODS

We studied the working conditions of outfitters filling passenger cars with water (hereinafter referred to as outfitters) from 2021 to 2025 at several service stations: Moscow-3, Belorusskaya, and Studencheskaya (all belong to the Moscow Railway).

The work included a systematic analysis of scientific literature, compilation of a hygienic report, registration of labor hours, and measurement of physical factors. To record the levels of noise and assess its effect on the hearing of outfitters, we used an Octava-111 noise meter (Oktava–ElectronDesign; Russia). The equivalent sound level was calculated according to GOST ISO 9612–2016 [18]. The intensity of artificial illumination was measured using a Testo-540 luxmeter (Testo SE & Co KGaA; Germany) according to GOST 24940–2016 "Buildings and structures. Methods of measuring illumination" [19]. To assess bacterial contamination of palmar skin and work clothing, we collected palm prints and swabbed overalls according to the methodological guidelines [20]. Morbidity with temporary disability was assessed at the individual level, using ICD-10 for classification. For each outfitter, we completed an individual data card. Workers included in the study were required to have at least one year of employment with the company. Morbidity with temporary disability was assessed at the Moscow railway node. Ultimately, we processed the morbidity with temporary disability data of 229 outfitters filling passenger cars with water, who had at least one year of employment, for three years.

Statistical processing of the collected information was performed using the SPSS Statistics 27 package (IBM; USA). We calculated M , the arithmetic mean, m , the standard error of the mean, and P , the confidence interval.

RESULTS

For outfitters filling passenger cars with water, a day is divided into two 12-hour shifts. Their duties include supplying water to cars from water standpipes at service and intermediary stations where the consists are compiled and processed.

As a rule, passengers cars are filled with water when being formed into a consist or otherwise processed on servicing tracks, which feature cold and hot water piping outlets. At intermediary stations, water is generally refilled on general purpose tracks equipped with standpipes.

The outfitter's job involves supplying water from a standpipe to the car's water tank via a hose.

The outfitter plugs one end of the hose into a special inlet in the car, connects the other end to the pump, and opens the valve of the pump to allow water to enter the tank of the car. When the tank is full, the outfitter closes the pump valve and disconnects the hose from the pump and the car.

At some stations, each standpipe has its own hose, which allows the outfitter to skip connecting the hose to the source of water. The opposite end of the hose (the one for the car) is fixed in a special clamp on top of the standpipe. This is a proper arrangement from the hygienic point of view, as it prevents the penetration of various pollutants into the water. In most cases, however, the number of connecting hoses is insufficient, and outfitters have to drag them over considerable distances between standpipes. Dragged across the surface, the hose gets contaminated. The average weight of the hose is about 20 kg; dirt and ice can make it 30–40 kg. Therefore, carrying or dragging a hose is a physically demanding task.

Chronometry (cold weather period) yielded the following results: filling cars with water is the main activity of outfitters that takes up 48.4% of their working time on average; they spend 6.4–8.2% of the working time (mean 7.2%) on hose movement; and 26.7% of the working time they stand by.

The average time spent on a lunch break is 35 minutes. There is no designated period of the shift for this break, the outfitters make it when standing by.

Table 1. Occupational factors outfitters are exposed to when filling passenger cars with water

Occupational factor	Standard MPC, MAL	Actual value	Working conditions class (Guidelines R 2.2.2006-05 [21])
Noise (equivalent sound level), dBA	80	88 ± 0.8	3.2
Lighting (outdoor work at night), lx	10	7 ± 0.1	3.1
Microclimate (outdoor work): – cold season – warm season	Depend on the climatic zone		2–3.4 2–3.1
Physical intensity of labor			
– physical dynamic load per shift, kgm when moving cargo over a distance of more than 5 m (for males)	up to 46 000	48 000 ± 3.87	3.1
– static load, kgf (the amount of static load per shift when holding the load, applying effort), involving muscles of the body and legs (for males)	up to 100 000	115 000 ± 4.35	3.1
– working position (uncomfortable), % of shift time	up to 25	26 ± 0.4	3.1
– body tilts, number per shift	up to 100	120 ± 0.84	3.1
– horizontal movement (per shift), km	up to 8	10 ± 0.08	3.1
Overall assessment of the "physical intensity of labor" indicator			3.2
Biological factor	lacking	present	3.2

During the filling of passenger cars with water, outfitters are exposed to adverse occupational factors, including significant physical exertion, an unfavorable outdoor microclimate, increased noise from train traffic, and insufficient artificial lighting at night.

Since outfitters risk bacterial contamination when filling cars with water, we took prints and swabs of their palmar skin and overalls seeking to detect *E. coli* group bacteria.

Table 1 presents the occupational factors the outfitters are exposed to when filling passenger cars with water.

With all the occupational hazards factored in, the working conditions of outfitters filling passenger cars with water belongs to class 3.3 (R 2.2.2006-05) [21].

Adverse working conditions for outfitters filling passenger cars with water may contribute to the development of various diseases. The analysis of their health status is based on the frequency of cases of temporary disability.

Age-wise, this professional group has an even composition (workers under 25 years old — 18.2%, 26–30 years old — 20.3%, 31–40 years old — 20.3%, 41–50 years old — 27.3%, over 50 years old — 13.9%), except for the subgroup of 41–50 year-olds, which was slightly more numerous and made up about one third compared to other age groups.

As for the length of service, the distribution was as follows: from 1 to 5 years — 32.8%, from 6 to 10 years — 20.7%, from 11 to 20 years — 33.6%, from 20 to 30 years — 12.1%, over 30 years — 0.8%. Thus, most of the outfitters filling passenger cars with water have been doing this job for 1–5 years or 11–20 years.

Tables 2 and 3 show the mean annual morbidity with temporary disability among the outfitters filling passenger cars with water for three years.

As shown in Table 2, respiratory tract diseases account for the largest proportion of all cases (49.5%). Skin and subcutaneous tissue diseases rank second (14.9%), followed by injuries and poisoning — the third most common cause of temporary disability (10.8%) — and diseases of the circulatory system (9.8%).

Diseases of the respiratory system account for the largest share of disability days (34.2% of the total), followed by injuries and poisoning (24.7%). Diseases of the skin and subcutaneous tissue rank third (14.9%), followed by the diseases of the circulatory system (10.4%).

The analysis of the data from Table 3, which shows mean annual morbidity with temporary disability figures per 100 outfitters, revealed a direct relation to the distribution of the causing diseases shown in Table 2, with the diseases of the respiratory system (62.0) ranking first, followed by injuries and poisoning (13.5), diseases of the circulatory system (12.2), mental disorders (3.9), diseases of the nervous system (3.5), and diseases of the digestive system (3.1).

By the number of disability days caused, the first place belongs to the diseases of the respiratory tract (482.1 days), second — to injuries and poisonings (348.0 days), third — to the diseases of the musculoskeletal system (210.9 days), and fourth — to the circulatory system diseases (146.7 days). The longest temporary disability leaves were registered for the diseases of the following classes: injuries and poisonings — 25.7 days, diseases of the urogenital system — 19.0 days, diseases of the digestive system — 16.0 days.

A three-year analysis of the causes of morbidity with temporary disability among workers who fill passenger cars with water showed that, in this group, rates were higher than in the industry overall: the number of cases was 27.8% higher (125.2 vs. 90.4 per 100 employees), and the number of disability days was 29.0% higher (1409.4 vs. 1000.6 per 100 employees).

DISCUSSION

Railroad car outfitters are an important professional group within the railway industry that ensures the comfort and safety of passengers.

Their labor is considered intense, belonging to class 3.2 (R 2.2.2006-05).

High physical loads are combined with an adverse microclimate, poor lighting, and high noise levels. Researchers

Table 2. Fraction of mean annual values in the structure of morbidity with temporary disability among outfitters filling passenger cars with water (3-year period)

Classes of diseases	Cases of disability		Disability days	
	in %	Rank	in %	Rank
Diseases of the endocrine system	1.0	IX	1.3	IX
Mental disorders	3.1	VI	2.7	VIII
Nervous system diseases	2.8	VII	2.9	VII
Diseases of the circulatory system	9.8	IV	10.4	IV
Respiratory diseases	49.5	I	34.2	I
Diseases of the digestive system	2.4	VIII	3.5	VI
Diseases of the genitourinary system	0.8	X	1.2	X
Diseases of the skin and subcutaneous tissue	14.9	II	14.9	III
Diseases of the musculoskeletal system and connective tissue	4.9	V	4.2	V
Injury, poisoning and certain other consequences of external causes	10.8	III	24.7	II
Total	100.0	–	100.0	–

have previously established that these factors indeed affect the work of core categories of the railway industry workforce [22, 23].

Exposure to biological hazards in the working environment of outfitters may impair immune function and, under certain conditions, increase the risk of intestinal infections [24, 25].

These hazards allow attributing the working conditions of outfitters filling wagons with water to class 3.2 (R 2.2.2006-05), since there is a risk of infection by contact with *E. coli*-infested car equipment and soil surface.

With all the occupational hazards factored in, the working conditions of outfitters belong to class 3.3 (R 2.2.2006-05).

Harmful working conditions can induce changes in the cardiovascular and nervous systems and in the musculoskeletal system, and may lead to serious diseases, including occupational disorders, as confirmed by numerous authors [26–34]. Our own findings support this: the average annual rates of temporary disability among outfitters filling railway cars with water are significantly higher than the industry-wide rates for railway transport employees (by 27.8% in terms of cases and by 29.0% in terms of disability days), mainly due to respiratory diseases, which account for the largest proportion of all cases (49.5%), followed by diseases of the skin

and subcutaneous tissue (14.9%), injuries (10.8%), diseases of the circulatory system (9.8%), and diseases of the musculoskeletal system and connective tissue (4.9%).

CONCLUSIONS

This study is the first to comprehensively evaluate the work of the outfitters filling passenger cars with water. We found that most occupational hazards in this line of work are difficult to eliminate with current technical means and changes of the organization of labor. The work itself was found to be associated with physical exertion, unfavorable microclimate, poor lighting conditions, loud noise, and bacterial contamination of the palmar skin and overalls.

A comprehensive evaluation of working conditions for outfitters filling cars with water, which considered all harmful occupational factors, resulted in classifying this occupation as heavy work with an environmental hazard level corresponding to class 3.3 (R 2.2.2006-05).

We observed markedly elevated morbidity leading to temporary disability among railway transport workers, exceeding industry-wide rates by 27.8% in number of cases and by 29.0% in disability days.

Table 3. Mean annual morbidity with temporary disability among outfitters filling passenger cars with water for three years (per 100 individuals)

Classes of diseases	Cases of disability	Disability days	Single case duration, days
Diseases of the endocrine system	1.3	17.0	13.0
Mental disorders	3.9	37.9	9.6
Nervous system diseases	3.5	41.5	11.8
Diseases of the circulatory system	12.2	146.7	12.0
Respiratory diseases	62.0	482.1	7.7
Diseases of the digestive system	3.1	48.9	16.0
Diseases of the genitourinary system	0.8	16.6	19.0
Diseases of the skin and subcutaneous tissue	6.1	59.8	9.7
Diseases of the musculoskeletal system and connective tissue	18.8	210.9	11.2
Injury, poisoning and certain other consequences of external causes	13.5	348.0	25.7
Total	125.2	1409.4	13.6
industry-wide indicators on railway transport (three years)	90.4	1000.6	11.1

Based on a study of railway carriage outfitters' work, preventive measures were developed to improve working conditions, protect health, prevent diseases and injuries, support

professional longevity, and enhance medical and preventive care through organizational, technical, and sanitary-hygienic interventions.

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METHODOLOGICAL APPROACHES TO SUBSTANTIATING QUALITY AND SAFETY STANDARDS FOR VARIOUS TYPES OF WATER AND SOIL IN POPULATED AREAS USING THE *DANIO RERIO* BIOLOGICAL MODEL

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Today, environmental pollution with chemicals represents one urgent hygienic problem. In the context of intensification and modernization of the road transport complex and industrial production the development of methodology for hygienic rationing based on experimental research is relevant. The conventional use of small rodents (rats, mice) as biological models has a number of ethical, methodological and economic limitations, which necessitates the search for and implementation of alternative biological models in research practice. Our aim was to substantiate a unified methodological approach to establishing quality and safety standards for various types of water, except for technical water, and soil in populated areas using the *Danio rerio* (Hamilton, 1822) biological model. The reported method integrating existing international and national standards, confirms the possibility of using *D. rerio* as a valid and highly informative test system in biomedical research. The approach assumes prompt (1–1.5 months), reliable, cost-effective, humane yielding of results, which is necessary for the scientific substantiation of safety criteria and hygienic standards.

Keywords: rationing, safety, chemicals, water, soil, *Danio rerio*, acute toxicity, chronic toxicity, long-term effects

Author contribution: Zaitseva NV — study concept and design; Zemlyanova MA — study design, manuscript editing; Kamenskikh DM, Peskova EV — manuscript writing.

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Received: 10.07.2026 **Accepted:** 07.08.2026 **Published online:** 07.09.2026

DOI: 10.24075/rbh.2026.171

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МЕТОДИЧЕСКИЕ ПОДХОДЫ К ОБОСНОВАНИЮ НОРМАТИВОВ КАЧЕСТВА И БЕЗОПАСНОСТИ РАЗЛИЧНЫХ ВИДОВ ВОД И ПОЧВЫ НАСЕЛЕННЫХ МЕСТ НА БИОЛОГИЧЕСКОЙ МОДЕЛИ *DANIO RERIO*

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В настоящее время загрязнение объектов среды обитания химическими веществами представляет собой одну из значимых гигиенических проблем. В условиях интенсификации и модернизации дорожно-транспортного комплекса и промышленного производства актуальным является развитие методологии гигиенического нормирования, основанной на экспериментальных исследованиях. Традиционное использование в качестве биологической модели мелких грызунов (крыс, мышей) имеет ряд этических, методологических и экономических ограничений, что обуславливает необходимость поиска и внедрения альтернативных биологических моделей в исследовательскую практику. Целью работы было обосновать унифицированный методический подход к установлению нормативов качества и безопасности различных видов вод, кроме технической, и почвы населенных мест на биологической модели *Danio rerio* (Hamilton, 1822). Представленная методика, интегрирующая существующие международные и национальные стандарты, подтверждает возможность применения *D. rerio* в качестве валидной и высокоинформативной тест-системы в биомедицинских исследованиях. Подход предполагает оперативное (1–1,5 месяца), достоверное, финансово малозатратное, гуманное получение результатов, что необходимо для научного обоснования критериев безопасности и гигиенического нормирования.

Ключевые слова: нормирование, безопасность, химические вещества, вода, почва, *Danio rerio*, острая токсичность, хроническая токсичность, отдаленные эффекты

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Статья получена: 10.07.2026 **Статья принята к печати:** 07.08.2026 **Опубликована онлайн:** 07.09.2026

DOI: 10.24075/rbh.2026.171

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Issue of hygienic rationing of new chemical compounds

Pollution of environmental objects (water, soil, atmospheric air) represents one significant hygienic problem. The road transport complex intensification and modernization, as well as the industrial production expansion, lead to the entry of new chemical compounds into the environment as components of emissions and discharges. There are no experimentally verified maximum permissible concentrations (MPCs) and reference doses for chronic oral intake (RfD) for most such chemicals. New pollutants actually present in environmental objects can

negatively affect the exposed population health. In this regard, justification of quality standards (MPC) and safety standards (RfD) for new chemical compounds is an important aspect of ensuring the population sanitary and epidemiological well-being.

Justification of MPC and RfD for new substances is based on the strictly regulated approaches to experimental research considering the acute, chronic and long-term effects of toxicants. This approach allows one to determine general patterns of toxicity of compounds, specific manifestations during long-term exposure, define the lowest effective (LOEC) and no effective concentrations (NOEC). Historically, such research involves

warm-blooded animals, including small rodents (rats, mice), as biological models [1, 2]. Despite proven effectiveness and widespread use in scientific research, the use of those is associated with some limitations. The ethical aspect comes down to the need to justify the sample size and compliance with the requirements of humane research, due to the implementation of invasive procedures, surgical interventions and prolonged painful treatment of laboratory animals. It is very difficult to extrapolate the data obtained in small rodent experiments to the human body due to pronounced interspecies metabolic, structural, and physiological differences. An additional limitation is the significant costs of keeping laboratory animals in specialized vivariums. These difficulties highlight the need to search for and implement into research practice a valid and highly informative biological model characterized by the high genetic and physiological homology with humans, economic accessibility, and compliance with ethical standards. In this context, *Danio rerio* (Hamilton, 1822), the tropical freshwater fish, is considered as one of the most promising model organisms due to a combination of biological, genetic, and methodological advantages. The *D. rerio* whole genome sequencing revealed significant similarities between its genetic structure and that of humans: 70% of human genes have orthologs in *D. rerio* and 82% of *D. rerio* genes are associated with human disorders. This determines comparability of the key biochemical and physiological processes [3–5]. The possibility of conducting diverse experimental studies within a single biological system ensures differentiated assessment of various types of toxic effects (lethal and sublethal). When testing the effects of toxicants using the *D. rerio* biological model, it is possible to simulate the conditions of a real complex exposure caused by the entry of substances from environmental objects (water, soil, air). Such an approach reflects the simultaneous entry of chemicals into the human body through three pathways: oral, transdermal, and inhalation ones. Similarity of metabolic profiles of adult *D. rerio* and humans (the ability to absorb, oxidize, and excrete metabolites of toxicants) makes it possible to effectively extrapolate the results to the human body [6, 7]. Along with the biological and genetic advantages, the use of *D. rerio* in experiments is fully consistent with the provisions of the 3R concept (Replacement, Reduction, Refinement) that are fundamental for experimental research [8]. Replacing warm-blooded animals (small rodents) with fish allows for a significant reduction of the number of mammal experiments, which simultaneously reduces the ethical burden of research and reduces the logistical costs associated with the purchase, maintenance, and disposal of laboratory animals. High reproductive capacity and a fast life cycle ensure high statistical significance and promptness of yielding results (1–1.5 months), thereby ensuring compliance with the reduction principle [9]. The refinement principle is realized through the optimization of methods and experimental conditions aimed at minimizing or completely eliminating pain and stress effects. Extracorporeal development and optical transparency of *D. rerio* embryos enable the real-time noninvasive monitoring of morphogenesis, and the introduction of chemicals is carried out by simply adding those to the aquatic environment, which eliminates injection manipulations [10, 11].

The *D. rerio* model represents a highly sensitive and methodologically accessible instrument for studying the toxicity of new chemicals in both acute and chronic experiments, which determines its importance for advances in hygienic research [12–14]. The experimental use of *D. rerio* is regulated by international guidelines (OECD) and national standards (GOST). They standardize the key testing parameters,

such as exposure time, controlled environmental conditions, fish development stages, and outcome assessment criteria. At the same time, there is a unified stage-by-stage research methodology, since the existing approaches to rationing use different experimental protocols, which can lead to discrepancies in results, decreased objectivity and quality of the MPC and RfD justification.

Our aim was to provide scientific and methodological substantiation of the unified integrated approach to establishing maximum permissible concentrations and reference doses for chronic oral intake of chemicals using the *D. rerio* biological model.

Concept of an integrated methodological approach to substantiating quality and safety standards for new chemical compounds

An integrated methodological approach to substantiating quality and safety standards for various types of water and soil using the *D. rerio* biological model represents a multilevel algorithm. Within its framework, a preparatory stage is consistently implemented, experimental studies are conducted that involve determining the parameters of acute and chronic toxicity, as well as delayed effects, including teratogenic, mutagenic, and reprotoxic effects during long-term exposure, establishing the lowest effective (LOEC) and no effective (NOEC) concentrations for *D. rerio* to substantiate the MPC of chemicals in water and soil and RfD for humans during chronic oral intake (Fig.).

The integrated methodological approach to establishing MPC and RfD is based on international methods and national standards: GOST 32428—2013 [15], GOST 32473—2013 [16], GOST 32538—2013 [17], GOST 32541—2013 [18], GOST 33774—2016 [19], GOST 32368—2013 [20], OECD Test Guideline No. 229 [21], OECD Test Guideline No. 425 [22], OECD Test Guideline No. 203 [23], OECD Test Guideline No. 236 [11], OECD Test Guideline No. 210 [24].

Samples (water, soil) are prepared in accordance with the provisions of current national standards. Soil samples are collected in accordance with GOST 17.4.3.01—83 [25] and GOST 17.4.4.02—84 [26], depending on the test substance. When isolating chemicals from soil, standardized extraction procedures are used (e.g., obtaining aqueous extracts or extraction with organic solvents) [27]. Critical parameters include the solid-to-liquid ratio, duration, and temperature of extraction. Water sampling is conducted in accordance with GOST R 59024—2020 [28] regulating the localization of sampling sites taking into account the hydrological characteristics of the reservoir or watercourse and the potential impact of pollution sources. Isolation of test chemicals from the aqueous medium is carried out using sorption (for example, solid-phase extraction) or liquid-liquid extraction methods, selected based on the concentration. Special attention is paid to preventing the loss of volatile compounds by controlling the temperature regime.

Statistical processing of the experimental study results is carried out considering the nature of the distribution of the data set, estimated using the Kolmogorov–Smirnov test. When random variables of the test indicators are normally distributed, parametric statistical methods are used and the following characteristics are calculated: mean (M); standard error (m), Student's t -test when assessing significance of intergroup differences ($p \leq 0.05$), Fischer's exact test ($F > 3.96$) when assessing differences in variances, and the determination coefficient (R^2).

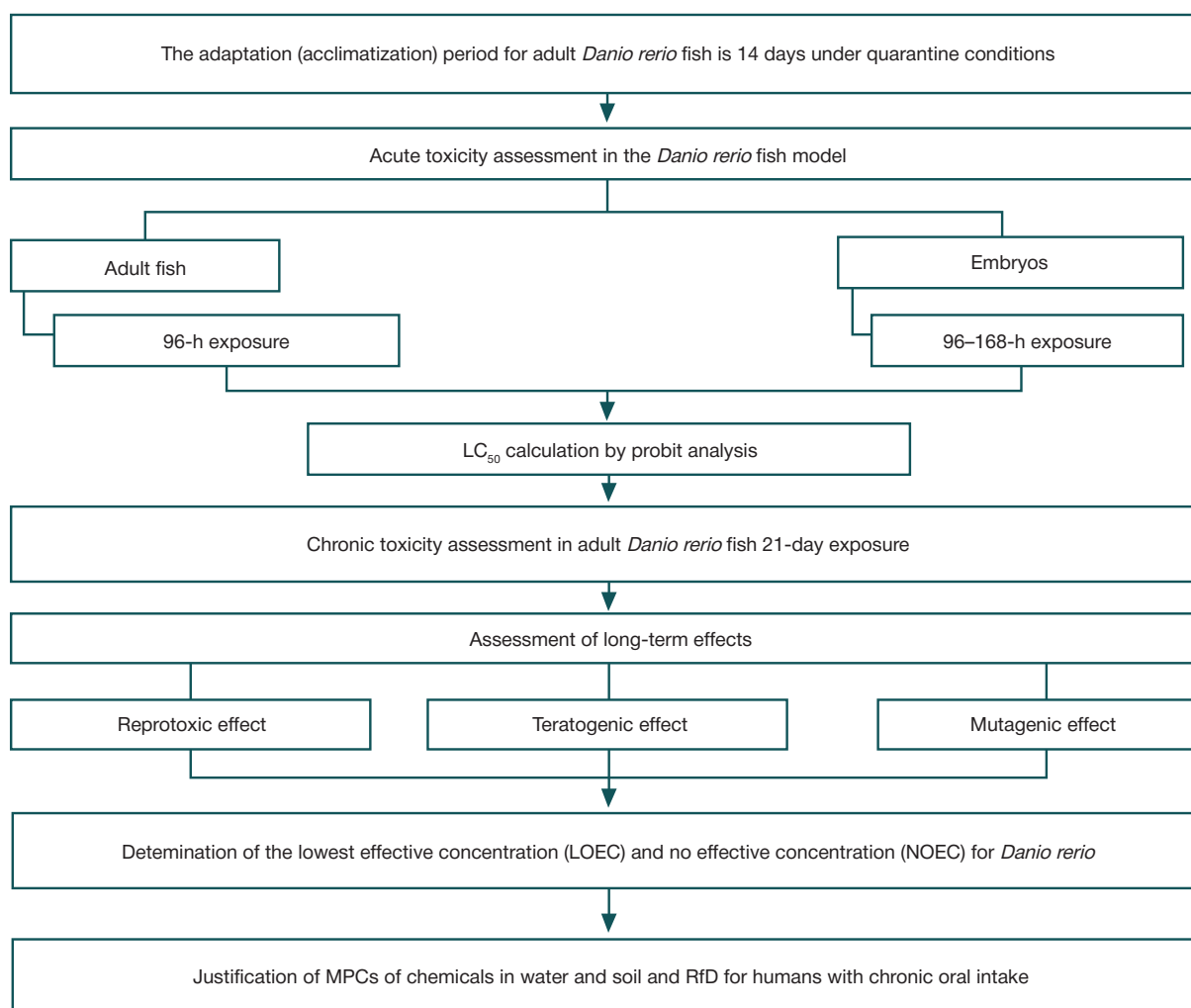


Fig. Integrated methodological approach to substantiating quality and safety standards for various types of water and soil in populated areas using the *Danio rerio* biological model

Modeling and evaluation of acute toxicity at different stages of *Danio rerio* ontogenesis

A unified integrated approach is implemented from the preparatory stage. *D. rerio* fish are kept in quarantine conditions for 14 days, during which the water hydrochemical parameters and the laboratory animals' health status are monitored daily in accordance with GOST 32473—2013 [16]. After 14 days, healthy sexually mature fish are randomly selected to form representative samples that ensure statistical significance of the results. Inclusion criteria include the fact of having no external signs of disease (fin damage, corneal clouding, color changes, scale ruffling), adequate response to external stimuli, and the fact of showing no abnormal motor activity. Such selection ensures minimization of false positives associated with the baseline heterogeneity of experimental groups.

After the adaptation period completion, the first stage of the study is carried out according to standardized protocols (OECD Test Guideline No. 203 [23] and GOST 32473—2013 [16]). The study continues for 96 h (adults and embryos) with an extension of up to 168 h (for embryos) to determine acute toxic effects. The selection of test substance concentrations is regulated by the specified standards and is based on testing to determine the concentration range. It is necessary to identify the sensitivity threshold and the maximum possible concentration of a substance during its single administration in order to rule out the development of negative effects caused

by nonspecific factors. When the appropriate range is obtained, the exposure ensured using at least five concentrations that form a geometric progression with a denominator of no more than 2.2.

Adult animals are exposed to toxicants in the semistatic mode under controlled conditions in accordance with GOST 32473—2013 [16]. Visual recording of outcomes is performed 3, 6, 24, 48, 72, and 96 h from the beginning of the experiment. The number of dead individuals, the time of death, apparent behavioral anomalies, and intoxication signs are recorded. Reliability of the results obtained confirmed by the low mortality rate in the control group (less than 10%), adherence to constant experimental conditions, and maintenance of optimal test concentrations throughout the entire exposure period in accordance with GOST 32473—2013 [16].

The intact parent stock is the source of embryos required for assessing the acute toxicity of chemicals. The spawning procedure is compliant with GOST 32541—2013 [18]. The resulting spawn is treated with a solution of methylene blue to prevent fungal and bacterial contamination. Then a visual inspection is carried out to assess the quality of the eggs and remove unfertilized and damaged eggs. Criteria for selection of viable fertilized spawn that are compliant with GOST 33774—2016 [19] include transparency of the chorion, the presence of a perivitelline space between the egg wall and the embryo, the onset of cleavage (4–64 blastomere stage), and no signs of coagulation. According to the above standard, viable spawn

at the early cleavage stage is transferred using sterile plastic pipettes into 24-well plates for cultivation and distribution into experimental groups.

The test concentration range is determined by OECD Test Guideline No. 236 [11]. Preliminary testing is performed to justify the concentration range, similar to that used for the acute toxicity assessment in adult *D. rerio*.

The mortality of embryos is assessed daily at the same time (every 24 h) using an inverted microscope. The indicators are recorded in absolute and relative units based on the presence of embryo coagulation, non-separation of the tail part from the yolk sac, absence of somite formation and heartbeat. The detection of any of the listed signs indicates the embryo death. In addition, the hatching rate (number of free-swimming larvae) is recorded in the experimental groups starting from 48 h of exposure. The experimental results are considered reliable provided that the total level of fertilized spawn in the batch is at least 70%, the hatching rate and survival rate of embryos in the negative control at the end of the 96-h exposure exceeds 80%, the temperature during incubation of the plates is maintained at the level of 26 ± 1 °C, pH of test solutions is within the range of 7.5 ± 0.5 in accordance with GOST 33774—2016 [19]. An in-depth assessment of toxic effects of chemical compounds in early *D. rerio* ontogenesis is carried out under conditions of a prolonged acute experiment (up to 168 h) in accordance with the guidelines for assessing toxicity in the early fish life [19]. Such an approach makes it possible to register acute lethal and sublethal (delayed) effects in embryos, prelarvae and larvae (the stage of transition to exogenous feeding and active swimming).

At the end of the exposure, based on the results of the concentration-effect (lethality) relationship assessment, the mean lethal concentration (LC_{50}) is calculated for adult animals and embryos using probit analysis [29], which makes it possible to justify the choice of concentrations for subsequent experiments to assess chronic toxicity. When no lethality is reported, the highest concentration tested is taken as LC_{50} .

Modeling and assessment of chronic toxicity and long-term effects of chemicals

Chronic toxicity is assessed at the second stage of the study. The test substance concentrations are determined based on the average lethal concentration values obtained (LC_{50}). According to GOST 32538—2013 [17], at least two concentrations of test substances are selected: $1/100 LC_{50}$ and $1/1000 LC_{50}$. *D. rerio* fish are exposed for 21 days in accordance with the guidelines [30] considering the *D. rerio* species-specific features, and GOST 32428—2013 [15]. Every 24 hours from the start of the experiment, the condition of the fish is monitored, and the indicators regulated by the state standard are recorded. The number of dead animals, the time of death, apparent behavioral anomalies, and signs of intoxication are recorded.

The assessment of the long-term effects of toxicants involves assessment of reprotoxic, mutagenic, and teratogenic effects. The choice of test concentrations is similar to that used in chronic toxicity assessment.

The study of the toxic effect of compounds on the reproductive potential of fish is carried out in accordance with the regulated methodology [21]. The assessment is based on qualitative and quantitative indicators of the *D. rerio* reproductive function state according to GOST 32368—2013 [20].

Quantitative indicators are assessed after spawning. The spawning and spawn processing procedures comply with

the requirements of GOST 32541—2013 [18]. After collecting spawn, a visual inspection is carried out to control quality and the total number of fertilized and unfertilized eggs is counted in absolute and relative units (abs./%). Criteria of viable fertilized spawn are transparency of the chorion, the presence of a perivitelline space between the egg wall and the embryo, the onset of cleavage (4–64 blastomere stage), and no signs of coagulation. Unfertilized and damaged eggs are removed after counting.

The viable spawn is used to assess teratogenic effects in accordance with OECD Test No. 236 [11], GOST 33774—2016 [19], and GOST 32541—2013 [18]. The duration of the study is 168 h (7 days), embryos and larvae are not exposed to negative effects.

Every 24 h, lethal effects are recorded using an inverted microscope according to the criteria specified in GOST 33774—2016 [19] and GOST 32541—2013 [18]: coagulation (opalescence, turbidity) of the embryo, no somite formation (abnormal segmentation), failure of the tail to separate from the yolk sac, no heartbeat. The detection of any of the listed signs indicates the death of the embryo. Additionally, the hatching rate (number of free-swimming larvae) is recorded starting from 48 h of exposure. Sublethal effects indicating the presence of a teratogenic effect are assessed according to the following criteria: the presence of deformation of the chord and tail section; delayed hatching (starting from 48 h); early postembryonic (post hatching) lethality; development of postembryonic edema. Additionally, the presence of combined morphological anomalies in specific embryos is assessed. The criteria for normal development of prelarvae in the control group are complete or almost complete yolk sac resorption, swim bladder fullness, active locomotion, and no signs of distress.

The experimental results are considered reliable when these meet the validity criteria: the overall fertilization rate in the collected batch of spawn is at least 70%, and the embryo survival rate and hatching rate in the negative control at the end of the 96-h exposure is at least 80%.

After completion of the 96-h period of recording lethal effects, monitoring the surviving prelarvae is extended to 168 hours (7 days) in accordance with GOST 32541—2013. The method allows for a comprehensive assessment of lethal and sublethal effects. The coping environment remains unchanged. Lethal effects are assessed daily (every 24 h) using an inverted microscope according to the above criteria. The assessment of teratogenic effects is completed after 168 h (7 days).

After spawning, fish are euthanized for further assessment of morphological alterations. According to the international guidelines on euthanasia of laboratory animals, the methods used must ensure rapid and irreversible death with minimization of pain and psycho-emotional stress in animals [31]. In this regard, an anesthetic substance called eugenol (clove oil) pre-dissolved in 96% ethyl alcohol in a volume ratio of 1 : 9 (1 cm³ of eugenol per 9 cm³ of alcohol) is used. The resulting solution is added to the water gradually (1 cm³ every 10 min) until deep anesthesia is achieved. The criteria for the onset of death are the gill cover motor activity cessation and no response to external stimuli. After that the fish are dried with filter paper and weighed with an accuracy of 0.1 g. The samples obtained are labeled. The gonadal histopathology assessment (identification of structural abnormalities in the tissues of the ovaries and testes) is performed. Histological slices are prepared by conventional methods.

The study and assessment of the mutagenic effect of chemicals is carried out using a micronucleus test in accordance with the Guideline (international standard) ISO 21427-1:2006

[32] representing the generally accepted methodology for assessment of the aquatic environment genotoxicity, including using fish as test objects. After 21 days of exposure, the fish are euthanized in the above manner. Blood is collected from the caudal artery by amputating the caudal peduncle distal to the anal fin. One drop of blood (5–10 µL) is immediately applied to the clean, degreased glass slide and spread in an even layer. Smears are fixed and dried in air at room temperature. The fixed smears are May–Grünwald–Giemsa stained. In each smear, erythrocytes are examined microscopically using an immersion lens.

The lowest effective concentration (LOEC) and no effective concentration (NOEC) of chemicals are determined based on the chronic toxicity assessment results. These parameters are used for subsequent justification of MPC in water and soil and RfD for humans with chronic oral intake.

Benefits of introducing the integrated approach into the hygienic rationing practice

The reported methodology, which integrates existing approaches to assessing acute and chronic toxicity in the *D. rerio* biological model into a single algorithm, makes it possible to use different model organism development stages (adult animals and embryos). In terms of methods this is different from the similar study [33], in which toxic properties were assessed at the embryonic stage only. The simultaneous use of model organisms at different stages of development allows

for the implementation of a comprehensive approach to the study of pathogenetic mechanisms underlying negative effects of test chemicals and for confirmation of the hygienic hypothesis about the living systems specific sensitivity depending on the development stage [13, 14].

In terms of hygiene, the exposure period extension to 168 h is a critically important step that makes it possible to record long-term negative effects of toxicants not detected during the standar 96-h biotesting. This fact is fully consistent with the conclusions that the abridged toxicology testing protocols may significantly underestimate the true hazard of compounds with high cumulative potential [34]. The reported step-by-step design allows for increased accuracy and objectivity in determining doses and ineffective concentrations of new chemical substances during chronic oral intake by humans.

CONCLUSION

The paper considers the use of the *Danio rerio* (Hamilton, 1822) freshwater fish as a highly informative, valid model organism in experimental studies to substantiate quality and safety standards for various types of water, except for industrial water, and soil in populated areas. An integrated approach that implements short-term and long-term studies in a single experimental design allows for the establishment, with a high degree of reliability, of quantitative parameters necessary for calculating maximum permissible concentrations and reference doses for chronic oral intake of chemical compounds by humans.

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ASSOCIATION OF CORTISOL WITH ANXIETY AND DEPRESSIVE CONDITIONS IN STUDENTS AT VARIOUS STAGES OF TRAINING

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The students' cortisol levels reflecting stress are associated with the anxiety and depression manifestations, which is important in terms of the educational process hygienic optimization. The study aimed to assess the correlation on students' blood levels of cortisol with anxiety and depressive conditions at various stages of training. A total of 200 1st-year students, who were taught during the academic year 2023–2024, took part in the comparative cross-sectional study. Serum cortisol levels were determined by enzyme immunoassay (ELISA), and the HADS scale was used to detect anxiety and depressive disorders. Signs of anxiety depression at training stages were detected in 34.4–43.6% ($p = 0.189$) and 18.2–24.7% ($p = 0.256$) of students. In the end of the academic year the share of clinical form in the structure of anxiety increased by 19.3% and that in the structure of depression increased by 4.3%. The cortisol levels associated with anxiety were higher in spring, than on autumn — 32.3% ($p = 0.001$), including 35.3% with subclinical form ($p = 0.001$), 28.4% with clinical form ($p = 0.028$); the values associated with depression were 53.9% higher in spring ($p = 0.001$), including 55.4% with subclinical form ($p = 0.001$), 45.6% with clinical form ($p = 0.052$). There was no association of cortisol levels with anxiety in autumn ($r = 0.07$, $p = 0.488$), there was a moderate positive one in spring ($r = 0.51$, $p = 0.001$), including the following: girls in autumn had $r = 0.03$, $p = 0.771$, in spring $r = 0.49$, $p < 0.001$, while boys in autumn had $r = 0.18$, $p = 0.296$, in spring $r = 0.57$, $p = 0.001$, respectively. A nonlinear log model showed a significant effect of anxiety ($F = 16.26$, $p < 0.001$), explaining 7.7 % of variance. The findings are important for the development of preventive programs focused on stress management in students.

Keywords: students, autumn, spring, anxiety, depression, cortisol, relationship

Author contribution: Rakhmanov RS — study concept and design, manuscript writing; Tarasov AV — primary data acquisition and systematization, statistical data processing, manuscript writing; Razgulin SA — literature review; Skoblina NA — data interpretation, manuscript writing; Kiselev SV — literature data acquisition.

Compliance with ethical standards: the study was compliant with the ethical standards of the World Medical Association Declaration of Helsinki. It was approved by the Ethics Committee of the Immanuel Kant Baltic Federal University (protocol No. 38 dated March, 2023). Each subject submitted the informed consent to take part in the study and for personal medical information to be published in an anonymized form.

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Received: 19.03.2026 **Accepted:** 31.08.2026 **Published online:** 15.09.2026

DOI: 10.24075/rbh.2026.172

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АССОЦИАЦИЯ КОРТИЗОЛА С ТРЕВОЖНО-ДЕПРЕССИВНЫМИ СОСТОЯНИЯМИ У СТУДЕНТОВ НА РАЗЛИЧНЫХ ЭТАПАХ ОБУЧЕНИЯ

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Отражающий стресс уровень кортизола у студентов связан с проявлениями тревожности и депрессии, что важно с точки зрения гигиенической оптимизации учебного процесса. Целью исследования было оценить взаимосвязь уровня кортизола в крови студентов с тревожно-депрессивными состояниями на разных этапах обучения. В сравнительном поперечном исследовании приняли участие 200 студентов 1-го курса, обучавшихся в 2023–2024 учебном году. Уровень кортизола в сыворотке крови определяли методом иммуноферментного анализа (ИФА), для выявления тревожно-депрессивных состояний использовали шкалу HADS. Признаки тревоги и депрессии по этапам обучения выявлены у 34,4–43,6% ($p = 0.189$) и 18,2–24,7% ($p = 0.256$) студентов. В конце года обучения доля клинически выраженной формы в структуре тревоги увеличилась на 19,3%, в структуре депрессии — на 4,3%. Показатели кортизола при тревоге весной выше, чем осенью, — на 32,3% ($p = 0.001$), в том числе при субклинической форме на 35,3% ($p = 0.001$), при клинически выраженной форме на 28,4% ($p = 0.028$); при депрессии весной они выше на 53,9% ($p = 0.001$), в том числе при субклинической форме на 55,4% ($p = 0.001$), при клинически выраженной форме на 45,6% ($p = 0.052$). Ассоциация уровня кортизола с тревогой осенью отсутствует ($r = 0.07$, $p = 0.488$), весной она умеренная прямая ($r = 0.51$, $p = 0.001$), в том числе у девушек осенью $r = 0.03$, $p = 0.771$, весной $r = 0.49$, $p < 0.001$, а у юношей осенью $r = 0.18$, $p = 0.296$, весной $r = 0.57$, $p = 0.001$ соответственно. Нелинейная логарифмическая модель показала значимый эффект тревожности ($F = 16.26$, $p < 0.001$), объясняющий 7,7 % дисперсии. Результаты исследования имеют значение для разработки профилактических программ, направленных на управление стрессовой нагрузкой студентов.

Ключевые слова: студенты, осень, весна, тревога, депрессия, кортизол, взаимосвязь

Вклад авторов: Р. С. Рахманов — концепция и дизайн исследования, написание текста статьи; А. В. Тарасов — сбор, систематизация первичного материала, статистическая обработка данных, написание текста статьи; С. А. Разгулин — анализ литературы; Н. А. Скоблина — интерпретация данных, написание текста статьи; С. В. Киселев — сбор данных литературы.

Соблюдение этических стандартов: исследование проведено с соблюдением этических норм Хельсинкской декларации Всемирной медицинской ассоциации. Получено одобрение этического комитета БФУ им. И. Канта (протокол № 38 от 31 марта 2023 г.). Каждый участник исследования дал письменное добровольное информированное согласие на участие в исследовании и публикацию персональной медицинской информации в обезличенной форме.

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Статья получена: 19.03.2026 **Статья принята к печати:** 31.08.2026 **Опубликована онлайн:** 15.09.2026

DOI: 10.24075/rbh.2026.172

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Modern students experience significant psycho-emotional stress associated not only with gaining independence and the educational process specifics, but also with the need to adapt to new social conditions, as well as the professional and personal identity development [1, 2]. The transition to adulthood increases stress: students face high academic demands, competition, and expectations of success; some have to combine study with work, live away from family, and arrange their daily lives [3–6]. The complex influence of factors leads to the increased mental health vulnerability, contributing to susceptibility to anxiety disorders, depression, and chronic stress [7, 8]. Thus, the study of the body's stress responses is becoming especially important, and data on the prevalence of such conditions and the factors influencing those become necessary for the development of adequate preventive measures [9, 10].

The conditions that lead to the development of chronic stress also negatively affect the body's physiological parameters, in particular the of the hypothalamic-pituitary-adrenal (HPA) axis activity. Cortisol is a key hormonal marker of stress, reflecting the HPA axis activation and ensuring the body's adaptive responses to psycho-emotional stimuli [11]. Studying the relationship between cortisol levels and manifestations of anxiety and depression makes it possible to determine the stress response biological mechanisms, identify groups at risk, and develop preventive measures to maintain the students' psycho-emotional and physical health [12].

Previous research suggests that women and men may respond differently to stressful stimuli, and seasonal fluctuations affect hormonal levels and psycho-emotional state [13]. However, the data on the relationship between anxiety, depression, and cortisol levels in students, considering these factors, remain limited and contradictory.

The study aimed to assess the correlation between the student's blood levels of cortisol and anxiety and depressive conditions at various stages of training.

METHODS

A comparative cross-sectional study was conducted involving two independent groups of 1st-year students assessed in the beginning (autumn, $n = 99$) and in the end of the academic year (spring, $n = 101$). A total of 200 students (140 girls and 60 boys), whose average age was 19.8 ± 0.6 years, took part in the study. All participants had previously undergone a medical examination and were in good health. Inclusion criteria: no earlier diagnosed anxiety or depressive disorder with the confirmation of belonging to the first or second health group. Exclusion criteria: the third health group and the diagnosis of mental disorder. The representative sample was calculated using the Epi Info software tool (<http://www.cdc.gov/epiinfo/>) with the 95% confidence level. The minimum sample size was 174 subjects, based on the number of 1st-year university students in the academic year 2023–2024.

No specific assessment of dietary patterns, dietary restrictions, and physical activity was conducted in the period immediately preceding the study. To standardize the testing conditions, blood samples were collected by puncture of the cubital vein in the fasting state from 8 to 9 a.m. by the nurse at the university clinic. Serum cortisol levels were determined by enzyme-linked immunoassay (ELISA; ELISA Test for Quantitative Determination of Cortisol in Human Serum. Human GmbH, REF 55050; Germany) with the minimal sensitivity of 2.5 ng/mL. Optical density was measured using the AMR-100 microplate reader (Allsheng; China) at a wavelength of 450 nm using an automatic Bio-Plex Pro II Wash Station (Bio-Rad; Austria).

The Hospital Anxiety and Depression Scale (HADS) representing a clinical instrument allowing one to detect and quantify symptoms of anxiety and depression was used to assess psycho-emotional state. The method includes two subscales (each of 7 items) focused on anxiety and depression, respectively. For each item, the respondent assigns a score ranging from 0 to 3 points, after which a total score is calculated for each subscale (maximum score 2). The results are interpreted based on three ranges: 0–7 points indicate that there are no symptoms, 8–10 points correspond to a subclinical form, and 11 points or higher indicate a clinical form of the disorder. Thus, HADS provides a differentiated assessment of anxiety and depression severity, increasing the accuracy of the emotional state diagnosis [14].

Statistical data processing was performed using the STATISTICA 12.0 software (StatSoft, Inc.; USA). The sample distribution was tested for normality using the Kolmogorov–Smirnov test. Mean values were compared using the Student's *t*-test for independent samples, the analysis of share differences was conducted using the Z-test, and the Spearman's rank correlation coefficient was used to assess the correlation between continuous variables. The differences were considered significant at $p < 0.05$. The 95% confidence intervals (95% CI) were calculated for quantitative indicators.

A general nonlinear log model was constructed using sigma-restricted parameterization to assess the impact of psychosocial, biological, and climatic factors on blood cortisol levels in students. Severity of anxiety and depression on the HADS scale, gender, season, and the "gender – season" interaction were included in the model as independent variables. The model made it possible to assess the contribution of each factor to the variability of cortisol levels.

RESULTS

Testing showed that the proportion of students with no signs of anxiety was significantly (1.6 times) higher than the proportion of students with anxiety symptoms. Among girls, it was 1.4 times higher than in individuals with anxiety, while among boys, it was 2.2 times higher. In autumn, the proportion of students without anxiety was 1.9 times higher, while in spring, there were no significant differences in the proportional distribution of individuals having and not having anxiety symptoms. Furthermore, only in the cohort examined in autumn was the subclinical form of anxiety encountered 1.8 times more often, than the clinical form (Table 1).

Among the examined individuals, no signs of depression were observed 3.7 times more often, than depressive symptoms. Furthermore, the proportion of individuals with the subclinical depression form was 2.9 times higher, than the proportion of individuals with the clinical form. Depression was diagnosed 4.4 times less often in girls. In individuals with depression, the subclinical form occurred 4.2 times more often, than the clinical one. Among boys, the proportion of individuals without depression was 2.5 times higher, than that of individuals with depressive symptoms. No significant differences in the prevalence of depressive symptoms or the distribution of subclinical and clinical forms between girls and boys were found. In autumn, the proportion of students with no signs of depression was 4.5 times higher, than that of students with depression, while the subclinical form was reported 3.5 times more often, than the clinical one. In spring, the proportion of students with no signs of depression was 3.0 times greater, than the proportion of those with depressive symptoms. Furthermore, the subclinical form

Table 1. Structure of student distribution based on the presence of anxiety signs, %

Comparison groups	No signs of anxiety	Signs of anxiety	including the form		p^*
			subclinical	clinical	
	1	2	3	4	
Sample size	61	39	53.8	46.2	$p_{1-2} < 0.001$ $p_{3-4} = 0.336$
Girls	57.9	42.1	55.9	44.1	$p_{1-2} = 0.008$ $p_{3-4} = 0.197$
Boys	68.3	31.7	47.4	52.6	$p_{1-2} < 0.001$ $p_{3-4} = 0.988$
p^{**}	0.163	0.177	0.512	0.536	
Spring	56.4	43.6	45.4	54.6	$p_{1-2} = 0.393$ $p_{3-4} = 0.793$
Autumn	65.6	34.4	64.7	35.3	$p_{1-2} < 0.001$ $p_{3-4} = 0.015$
p^{**}	0.181	0.189	0.09	0.452	

Note: * — significance of differences for groups with various anxiety severity; ** — significance of differences for groups of males and females and for seasons of the year.

occurred 4.0 times more often, than the clinical one. Seasonal differences in the detection rates of anxiety and depressive conditions, as well as subclinical and clinical forms, were non-significant (Table 2).

Cortisol levels were significantly (1.3 times) higher in individuals with anxiety, than in those without it ($p < 0.001$); with the subclinical form, it was 1.3 times higher than in individuals with no signs of anxiety ($p < 0.001$), and with the clinical form it was 1.3 times higher ($p < 0.001$). There were no differences in levels between the subclinical and clinical forms.

It was found that cortisol levels of girls with anxiety were higher compared to that of girls with no anxiety: by 34.7%. There were no differences in hormone levels between the subclinical and clinical forms. An increase in cortisol levels (by 22.3%) was also observed in boys with anxiety. In cases of subclinical anxiety, cortisol levels did not differ from those in the group without anxiety, whereas in individuals with the clinical form these were significantly higher—by 28.5%. The values did not differ between the subclinical and clinical forms.

Intergroup differences in blood cortisol levels (between males and females) were significant only in the group without signs of anxiety, where boys had higher cortisol levels. No differences between gender groups were found regarding the presence of the assessed signs, including in the subclinical and clinical forms.

In autumn, there were no differences in cortisol levels between individuals with and without anxiety (including subclinical and clinical forms). In spring, Students with anxiety had cortisol levels 56.8% higher, than students without anxiety. This same ratio was true for both subclinical and clinical anxiety: cortisol levels exceeded those in the group without anxiety by 58.5% and 55.5%, respectively. At the same time, seasonal differences proved to be significant: in autumn, cortisol levels in the group of students showing no signs of anxiety were 1.1 times higher, than in spring. An opposite trend was observed in the group of students showing signs of anxiety: cortisol levels were 1.3 times higher in spring, than in autumn, in individuals with both subclinical and clinical forms of anxiety (Table 3).

Students with signs of depression had significantly higher cortisol levels than students without depression (by 24.3%). In individuals with subclinical depression, the levels were 1.3 times higher than in those without depression, whereas in cases of clinical depression, the differences from the group with no depression were non-significant. The values did not differ between the subclinical and clinical forms.

Cortisol levels in female students with depression were significantly higher (by 28.2%), than in those without depression. In individuals with subclinical depression, these 31.3% higher compared to that in individuals with no depression, whereas no differences were reported for the clinical form. Cortisol

Table 2. Structure of student distribution based on the presence of depression signs, %

Comparison groups	No signs of depression	Signs of depression	including the form		p^*
			subclinical	clinical	
	1	2	3	4	
Sample size	78.5	21.5	74.4	25.6	$p_{1-2} < 0.001$ $p_{3-4} < 0.001$
Girls	81.4	18.6	80.8	19.2	$p_{1-2} < 0.001$ $p_{3-4} < 0.001$
Boys	71.7	28.3	64.7	35.3	$p_{1-2} < 0.001$ $p_{3-4} = 0.095$
p^{**}	0.123	0.128	0.912	0.085	
Spring	75.3	24.7	72	18	$p_{1-2} < 0.001$ $p_{3-4} < 0.001$
Autumn	81.8	18.2	77.7	22.3	$p_{1-2} < 0.001$ $p_{3-4} = 0.015$
p^{**}	0.258	0.256	0.675	0.66	

Note: * — significance of differences for groups with various depression severity; ** — significance of differences for groups of males and females and for seasons of the year.

Table 3. Cortisol levels in individuals showing and not showing signs of anxiety, nmol/L, $M \pm \sigma$ (95% CI)

Comparison groups	No signs of anxiety	Signs of anxiety	including the form		p^*
			subclinical	clinical	
	1	2	3	4	
Girls	316.5 $\pm$ 14.1 (288.3–344.7)	426.5 $\pm$ 16.8 (392.8–460.2)	421.2 $\pm$ 19.4 (381.6–460.9)	433.3 $\pm$ 29.5 (372.5–494.0)	$p_{1-2} < 0.001$ $p_{1-3} < 0.001$ $p_{1-4} < 0.001$ $p_{3-4} = 0.724$
Boys	365.6 $\pm$ 17.8 (329.4–401.7)	447.3 $\pm$ 26.8 (390.9–503.6)	422.3 $\pm$ 43.9 (320.9–523.7)	469.7 $\pm$ 32.7 (395.6–543.7)	$p_{1-2} = 0.013$ $p_{1-3} = 0.196$ $p_{1-4} = 0.011$ $p_{3-4} = 0.393$
p^{**}	0.04	0.535	0.978	0.488	
Spring	307.9 $\pm$ 19.4 (269.0–346.8)	482.9 $\pm$ 17.7 (447.2–518.7)	488.1 $\pm$ 20.1 (446.0–530.3)	478.7 $\pm$ 28.2 (420.3–537.0)	$p_{1-2} < 0.001$ $p_{1-3} < 0.001$ $p_{1-4} < 0.001$ $p_{3-4} = 0.793$
Autumn	355.0 $\pm$ 12.2 (330.6–379.4)	365.0 $\pm$ 17.8 (328.7–401.4)	360.8 $\pm$ 21.6 (315.9–405.7)	372.8 $\pm$ 32.7 (300.7–444.9)	$p_{1-2} = 0.637$ $p_{1-3} = 0.812$ $p_{1-4} = 0.575$ $p_{3-4} = 0.753$
p^{**}	0.037	< 0.001	< 0.001	0.028	

Note: * — significance of differences for groups with various anxiety severity; ** — significance of differences for groups of males and females and for seasons of the year.

levels did not differ between subclinical and clinical forms of depression. Differences in the levels of this hormone in males having and not having depression, including with various depression severity, were non-significant. There were no differences in cortisol levels in gender groups.

In autumn, cortisol levels did not differ based on the fact of having or not having depression; however, in spring, the levels were significantly higher (by 50.7%) in individuals with depression compared to those with no depression. The differences compared to data for subclinical and clinical depression reached 55.6% and 38.1%, respectively, whereas there were no differences between the data for the subclinical and clinical forms. Furthermore, in spring, cortisol levels in individuals with depression exceeded the levels measured in autumn by 53.9%, including by 55.4% with the subclinical form (Table 4).

The correlation analysis revealed a significant association between cortisol levels and the fact of having anxiety: the association was positive, of moderate strength ($r_s = 0.33$; $p < 0.001$). Moderate positive correlations were found in both girls and boys. No significant correlation was detected in autumn. The most pronounced association was observed in spring: a moderate-to-strong, positive association (Table 5). A positive association was also reported for individuals with depression: a positive one of moderate strength. The associations were positive, of moderate strength in the groups of both females and males. In autumn, there was no significant correlation between cortisol levels and depressive symptoms; moderate-to-strong, positive correlation was reported in spring (Table 5).

When constructing a nonlinear regression model to test the influence of psychosocial and demographic factors on blood cortisol levels in students, high overall model significance was determined ($F = 214.00$, $p < 0.001$). In general, the model explained 62.5% of cortisol level variance, and 37.5% of variance were not taken into account. Anxiety proved to be the most significant factor: the statistical significance was achieved for it ($F = 16.26$, $p < 0.001$). As for depression, no significant association with cortisol levels was revealed ($F = 0.16$, $p = 0.691$). Gender demonstrated borderline statistical significance ($p = 0.049$) and explained 2.0% of cortisol level variance. Other factors included in the model were non-significant. However, it should be noted that the model residual variance

turned out to be rather high ($SS = 3\,031\,396.73$, $MS = 15\,625.76$), which suggests that there are unaccounted-for factors capable of influencing cortisol levels, including dietary habits, sleep quality, physical activity, chronic stress, and individual characteristics of HPA axis regulation.

DISCUSSION

The study results demonstrate a complex pattern of correlations between the students' psycho-emotional state and cortisol levels. Thus, in the combined sample, the proportion of individuals with signs of anxiety was 1.8 times higher than the proportion of individuals with signs of depression ($p < 0.001$), including the proportion of students with subclinical signs of anxiety was 1.4 times lower than the proportion of students with subclinical signs of depression ($p = 0.026$), and the proportion of students with clinical signs of anxiety was 1.8 times higher than the proportion of students with clinical signs of depression ($p = 0.027$). The average HADS scores were significantly higher in spring, than in autumn: 1.1 times higher for anxiety показатель ($p = 0.040$), 1.2 times higher for depression ($p = 0.031$).

Cortisol levels were higher in individuals showing signs of anxiety, than in those showing signs of depression. A significant positive correlation and a significant contribution to the model's variance indicated that students with higher anxiety levels had elevated stress hormone levels. These data confirm the results of previous studies, in which a strong correlation between the depression severity and the HPA axis activation was reported [15, 16].

In contrast to anxiety, depression did not have a significant effect on cortisol levels within the nonlinear model, although correlation analysis showed moderate positive associations. This suggests that in healthy students, mild and subclinical manifestations of depression may not lead to pronounced HPA axis activation. This finding is consistent with other research results, according to which subclinical depressive symptoms showed a weak correlation with the cortisol concentration [17].

Data on the prevalence of anxiety among the students in the studied cohort confirm that anxiety symptoms are more common in the student population, than depressive symptoms [18]. Seasonal differences reflected by the fact that average

Table 4. Cortisol levels in individuals showing and not showing signs of depression, nmol/L, $M \pm \sigma$ (95% CI)

Comparison groups	No signs of depression	Signs of depression	including the form		p^*
			subclinical	clinical	
	1	2	3	4	
Girls	344.7 $\pm$ 12.4 (320.1–369.4)	442.3 $\pm$ 27.2 (386.1–498.4)	452.5 $\pm$ 32.1 (385.5–519.5)	399.5 $\pm$ 43.8 (277.8–521.2)	$p_{1-2} = 0.001$ $p_{1-3} = 0.001$ $p_{1-4} = 0.365$ $p_{3-4} = 0.455$
Boys	374.6 $\pm$ 17.5 (339.3–401.7)	434.0 $\pm$ 30.9 (368.5–499.5)	440.7 $\pm$ 44.1 (342.3–539.0)	421.7 $\pm$ 38.3 (323.1–520.3)	$p_{1-2} = 0.085$ $p_{1-3} = 0.108$ $p_{1-4} = 0.114$ $p_{3-4} = 0.850$
p^{**}	0.195	0.844	0.688	0.71	
Spring	341.3 $\pm$ 17.6 (306.2–376.4)	514.4 $\pm$ 19.5 (474.0–554.8)	531.2 $\pm$ 25.8 (476.6–585.8)	471.3 $\pm$ 12.9 (439.7–502.3)	$p_{1-2} < 0.001$ $p_{1-3} < 0.001$ $p_{1-4} < 0.028$ $p_{3-4} = 0.174$
Autumn	363.8 $\pm$ 11.1 (341.8–385.8)	334.2 $\pm$ 17.8 (283.9–384.5)	341.9 $\pm$ 23.8 (277.5–406.3)	323.8 $\pm$ 60.0 (132.5–515.0)	$p_{1-2} = 0.258$ $p_{1-3} = 0.458$ $p_{1-4} = 0.439$ $p_{3-4} = 0.780$
p^{**}	0.274	< 0.001	< 0.001	0.052	

Note: * — significance of differences for groups with various depression severity; ** — significance of differences for groups of males and females and for seasons of the year.

anxiety and depression severity was higher in spring, than in autumn, which was probably due to academic workload and stressful events of the academic year, as well as general seasonal factors affecting emotional well-being [19].

Cortisol levels in students with anxiety were significantly higher than in those without it. This effect was reported for both subclinical and clinical anxiety forms. In girls, anxiety was associated by a similar rise in cortisol levels in both forms, whereas in boys, a significant increase was reported only in cases of clinical anxiety. Seasonal analysis showed that differences between the groups with and without anxiety were more pronounced in spring, than the autumn, which was consistent with the correlation analysis data: there was

a positive correlation (moderate-to-strong) in spring, whereas no significant correlation was observed in autumn. These findings are in line with the data of previous studies, in which elevated cortisol levels were observed in students and young adults under conditions of anxiety and stress [20].

In the context of depression, cortisol levels in students with the subclinical form were higher compared to the group without depression. There were no gender differences in the groups with depression. Seasonality was evident only in spring, when the correlation was moderate and significant, whereas no association was observed in autumn. The findings are consistent with the results of the earlier study, in which a correlation between symptoms of depression and anxiety and the characteristics

Table 5. Characteristics of correlations between the students' blood cortisol levels and the signs of anxiety and depression

Comparison groups	Spearman's rank correlation coefficient, r_s	Correlation strength and direction	Significance, p
Anxiety			
Total sample	0.33	Moderate positive	< 0.001
Girls	0.35	Moderate positive	< 0.001
Boys	0.37	Moderate positive	0.003
Spring	0.51	Moderate positive	< 0.001
Autumn	0.07	No	0.488
Girls spring	0.49	Moderate positive	< 0.001
Boys spring	0.57	Moderate positive	0.001
Girls autumn	0.03	No	0.771
Boys autumn	0.18	No	0.296
Depression			
Total sample	0.25	Moderate positive	< 0.001
Girls	0.22	Moderate positive	0.007
Boys	0.30	Moderate positive	0.016
Spring	0.45	Moderate positive	< 0.001
Autumn	0.02	No	0.180
Girls spring	0.39	Moderate positive	< 0.001
Boys spring	0.62	Moderate positive	< 0.001
Girls autumn	0.08	No	0.509
Boys autumn	0.03	No	0.841

of the cortisol response to stressful situations was identified in young people, even in those having no clinical diagnosis [21].

The nonlinear model confirmed the findings of the correlation analysis: anxiety was the most significant predictor of cortisol levels, while the gender factor showed borderline significance. Furthermore, the residual variance was 37.5%, which suggested that there were additional factors, not included in the analysis, such as dietary habits, chronic stress, sleep quality, physical activity, and individual features of the HPA axis regulation. These findings are in line with the reported data showing that physiological stress responses in students, including the HPA axis activation and elevated cortisol levels, were associated with emotional and psychological manifestations of stress, such as anxiety and depression, particularly in the context of academic demands [22].

Thus, the results obtained demonstrate that the students' cortisol levels are strongly associated with the anxiety severity and are less dependent on depression. Despite the fact that the cortisol level increase absolute values were within the reference ranges, these provided important information. Cortisol has a systemic effect on the body: it intensifies catabolic processes associated with the increased consumption of proteins, fat, vitamins, and minerals. This can deplete energy resources and reduce the body's adaptive capabilities [23]. Long-term adverse changes may manifest as the muscle mass loss, the development of osteoporosis, visceral fat accumulation, and the increased

risk of cardiovascular disease, effects on the immune, reproductive, and nervous systems, cognitive decline, and emotional instability [24–28].

In the university settings, preventive work may include the early detection of anxiety signs, the optimization of work-rest regime, and measures to reduce stress. The reported strengthening of the association between anxiety and cortisol levels in spring indicates the feasibility of closer monitoring of students' psycho-emotional state during periods of increased academic workload. Preventive measures in the university settings may include the early detection of anxiety signs, psychological support for students, the work-rest regime optimization, and measures to reduce stress.

CONCLUSIONS

Signs of anxiety were detected more often than signs of depression among 1st-year students, with no significant seasonal differences in their prevalence. In spring, cortisol levels associated with anxiety and depression were higher, than in autumn, and the association between cortisol and anxiety and depressive symptoms was more pronounced. The most significant correlation reported was between cortisol levels and anxiety, as confirmed by the nonlinear model results. The obtained data justify the importance of early detection of anxiety states and the reduction of stress among students, particularly at the end of the academic year.

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METHODOLOGICAL ASPECTS OF THE HYGIENIC REGULATION OF IONIZING RADIATION

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Technologies based on ionizing radiation (IR) are used in many areas of human activity, ranging from nuclear energy and national defense to medical diagnosis and therapy. Consequently, the hygienic assessment of the effects of IR is a scientifically and practically important interdisciplinary problem. This study aimed to analyze the challenges encountered and the approaches used to assess the radiation dose–effect relationship, thereby substantiating the need to harmonize radiation safety standards (RSS) at the current stage and highlighting the central role of evidence-based and preventive medicine in this field. We reviewed, researched, and analyzed IAEA's "Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards" and Russian SanPiN (sanitary norms and regulations) documentation, dose-related recommendations issued by the Russian Ministry of Health between 2020 and 2025, radiation therapy software solutions, and training manuals and clinical practice guidelines. The effort revealed a discrepancy between national, departmental, and international standards, dose tiers, and units of measurement. In some professions, such as piloting and spaceflight, occupational exposure to ionizing radiation exceeds the natural terrestrial background level by tens or even hundreds of times. The radiation-therapy doses specified in the Russian Ministry of Health's clinical recommendations differ by as much as tenfold across anatomical sites. There is a shortage of educational software designed to teach radiation therapy treatment planning. The authors translated three textbooks published by the IAEA and WHO into Russian and made these freely available. The following measures were identified as feasible and advisable: organizing interdepartmental cooperation on the development and approval of new RSS, taking into account current Russian and international practices; verifying radiotherapy dose recommendations in clinical guidelines; aligning dose categories for specific professions and harmonizing methods for assessing occupational radiation risks; and supplementing university curricula with radiotherapy-planning software, as well as WHO and IAEA textbooks and guidelines.

Keywords: ionizing radiation, radiation safety standards, occupational health, doses

Author contribution: Eryomin AL — study design, material collection and processing, text authoring; Bogatov NM — text editing, formalization of the concept of medical physics; Bey NE — analysis of clinical recommendations of the Ministry of Health of Russia, review of software solutions; Baranov VA — analysis of the law enforcement practice in the field of RSS control; Klenevskii AV — analysis of RSS in the clinical practice; Dahuzhev TS — testing of radiotherapy planning software; all authors — approval of the final version of the article, responsibility for the integrity of all parts of the article.

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Received: 22.07.2026 **Accepted:** 08.08.2026 **Published online:** 18.09.2026

DOI: 10.24075/rbh.2026.173

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МЕТОДИЧЕСКИЕ АСПЕКТЫ ГИГИЕНИЧЕСКОГО НОРМИРОВАНИЯ ИОНИЗИРУЮЩИХ ИЗЛУЧЕНИЙ

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Технологии на основе ионизирующих излучений (ИИ) проникли во многие сферы человеческой деятельности — от атомной энергетики и оборонных комплексов до медицинской диагностики и терапии, что делает проблему гигиенической оценки воздействия ИИ междисциплинарной и сохраняющей высокую научно-практическую значимость. Целью работы было проанализировать проблемы и подходы к верифицированной оценке влияния «доза–эффект» физического фактора ИИ для обоснования целесообразности унификации на современном этапе норм радиационной безопасности (НРБ) и императива доказательной и профилактической медицины. Проанализированы публикации НРБ МАГАТЭ и СанПиН, дозы по клиническим рекомендациям Минздрава России 2020–2025 гг., ряд компьютерных систем дозиметрического планирования, учебные пособия и пособия для специалистов. Имеет место несоответствие национальных, ведомственных, международных норм, доз, единиц измерений. Люди некоторых профессий (летчики, космонавты) подвергаются воздействию ИИ, превышающему естественный фон на земле в десятки и сотни раз. В клинических рекомендациях Минздрава России дозы для лучевой терапии разной локализации различаются в десятки раз. Зафиксирован недостаток учебных компьютерных систем по планированию лучевой терапии. Авторами переведены на русский язык для открытого использования три учебных пособия МАГАТЭ, ВОЗ. Признано целесообразным организовать межведомственное взаимодействие при разработке и утверждении новых НРБ с учетом современного российского и международного опыта; верифицировать дозы лучевой терапии в клинических рекомендациях; унифицировать дозы для отдельных профессий и методики оценки профессиональных радиационных рисков; внедрить в образовательный процесс вузов компьютерные программы планирования лучевой терапии, учебные пособия и руководства ВОЗ, МАГАТЭ.

Ключевые слова: ионизирующие излучения, нормы радиационной безопасности, гигиена труда, дозы

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Статья получена: 22.07.2026 **Статья принята к печати:** 08.08.2026 **Опубликована онлайн:** 18.09.2026

DOI: 10.24075/rbh.2026.173

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Ionizing radiation (IR), discovered during the nineteenth and twentieth centuries, has been extensively studied and applied throughout the twentieth and twenty-first centuries. Dosimetry systems have been developed for a wide range of settings, including industrial, environmental, and space environments, while dose–effect relationships have been established through evidence-based medical research. IR-based technologies are widely used in key areas of human activity, including nuclear energy, national defense, medical diagnostics and therapy, basic scientific research, and radiation therapy involving cyclotrons and synchrotrons. Therefore, the hygienic assessment of the effects of IR constitutes an interdisciplinary problem of substantial scientific and practical importance. According to the WHO (2023), more than 4.2 billion diagnostic radiology examinations, 40 million nuclear medicine procedures, and 8.5 million radiotherapy treatments are performed worldwide each year. "Physicist expert in the control of ionizing and non-ionizing radiation sources" and "medical physicist" are occupations included in the list approved by an order of the Russian Ministry of Health issued in 2023 [1]. The requirements include higher education and a specialist or master's degree in medical physics. However, effective radiation control requires harmonized and approved standards, including maximum permissible levels (MPLs) for ionizing radiation and maximum permissible doses (MPDs). To ensure effective and safe radiotherapy, single boost doses (SBDs) and total boost doses (TBDs) should also be clearly defined. At the international level, efforts to harmonize standards across departments have led to the transfer of responsibility from several specialized organizations within the UN system to the IAEA, which coordinates, synthesizes, and publishes work on this topic in cooperation with the WHO [2]. In Russia, radiation safety standards (RSS) are traditionally approved by Rospotrebnadzor.

This study aimed to analyze the challenges encountered and the approaches used to assess the radiation dose–effect relationship, thereby substantiating the need to harmonize radiation safety standards (RSS) at the current stage and highlighting the central role of evidence-based and preventive medicine in this field.

Materials and methods

We compared international and Russian regulatory frameworks, including the IAEA Safety Standards and SanPiN, regulatory enforcement practices, clinical dose recommendations issued by the Russian Ministry of Health between 2020 and 2025, several radiotherapy software solutions, training manuals, and practical guides.

The evolution of IR units of measurement and modern unification in the SI system

In 1928, roentgen was adopted as the first international unit for measuring IR. Later, within the period from the 1940s to the 1970s, several units have been defined and introduced, including curie, rutherford, erg, coulomb/kg, J/kg, rad, rem as roentgen equivalent, rem as roentgen equivalent-man, etc., with some used with time units. The large number of parameters and the growing body of knowledge about dose–effect relationships threatened to make the field of dosimetry confusing [3]. In 2018, the General Conference on Weights and Measures (CGPM) approved revisions to the International System of Units (SI), as described in the ninth edition of the SI Brochure [4]. Among other provisions, the activity of a radionuclide is expressed in becquerels (Bq), the absorbed

dose and kerma in grays (Gy), and the equivalent dose in sieverts (Sv). The ninth edition of the SI Brochure contains a section entitled "Units for quantities that describe biological and physiological effects." It states that, in medical diagnostics and therapy, units that cannot yet be expressed in SI units are also used to quantify biological activity. The mechanisms of action of some biological agents have not yet been sufficiently elucidated to permit their activity to be expressed in terms of physicochemical parameters. Because of the importance of these agents to health and safety, the WHO has assumed responsibility for defining the International Units (IU) of biological activity. Neither the SI Brochure nor the WHO documents refer to "international units" for radiopharmaceuticals used in diagnosis or brachytherapy. This may be important both for planning effective brachytherapy treatments and in the context of the launch of Europe's largest radiopharmaceutical production complex in Obninsk. The activities of the International Commission on Radiation Units and Measurements (ICRU) should also be mentioned here, including its work on photon-beam radiation therapy [5].

Unification of safety standards at the level of specialized UN agencies

Research on the health effects of ionizing radiation has been ongoing for more than 120 years, with contributions from several international organizations, including the International Commission on Radiological Protection (ICRP) [6], the International Organization for Medical Physics (IOMP), and the International Agency for Research on Cancer (IARC). At the international level, responsibility for the development of radiation-safety standards was transferred in 2012 from the WHO to the International Atomic Energy Agency (IAEA). On behalf of the sponsoring organizations — the WHO, the International Labour Organization (ILO), the Pan American Health Organization (PAHO), the Food and Agriculture Organization of the United Nations (FAO), and the United Nations Environment Programme (UNEP) — the IAEA published the "Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards" (IAEA IBSS) [7]. The contribution of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) should also be noted. Its 2022 report to the United Nations General Assembly "Sources, Effects and Risks of Ionizing Radiation" provided a comprehensive global assessment of the frequency and doses of medical exposure to ionizing radiation, trends across medical categories, and occupational exposure [8].

Radiation safety standards (RSS) in Russia, expediency of comparative analysis, updating and interagency cooperation

Rospotrebnadzor, as the heir to the USSR state sanitary supervision system, traditionally approves RSS in Russia. This tradition makes sense given the historically established levels of social hygiene and health care; radiation hygiene, occupational hygiene, hygiene of children and adolescents, preventive medicine, including the prevention and control of cancer (the second leading cause of death), the identification of risks to public health, and the prevention of the negative effects of physical factors. However, the RSS were approved and incorporated into the Sanitary Rules and Regulations 15 years ago [9, 10]. Since then, the units of measurement and irradiation standards have changed, and a substantial body of data has been accumulated in this field, necessitating

an update to Russian legislation. In Russia, production control, the approval of standards, radiation-dose monitoring, and federal oversight of compliance are currently distributed across multiple departments and are carried out by Rospotrebnadzor, Roszdravnadzor, the Ministry of Health, Rostekhnadzor, the Federal Medical Biological Agency, the Russian Academy of Sciences, Rosatom, Rostech, the Ministry of Defense, Roscosmos, and other bodies [11–14]. Taking into account international experience and Russian specifics, prospects for development in medical physics, nuclear, aerospace and other sectors of the economy, it is advisable to organize interdepartmental cooperation in the development and approval of new RSS. An obstacle on the path is the problem of cancellation of licensing: there is no agency that oversees the process of licensing the maintenance of ionizing radiation generating sources used in medicine, radiological medical devices; this function can be transferred to Roszdravnadzor. As the first step, it is feasible to analyze the qualifications, instrumentation, and staffing for a specialized federal supervision and production control.

Some aspects enabling an in-depth comparative analysis that should be considered in the updated RSS

The new SanPiN 2.6.4115-25 introduced in 2025 [15] confirm the relevance and validity of the basic SanPiN 2.6.1.2523-09 (NRB-99/2009) [9] and SP 2.6.1.2612-10 (OSPORB-99/2010) [10]. It should be noted that SanPiN 2.6.4115-25 uses the curie for expressing high levels of activity. Although the curie has been approved for use in Russia since 2009 [16], it is a non-SI unit and is generally regarded as obsolete for scientific and technical use. It has therefore been superseded by the becquerel, the corresponding SI unit of activity. The National Institute of Standards and Technology (NIST) strongly discourages the continued use of the curie, as well as the roentgen, rad, and rem [17]. In its recommendations, the International Organization of Legal Metrology (OIML) classifies the curie, rad, and roentgen as units of measurement that may be used temporarily until the date established by national regulations but should not be introduced where they are not already in use [18]. This provision should be taken into account in future reviews of Russian legislation. The annual dose limits and associated fatal risks specified in SanPiN NRB-99/2009 are consistent with those in ICRP Publication 103 (2007) and the IAEA Basic Safety Standards, except for the neutron radiation-weighting factor, which is represented as a continuous function. Meanwhile, the tissue-weighting factors and their corresponding risk coefficients are based on ICRP Publication 60 (1991); however, there are no data or references related to the later ICRP Publication 103 (2007) [6].

Radiological tests and maintenance of ionizing radiation sources: Russian standards and control practice

The importance of dosimetric monitoring during X-ray examinations in Russia has been demonstrated by radiation-hygiene specialists [19, 20]. The Decree of the Government of the Russian Federation [21] and the order of the Ministry of Health of the Russian Federation [1], as legislative documents, cover "non-medical use of IR" and the respective licensing practice. There has been published an analysis of radiation accidents in radiation and radionuclide diagnostics and therapy that compares Russian and international approaches to terminology and classification [22].

Prospects for the development of radiation therapy in Russia: the need for medical and technical standardization

According to analytical reviews, Russia's fleet of high-tech radiotherapy equipment meets the standards of developing countries [23]. In 2020, the Government of the Russian Federation issued a resolution supporting the development of synchrotron- and neutron-based treatment infrastructure [24]. The resolution also set the goal of bringing proton therapy in Russia up to the global standard by 2027 and designated the Kurchatov Institute as the lead organization for implementing the program [25]. At the same time, healthcare planning in Russia should factor in the growing problem of uneven availability of high-tech medical assistance in the country, and design remedial measures for this problem. To date, these barriers remain difficult to overcome, as specialized treatment modalities — including proton therapy, neutron therapy, neutron-capture therapy, Gamma Knife radiosurgery, and carbon-ion therapy — are available only at centers located in certain regions. Consequently, patients may have to travel thousands of kilometers to obtain treatment. Neutron-capture therapy is being researched in Novosibirsk at the Budker Institute of Nuclear Physics [26] and also at the National Research Nuclear University MEPhI, jointly with the Blokhin Russian Cancer Research Center and the Burnasyan Federal Medical Biophysical Center. Regions of Russia receive modern radiotherapy technology unevenly. For example, the Southern Federal District (SFD) and the North Caucasus Federal District (NCFD), which together are home to 27 million people, have no proton- or neutron-therapy units or other high-tech radiotherapy facilities. A feasible initial-stage effort would involve a country-wide analysis of the current situation and the development of measures to facilitate the deployment of high-tech equipment and the recruitment and training of relevant personnel, including medical engineers — such as specialists in biotechnical systems and technologies — healthcare managers, and other professionals. The resulting action plan should draw upon international experience, including the IAEA's approach to planning radiotherapy services [27]. To improve and harmonize the practices of medical engineers and technicians who service radiotherapy equipment in clinics, the authors of this study and their colleagues translated the WHO-IAEA international technical specifications for radiotherapy equipment used in cancer treatment into Russian and made the translation publicly available [28].

Radiation doses in radiation therapy: from the evolution of guidelines to evidence-based medicine and dose unification in Russia

In radiation therapy, the current Sanitary Rules and Regulations (SanPiN) follow the ALARA principle ("as low as reasonably achievable"), which was formally introduced by the ICRP in 1977. That is, without directly setting dose limits for patients, radiotherapy specialists expand the limits of permissible exposure to the extent they deem necessary. In Russian SanPiNs, there are no concrete numbers supporting the ALARA principle followed, which creates legal uncertainty. For example, clause 5.4.1 of SanPiN 2.6.1.2523-09 (NRB-99/2009) states: "...dose limits for patients are not established; instead, the principles of justification of medical procedures and optimization of patient protection are applied." Under paragraph 4.4 of the Sanitary Regulations SP 2.6.1.2612-10 (OSPORB-99/2010), "therapeutic radiological procedures should be justified taking

Table 1. Analysis of the number, range, lower and upper limits of radiation doses (Gy) for radiation therapy of various types of neoplasms from 90 issued of clinical recommendations by the Ministry of Health of Russia (2020–2025)

Treatment protocol	Number of fractions	Single boost dose, Gy	Total boost dose, Gy
Protocols from the Ministry of Health of Russia, 2020–2025	1.0–50.0	0.5–40.0	2.0–180.0

into account the requirements: the risk of rejection of radiation therapy obviously exceeds the risk of radiation exposure during its implementation"; there are no references to specific generally accepted calculations of "risks." According to clause 4.7 of SP 2.6.1.2612-10 (OSPORB-99/2010), "optimization of radiation protection of patients should provide for achieving a beneficial medical effect of radiological procedures, or a therapeutic result, at the lowest possible radiation levels." The international initiative "Quantitative Analysis of Normal Tissue Effects in the Clinic" (QUANTEC) should also be noted. It involves compiling databases of dose–effect relationships for various organs and tissues based on long-term follow-up data [29, 30]. The situation has changed due to the accumulation of experimental results and the determination of doses in the clinical recommendations of the Ministry of Health of the Russian Federation (Ministry of Health of the Russian Federation), approved on the basis of a decree by the Government of the Russian Federation [31]. Preventive medicine, guided by the principle of "do no harm," and evidence-based medicine, which ensures the effectiveness of treatment, are increasingly gaining prominence. This is an important factor: single and total boost doses prescribed by the Ministry of Health of the Russian Federation in the respective guidelines are exactly what a plan of a radiotherapy course begins with. We analyzed the number, range, and limits (Gy) of doses in the context of photon therapy recommended for various neoplasms in 90 clinical guidelines approved by the Ministry of Health of the Russian Federation between 2020 and 2025. The guidelines were retrieved from the "Clinical Recommendations" (clin-rec) section of the Ministry's official website (Table 1).

The analysis revealed that the dose values in 90 issues of clinical recommendations by the Ministry of Health of the Russian Federation can vary tenfold: single boost dose (SBD) — from 0.5 to 40.0 Gy, total boost dose (TBD) — from 7.0 to 180.0 Gy. It should be noted a large number of reputable specialists participated in the development of each recommendation, and the most doses therein are supported by references to publications in foreign sources.

On the one hand, the variation in the recommended SBD and TBD values across different nosologies may be considered expected and biophysically (i.e., in relation to hard and soft tissues) and radiobiologically (i.e., in relation to radiosensitivity) justified. However, similar variation is also observed within individual nosologies, including differences in the recommended stage-dependent doses, radiation modalities, and equipment. Therefore, these discrepancies warrant further investigation, validation, dosimetric analysis, and explanation.

In the course of this study, we developed a tabular matrix presenting clinical recommendations of the Russian Ministry of Health; this matrix accumulates data for the primary analysis of radiation doses. Table 2 presents examples from specific

protocols. Its purpose is to provide a picture demonstrating the scale of the problem.

The tenfold differences in radiation doses recommended by the Russian Ministry of Health for various oncogenic target organs can be compared with the differences in tissue weighting factors used to calculate effective dose: under SP 2.6.1.2612-10 and ICRP Publication 60 (1991), these factors varied 20-fold, from 0.01 for bone surfaces to 0.20 for the gonads; under ICRP Publication 103 (2007), they varied 12-fold, from 0.01 to 0.12. This may also indicate the need for further work in the field of evidence-based medicine, calculations, and reasoned explanations.

Standards and guidelines for specialists, aspects of hyperinformational multidepartmental work, expediency of unification, comparison with international experience

Given its long history of nuclear technology development, extensive nuclear industry, and numerous economic sectors that use ionizing radiation, Russia has developed numerous guidelines and recommendations on radiation safety. The official regulatory framework includes SanPiNs published on the Rospotrebnadzor website in the section "List of Regulatory Legal Acts Containing Mandatory Requirements for the Use of Ionizing Radiation Sources." It also includes guidelines (MU) and recommendations (MP) issued or approved by Rospotrebnadzor that address radionuclide diagnostics using radiopharmaceuticals (MU 2.6.1.1892-04), radiation therapy (MU 2.6.1.2135-06), brachytherapy (MU 2.6.1.2712-10), and the management of the consequences of radiation accidents (MP 2.6.1.0360-24), among other areas. In addition, the framework comprises state standards (GOST) approved by Rosstandart, including standards for personal protective equipment against ionizing radiation for medical personnel (GOST R 58168–2018), methods for monitoring radiation therapy (GOST R 57517–2017), radiometric instruments (GOST R 57518–2017), and radiometric monitoring (GOST R 72075–2025). Finally, it includes 103 current regulatory documents (NP) containing federal norms and rules in the field of atomic energy use, published on the official Rostekhnadzor website. The system of radiation safety regulations approved and controlled by Rostekhnadzor is developed under Article 6 of Federal Law No. 170-FZ [32]. From the viewpoint of law, it is important for public health. In particular, there is an ongoing discussion about the approval of standards for the maximum permissible emissions of radioactive substances into the atmospheric air and the establishment of the boundaries of the sanitary protection zone (SPZ) around the site of a NPP [33]. The latter is significant for expert appraisals of the documentation of new NPPs, including Southern NPP and other nuclear power plants planned for construction up to 2042, as approved

Table 2. Tabular matrix of radiation doses from protocols described in the clinical recommendations (two examples)

Nosological unit	SBD, Gy	TBD, Gy
Prostate cancer*	1.8–19.0	8.0–160.0
Follicular lymphoma**	1.8–2.0	4.0–30.0

Note: * — Prostate cancer. ICD-10: C61. Clinical recommendations. Moscow: Ministry of Health of the Russian Federation, 2021; ** — Follicular lymphoma. ICD-10: C82, C85.9. Clinical recommendations. Moscow: Ministry of Health of the Russian Federation, 2024.

Table 3. Radiation exposure limits for specialists of the ISS partner agencies and occupational exposure standards in SanPiN NRB-99/2009 and the IAEA IBSS

Space agencies, Rospotrebnadzor, the IAEA — subjects of limit setting	Career limit/occupational norms	Gender/age relationship
Roscosmos * Canadian Space Agency * European Space Agency *	1000 mSv	None
Japan Aerospace Exploration Agency *	3 % REID on average	Lower limit: 500 mSv for women aged 27 to 30 years. Upper limit: 1000 mSv for men over 46 years of age
NASA (current) *	3 % REID at confidence level of 95 %	Lower limit: ~180 mSv for women 30 years old. Upper limit: ~700 mSv for men 60 years old.
NASA (proposed update) *	600 mSv	None
Rospotrebnadzor, occupational radiation norms, SanPiN NRB-99/2009	Annual dose limits 100 mSv in 5 years/ but not more than 50 mSv per year	None
The IAEA, occupational radiation norms, the IAEA-2015 IBSS	Annual dose limits 100 mSv in 5 years/ but not more than 50 mSv per year	None

Note: * — data from [47].

by the Government of the Russian Federation [34]. The IAEA has developed numerous publications for specialists, including "Pocket Guide for Medical Physicists Supporting Response to a Nuclear or Radiological Emergency" [35]; "Radiation Protection and Safety in Medical Uses of Ionizing Radiation," developed in cooperation with the WHO and ILO [36]; "Selecting Megavoltage Treatment Technologies in External Beam Radiotherapy," which addresses radiation safety considerations [37]; IAEA Nuclear Safety and Security Glossary [38]; the IAEA's "Determination of Absorbed Dose in Remote Radiation Therapy: International Practical Recommendations on Dosimetry" [39]; and the report "Accuracy Requirements and Uncertainty Factors in Radiation Therapy" [40]. There are lists of literature in Russian for medical physicists working in the field of radiation therapy of neoplasms [41].

Standardization of radiation safety in aerospace medicine

Studies that investigated the effect of IR on the health of pilots have shown that at altitudes from 9000 to 12000 m, the intensity of ionizing radiation can exceed the natural radiation background by 31-41 times [42]. The risk of IR influence on pilots' health has been studied [43]. The effective doses received by aircraft crew members from cosmic radiation were compared with the dose limits recommended by international organizations [44]. However, there are no approved radiation safety limits in aviation medicine. Another study collated the radiation safety experience accumulated in Russia over the sixty years of manned space flights with Russian legislation and international recommendations [45]. The respective standards were analyzed retrospectively, as were estimates of the total radiation risk and the potential reduction in cosmonauts' life expectancy during long-term orbital and interplanetary flights [46]. Against the backdrop of the International Space Station (ISS) orbiting Earth, national space agencies currently adopt different approaches to dose limits, relating them to sex and age and defining the dose threshold in terms of the risk of radiation-induced death (REID) [47]. Table 3 presents a comparison of dose limits.

The relevance of the strategies of national space agencies and their joint projects in the field of manned flights and research is steadily increasing. Federal Law [48] approved cooperation between the Russian Federation and China in the International Scientific Lunar Station project. NASA's Moon to Mars Objectives [49] sets out an objectives-based framework for the agency's human deep-space exploration efforts.

The framework includes the Artemis program and the gradual development of lunar infrastructure to support subsequent crewed missions to Mars. The risks of space exploration are borne by a small group of people — cosmonauts, astronauts, taikonauts, and viomanauts — while society as a whole benefits from their work. This imbalance makes space agencies responsible for maximizing the protection of their specialists (spacecraft and station hulls, spacesuits, exposure time), minimizing operational disruptions during flight, throughout their careers, and after leaving the agencies. Efforts are being made to predict the risks associated with lunar and Martian missions, taking into account mission duration (days), absorbed dose (Gy), effective dose (mSv), and risk of death (%) [47]. Russian researchers and engineers are developing radiation safety measures that would apply in a nuclear-powered spacecraft [50].

Higher education and university textbooks on medical physics, radiation hygiene, and dosimetry

The IAEA has identified a need for medical physicists in radionuclide therapy and diagnostic imaging [51]. There is a noteworthy paper that analyzes why medical dosimetry is a profession only in the USA and what it means for medical physicists all over the world [52]. The relevance of providing dosimetric support in Russia for planning and evaluating the effectiveness of treatment as a fundamental methodological basis for modern radionuclide therapy has been confirmed [53]. In education and science communication, it is advisable to adopt a rational approach based on the principles of evidence-based medicine and information hygiene. This can help prevent radiophobia and provide concise, reliable information to people seeking knowledge in today's hyperinformational society [54]. In Russia, textbooks on radiation hygiene, dosimetry, and radiation medical physics for universities have been written and compiled by specialists from several universities and research institutes [55–61]. Due to their diversity and quantity, it is important to harmonize their contents while taking into account international experience. There are also international textbooks by the IAEA. They are prepared by leading specialists from dozens of countries. These textbooks cover a wide range of topics, including radiation physics, dosimetry and instrumentation, image quality and perception, visualization methods, specialized applications, advances in digital technology, radiation biology, radiation protection, and safety standards. They have also been approved by several international professional organizations, and can be useful for those preparing for certification as medical

physicists or radiologists. Despite the fact that Russia is a member of the IAEA, a number of voluminous textbooks have not been translated into Russian. The authors, together with colleagues, translated extensive (total volume 1,494 pages) textbooks published by the IAEA on the physics of nuclear medicine and diagnostic radiology for teachers and students into Russian and made them publicly available [62, 63].

Dosimetric planning educational software

In accordance with Government of the Russian Federation directives on digital transformation in higher education [64] and healthcare [65], it is particularly important to assess the availability, development, and university-based training related to computer systems for dosimetric radiotherapy planning, as well as their implementation in clinical practice. This assessment should cover treatment-plan verification, dose calculation, evaluation of treatment efficacy and safety, and other relevant functions, while taking into account the clinical recommendations by the Russian Ministry of Health, international experience, medical and technical support, and international clinical recommendations [39, 40]. We found that in 2026, Russian radiotherapists use 12 clinical dosimetric planning platforms, none of which is educational. Abroad, there are 33 such solutions, and 5 of them are used for training purposes. The list of Russian systems includes AMPHOTA, Gammaplan RT, ScanPlan, Plan B, Plan N, Plan D, Rplan, Plan X DLT, Plan P, Plan NE, Plan I, MMS. Foreign solutions are 3DVH, Accuray, Contour+, Corvus, Delta4DVH Anatomy, Eclipse, ERGO++, FULLACCESS, GPT-RadPlan, HDR+, MultiPlug, iPlan RT, MIM Symphony, MONACO, Multiplan,

MIM Maestro, Panther TPS, Plan W, BrainlabElements, PlanIQ, Prism, RapidPlan, SagiPlan, Spot, SunSCAN 3D, Theraplan Plus, TOPAS, Tracer, VariSeed, Vitesse, XiO-CE 3D, Pinnacle, Focal. Training systems — FoCa, MuriPlan, OpenTPS, PortPy, Vert. Fourteen solutions are dosimetric planning complexes for teletherapy and brachytherapy, 29 — only for teletherapy, and 7 for brachytherapy.

CONCLUSION

The increasing prevalence of ionizing radiation (IR) resulting from technological advances, the expansion of human activities, and its growing use in medicine requires increased attention to its effects on public health, healthcare organization, radiation regulation, and the higher education and training of qualified specialists. It is important to organize interdepartmental cooperation in the development and approval of new radiation safety standards, taking into account the historically established Russian specifics and modern international experience.

For highly specialized on-site assessments, it is advisable to:

- evaluate the qualifications of specialists, the staffing levels of medical physicists, the availability of experts qualified to measure physical factors for specialized federal supervision and production control, and the availability of appropriate measuring instruments;
- harmonize occupational radiation risk assessments and dose standards for individual professions;
- introduce the WHO and IAEA international textbooks into the curricula of universities, and to develop educational computer systems for radiation therapy dosimetric planning.

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APPROACHES TO ASSESSING NUTRITIONAL EFFECTS ON OBESITY AND THE AUTONOMIC NERVOUS SYSTEM

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The high prevalence of nutrition-related disorders among children necessitates the development of new methods for assessing the effects of nutrition on the body. Heart rate variability (HRV) analysis combined with the body mass index (BMI) calculation constitute an effective non-invasive health status assessment protocol. This cross-sectional study aimed to evaluate the dietary patterns of schoolchildren in Yekaterinburg and examine their associations with BMI and indicators of autonomic nervous system function. We recruited 202 schoolchildren aged 11–12 years; their diets were assessed using the frequency method and by calculating the nutrition quality index (NQI). We collected the participants' anthropometric data, measured their bioimpedance, and analyzed the HRV. Nonparametric methods, odds ratio calculation (ORC) and cluster analysis were used for statistical processing. It was found that the quality of the diets of 67.3% of schoolchildren was unsatisfactory: their diets were excessive in saturated fats, added sugars, and sodium, and deficient in dietary fiber, complete proteins, B vitamins, vitamin A, calcium, and magnesium. Children with a low NQI are 5.5 times more likely to be overweight and have a higher body-fat percentage than their peers with a satisfactory diet. HRV indicators differed significantly according to dietary patterns: children who consumed large amounts of vegetables and fruit exhibited more favorable heart rate variability, whereas those whose diets were high in added sugars and fats had the least favorable HRV. The identified abnormalities highlight the need to develop preventive programs aimed at improving eating habits and to consider introducing HRV monitoring into the schoolchildren's health hygienic assessment system.

Keywords: schoolchildren's nutrition, nutrition quality index, nutrients, body mass index, obesity, bioimpedance analysis, autonomic nervous system, heart rate variability

Author contribution: Mazhaeva TV — study concept and design, article authoring, editing and final approval; Potapkina EP — collection of materials, article authoring; Kutergina NI — data processing, article authoring; Chernova YuS — data processing.

Compliance with ethical standards: the study was approved by the local ethics committee of Yekaterinburg Medical Research Center for Prevention and Occupational Health of Industrial Workers (Minutes No. 5 of December 27, 2021). The participants voluntarily enrolled in the study, and their parents or legal representatives provided signed informed consent forms.

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Received: 26.03.2026 **Accepted:** 26.08.2026 **Published online:** 24.09.2026

DOI: 10.24075/rbh.2026.174

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ПОДХОДЫ К ОЦЕНКЕ ВЛИЯНИЯ ПИТАНИЯ НА ОЖИРЕНИЕ И ВЕГЕТАТИВНУЮ НЕРВНУЮ СИСТЕМУ

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В связи с распространенностью алиментарно-зависимых нарушений у детей необходим поиск новых методов оценки влияния питания на организм. Анализ вариабельности сердечного ритма (ВСР) в совокупности с индексом массы тела (ИМТ) является эффективным неинвазивным методом оценки состояния здоровья. Целью поперечного исследования было выполнить гигиеническую оценку питания учащихся школ г. Екатеринбурга, а также провести анализ его взаимосвязи с ИМТ и показателями вегетативной нервной системы. Обследованы 202 школьника в возрасте 11–12 лет. Оценку питания выполняли частотным методом и путем расчета индекса качества питания (ИКП). Применяли антропометрию, биоимпедансометрию, исследование ВСР. Для статистической обработки использовали непараметрические методы, расчет отношения шансов (ОШ) и кластерный анализ. Установлено, что качество питания 67,3% школьников неудовлетворительное, оно характеризуется избытком насыщенных жиров, добавленных сахаров и натрия при дефиците пищевых волокон, полноценного белка, витаминов группы В, А, кальция и магния. У детей с неудовлетворительным ИКП шансы возникновения избыточной массы тела и высокого содержания жировой массы в 5,5 раза выше, чем у их сверстников с удовлетворительным рационом. Установлены значимые различия показателей ВСР в зависимости от характера питания: наилучшие значения ВСР отмечены у детей с высоким потреблением овощей, фруктов, наихудшие — при избытке добавленного сахара и жиров в рационе. Выявленные нарушения обосновывают необходимость разработки профилактических программ, направленных на коррекцию пищевых привычек, а также возможность внедрения мониторинга ВСР в систему гигиенической оценки здоровья школьников.

Ключевые слова: питание школьников, индекс качества питания, нутриенты, индекс массы тела, ожирение, биоимпедансометрия, вегетативная нервная система, вариабельность сердечного ритма

Вклад авторов: Т. В. Мажаева — концепция и дизайн исследования, написание, редактирование и окончательное утверждение текста статьи; Е. П. Потапкина — сбор материалов, написание текста статьи; Н. И. Кутергина — обработка данных, написание текста статьи; Ю. С. Чернова — обработка данных.

Соблюдение этических стандартов: исследование одобрено локальным этическим комитетом ФБУН «Екатеринбургский медицинский-научный центр профилактики и охраны здоровья рабочих промпредприятий» Роспотребнадзора (протокол № 5 от 27 декабря 2021 г.). Участие в исследовании было добровольным, от всех родителей (законных представителей) получено информированное согласие.

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Статья получена: 26.03.2026 **Статья принята к печати:** 26.08.2026 **Опубликована онлайн:** 24.09.2026

DOI: 10.24075/rbh.2026.174

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The state of health of modern schoolchildren is a matter of reasonable concern: their habitual dietary patterns and lifestyle affect somatic and cognitive development, as well as the quality of life in the long term [1]. The global scientific community is particularly worried about the childhood obesity pandemic, as this condition is a key risk factor for the development of metabolic disorders and chronic noncommunicable diseases in adulthood. Studies indicate that early childhood and adolescence are critical periods for the development of overweight. Excess body weight gained during these periods often persists into adulthood and is associated with an increased risk of obesity, premature cardiovascular mortality, type 2 diabetes mellitus, and other nutrition-related diseases [2–4]. In childhood, obesity has a polysystemic negative effect, affecting the cardiovascular, endocrine, and neurohumoral systems, and leading to cognitive impairment [5].

In recent years, heart rate variability (HRV) analysis has increasingly been used to assess the impact of nutritional factors on health. HRV analysis is based on measuring a sequence of consecutive cardiac-cycle intervals using electrocardiography, rheocardiography, ballistocardiography, or other methods. The resulting numerical series are analyzed mathematically, using statistical, spectral and other tools. The results of mathematical analysis are interpreted as medical and physiological indicators of the functional state of the body [6]. HRV is an integrative indicator of the body's adaptive responses to internal and external stimuli. Decreased HRV is associated with higher morbidity and mortality. Thus, HRV can be regarded as an easily measurable and informative marker of the effects of environmental and lifestyle factors, including dietary patterns [7, 8]. Dietary patterns can be comprehensively assessed using the Nutrition Quality Index (NQI), which takes into account consumption at the level of foods and individual nutrients [9–11].

Given the ongoing improvement of the methodology for assessing the quality of nutrition and studying the risks associated with it, research aimed at finding non-invasive methods that can most accurately characterize the structure of nutrition and its effect on the body is becoming particularly relevant. The development and validation of such methods opens up prospects for their integration into modern hygienic approaches to assessing the health of the child population.

This study aimed to assess the dietary patterns of schoolchildren in Yekaterinburg and determine their associations with body mass index (BMI) and autonomic nervous system function, as described by the HRV analysis.

METHODS

The data for this cross-sectional study were collected in comprehensive schools of Yekaterinburg in April 2024. A total of 296 children aged 11–12 years were randomly selected from among pupils in grades 5–7 at four schools. The inclusion criteria were the absence of chronic diseases in the acute phase, submission of signed informed parental consent, and completion of all survey materials. Ninety-four children were excluded from the list of participants. The exclusion criteria were technical errors in the survey materials, missing complete date-of-birth data, and the inability to reliably determine body-fat percentage using bioelectrical impedance analysis in underweight children because of the method's technical limitations. The final sample comprised 202 schoolchildren, including 43.9% boys and 56.1% girls. Complete data were available for all participants, including anthropometric measurements, bioimpedance measurements,

HRV, and dietary patterns. The mean age of boys was 12.2 ± 0.7 years, girls — 11.1 ± 0.7 years.

Investigating dietary patterns, we applied a semiquantitative method and used a questionnaire and specialized software NUTRITEST-IP (Federal Research Center for Nutrition and Biotechnology; Russia). The participants completed the survey on three weekdays and one weekend. The collected data were entered into the program that calculated the average daily intake of foods and nutrients.

As no established norms for average daily food consumption exist for unorganized food intake settings, quantitative assessment of compliance with age-related food consumption standards was performed in accordance with SanPiN 2.3/2.4.3590-20 [12]. Nutrient intake was assessed in accordance with the methodological guidelines MP 2.3.1.0253-21 [13] and the age-specific physiological requirements for energy and nutrients of children.

We calculated NQI as part of the integral assessment of the diet using the learned dietary patterns of schoolchildren. The calculation method is based on that behind Healthy Eating Index (HEI) and Diet Quality Index (DQI); the NQI was established following the procedure described in a previously published work [14]. The algorithm was as follows: for each of the 10 components — bakery products; vegetables; fruits; meat, fish, and milk; confectionery and fats; polyunsaturated fatty acids (PUFAs); dietary fiber; added sugar; sodium; and variety — we calculated the deviation in consumption from the recommended value. For foods that are typically underconsumed, the recommended value was defined as the lower limit of the recommended range; for foods that are typically overconsumed, it was defined as the upper limit. A deviation of $\geq 50\%$ scored 0 points; for a deviation $<50\%$, the score was calculated using the following formula: $10 - (\% \text{ deviation} \times 0.1)$. For confectionery products and fats, added sugar, and sodium, we took into account only exceeding the upper limit [14]. The final score was the sum of the scores for 10 components (maximum 100). Criteria: ≥ 80 points — good diet, 51–79 points — satisfactory, and ≤ 50 — unsatisfactory [15].

Body length and weight were measured using an Omron BF-511 height meter and floor scales (Omron, Japan). BMI was calculated based on the data obtained. Physical development was assessed by calculating the Z-score (standard deviation scores, SDS) of BMI relative to the WHO reference values (2007). The results were interpreted in accordance with the WHO classification [14]: body weight deficiency — SDS BMI ≤ -2 ; normal body weight — SDS BMI from -1 to $+1$; overweight — SDS BMI $\geq +1$, but $< +2$; obesity — SDS BMI $\geq +2$.

Body composition, including body-fat percentage, was assessed by bioelectrical impedance analysis using an Omron BF-511 analyzer, an eight-sensor device that measures impedance through electrodes positioned on the hands and feet and is intended for individuals aged 6–80 years. The obtained values were compared with age norms [16].

Functional state of the autonomic nervous system was assessed using the Lotus diagnostic complex (Dynamic Technologies; Russia), which includes certified equipment Dynamics (TU 9442-001-50904116-2005) and the appropriate software. The assessment is based on ECG recordings and an analysis of the durations of consecutive R–R intervals during normal sinus rhythm. HRV parameters were recorded in the morning, in a sitting position, after a 5-minute rest supporting relative stabilization of hemodynamics. The recording time ranged from 5 to 15 minutes. The obtained results were compared with the reference values given by the developer of the software, and with the literature data [17, 18].

Table 1. The content of essential nutrients in the daily diet of schoolchildren

Indicator (daily)	Norm, ages 11–14 years		Me [Q ₁ ; Q ₃]		Significance of differences
	boys	girls	boys (n = 89)	girls (n = 113)	
Energy, kcal	2500	2300	1921.1 [1449.4; 2727.3]	1626.8 [1197.9; 2225.0]	$p < 0.001$
Protein, g	75	69	61.7 [47.7; 86.1]	52.8 [37.0; 69.3]	$p < 0.001$
Fat, g	83	77	80.6 [59.0; 123.6]	68.8 [53.3; 101.2]	$p < 0.001$
PUFA, g	17	15	11.0 [8.2; 17.3]	11.2 [7.4; 16.4]	$p > 0.05$
Cholesterol, mg	300	300	238.7 [151.2; 380.5]	203.2 [114.8; 322.5]	$p > 0.05$
SFA, % of kcal	< 10	< 10	16.0 [13.3; 18.6]	16.3 [13.8; 18.3]	$p > 0.05$
Carbohydrates, g	363	334	227.0 [161.1; 331.8]	186.4 [141.6; 252.2]	$p < 0.001$
Added sugars, % of kcal	< 10	< 10	12.9 [7.9; 20.0]	11.3 [7.7; 17.6]	$p > 0.05$
Dietary fiber, g	20	20	5.8 [3.4; 8.6]	5.4 [3.4; 7.5]	$p > 0.05$
Vitamin C, mg	70	60	112.3 [59.5; 221.1]	110.2 [63.8; 173.3]	$p > 0.05$
Vitamin B ₁ , mg	1.3	1.3	0.9 [0.6; 1.2]	0.7 [0.5; 1.0]	$p < 0.001$
Vitamin B ₂ , mg	1.5	1.5	1.1 [0.8; 1.6]	0.9 [0.7; 1.4]	$p < 0.05$
Niacin B ₃ (PP), mg niacin eq.	18	18	11.0 [8.5; 15.4]	9.0 [6.7; 12.7]	$p < 0.001$
Vitamin A, mcg ret. eq.	1000	800	685.7 [439.3; 1139.9]	671.8 [411.6; 1006.5]	$p > 0.05$
Calcium, mg	1200	1200	700.6 [455.9; 1093.0]	622.0 [428.9; 885.0]	$p > 0.05$
Phosphorus, mg	900	900	1047.9 [831.7; 1564.3]	935.7 [675.9; 1228.7]	$p < 0.001$
Magnesium, mg	300	300	258.8 [192.0; 376.2]	224.0 [164.7; 298.8]	$p < 0.001$
Potassium, mg	2500	2500	2819.8 [1900.8; 3904.4]	2446.1 [1759.8; 3175.3]	$p < 0.05$
Sodium, mg	1100	1100	2780 [1960.1; 3781.0]	2250.2 [1630.2; 3110.2]	$p < 0.001$
Iron, mg	12	12	14.2 [11.0; 19.1]	11.9 [9.2; 17.3]	$p < 0.05$

Statistical analysis was performed in MS Office Excel (Microsoft; USA) and SPSS Statistics 20 (IBM; USA). Because the variables were not normally distributed, nonparametric statistical methods were used. The data are presented as the median (Me) and interquartile range (Q₁–Q₃). The Mann–Whitney U-test was used to compare the two groups, and the differences were considered significant at $p < 0.05$. To compare quantitative indicators in three or more groups, we used the nonparametric Kruskal–Wallis test; the differences were considered significant at $p < 0.01$. Odds ratio (OR) with a 95% confidence interval (95% CI) was calculated to determine the strength of the association between the factors. The critical significance level was accepted at $p < 0.05$. Cluster analysis was applied to identify homogeneous groups of schoolchildren by the nature of their dietary patterns. Based on the calculated NQI, quantitative indicators of consumption of the main food groups, macro- and micronutrients were used as classifying variables. The optimal number of clusters ($k = 4$) was identified using the elbow method and confirmed by silhouette analysis, which yielded an average silhouette coefficient of 0.72. Functional states of regulatory systems were compared for each selected nutrition model based on the recorded HRV indicators.

RESULTS

Assessment of the nutritional composition of the diets of schoolchildren ($n = 202$) revealed pronounced sex-related differences in macronutrient and micronutrient content. Overall, the energy intakes of 68.3% of the children—74.3% of girls and 59.6% of boys — were below the recommended levels. The diets of 65.3% of schoolchildren (69.9% of girls 59.3% of boys) were deficient in protein, and diets of 52.0% of them (54.0% of girls and 49.4% of boys) lacked in fats. As for dietary fiber, almost all participants (99.5%) did not consume sufficient amounts of it; calcium deficiency in the diets were registered

in 83.7% of cases (85.8% of girls and 79.8% of boys), magnesium deficiency in 64.4% (69.0% of girls and 58.4% of boys), iron deficiency in 47.5% (61.9% of girls and 29.2% of boys). In addition, the respondents' diets provided insufficient amounts of several vitamins: vitamin B₁ was insufficient in 83.2% of participants (89.4% of girls and 76.4% of boys), vitamin B₂ in 72.8% (77.0% of girls and 67.4% of boys), and vitamin A in 62.9% (59.3% of girls and 67.4% of boys).

Children's diets were excessive in several critically important nutrients: saturated fatty acids (SFA) (95.5% of respondents overall; 97.3% of girls and 93.3% of boys), added sugars (58.9% overall; 57.5% of girls and 61.8% of boys), and sodium (94.1% overall; 92.0% of girls and 96.6% of boys). Table 1 summarizes the data on differences in the nutritional structure of boys and girls.

The caloric deficit was more pronounced among girls (a decrease of 29.3% versus 23.2% among boys). Macronutrient intake was imbalanced: an excess of saturated fats averaged 6.2% of the caloric content of the diet, and added sugars — 2.1% of the recommended level.

The analysis of micronutrient consumption revealed significant deviations: we registered essential nutrient deficiency and excessive sodium intake. The severity of these deviations was sex-dependent ($p < 0.001$) (Table 1). Among girls, the largest deficits were found for calcium (48.2% below the age-specific norm), B vitamins (B₁: 43.1% below the norm, B₂: 40.0%, B₃: 50.0%), magnesium (25.3%), and vitamin A (16.0%). At the same time, the recommended sodium intake was doubled (109.1%). Boys did not consume enough vitamin B₃ (38.9% deficit), vitamin A (31.4%), vitamins B₁ and B₂ (29.2% and 24.7%, respectively). The calcium content in the diet was 41.6% lower than normal, and the magnesium content was 13.7% lower. At the same time, they consumed 2.5 times more sodium (154.5%) than needed physiologically. The phosphorus–calcium ratio was abnormal in all participants: the Ca : P ratio was 1:1.4, indicating excessive phosphorus

Table 2. Assessment of the diet of schoolchildren based on the NQI calculation

The NQI component (maximum score)	Actual consumption, Me [Q ₁ ; Q ₃]		
	All <i>n</i> = 202	Boys <i>n</i> = 89	Girls <i>n</i> = 113
Bakery products, porridges, pasta + potatoes (10)	5.4 [2.5; 8.3]	5.6 [2.4; 8.8]	5.3 [2.4; 5.3]
Vegetables (10)	6.4 [2.6; 10.2]	6.3 [2.48; 10.1]	6.5 [2.9; 10.1]
Fruits (10)	6.5 [2.7; 10.3]	6.7 [2.2; 10.5]	6.3 [2.7; 9.9]
Meat + Fish + Dairy products (10)	7.5 [5.4; 10.5]	8.0 [5.5; 10.5]	7.2 [4.3; 10.1]
Confectionery products + Fats (10)	0.5 [0.1; 1.5]	0.4 [0.0; 1.7]	0.6 [0.0; 2.0]
PUFA (10)	8.2 [6.3; 10.1]	8.0 [5.5; 10.5]	8.4 [6.2; 10.2]
Dietary fiber (10)	3.1 [1.2; 5.0]	3.5 [1.0; 6.0]	2.8 [1.3; 4.2]
Added sugar (10)	2.0 [0.0; 4.9]	1.6 [0.0; 4.1]	2.3 [0.0; 5.2]
Sodium (10)	0.3 [0.0; 1.3]	0.0 [0.0; 0.0]	0.4 [0.0; 1.8]
Variety (10)	4.2 [2.3; 6.1]	4.5 [2.0; 7.0]	3.9 [1.7; 6.0]
Total score (100)	44.4 [31.0; 57.8]	44.5 [29.9; 59.1]	43.7 [31.0; 56.6]

intake, which may impair calcium absorption during periods of active skeletal growth..

Based on the learned dietary patterns we calculated the NQI (Table 2).

The analysis of the NQI distribution showed that none of the surveyed schoolchildren had a "good" diet (80 points or higher). The proportion of children with "satisfactory" diet (from 51 to 80 points) was 32.7% (*n* = 66). More than half of the participants (67.3%; *n* = 136) had a diet rated as "unsatisfactory" (less than 51 points). The vast majority of the surveyed schoolchildren (92.8%) did not consume sufficient amounts of complex carbohydrates. The intake of vegetables was below the norm in 66.3% of children, and that of fruits in 63.9%. More than half of the respondents — 57.8% — followed diets deficient in the sources of complete protein and essential amino acids (meat, fish and dairy products). All participants of the study had insufficient intake of dietary fiber. Almost half of the children had low polyunsaturated fatty acid (PUFA) intake. The diets of 59.0% of the respondents showed low dietary variability. Along with a deficiency of essential components, we registered excessive consumption of nutrients associated with nutrition-related diseases: confectionery and fats (79.5% of schoolchildren), added sugar (42.2%). Over 90% (91.6%) of participants consumed diets containing critically high levels of sodium. A comparative analysis of the diets of boys and girls did not reveal significant differences in the frequency of consumption of bakery products, fruits, as well as meat, fish and dairy products. Assessing the nutritional composition, we found that the sodium content in the diet of boys significantly exceeded that in the diet of girls (*p* < 0.05).

Anthropometry and bioimpedance measurements showed the prevalence of overweight in the examined sample to average at 17.8% (among both boys and girls). We found that eating disorders were sex-dependent: obesity was diagnosed more often in boys (26.8% higher than in girls), whereas body weight deficiency prevailed among girls (Table 3).

Table 3. Sample composition by BMI indicators, % of the surveyed individuals

BMI indicators	All children <i>n</i> = 202	Boys <i>n</i> = 89	Girls <i>n</i> = 113
Mild body weight deficiency	18 (8.9%)	0 (0.0%)	18 (15.9%)
Normal body weight	117 (57.9%)	46 (51.7%)	71 (62.8%)
Excess body weight	36 (17.8%)	16 (18.0%)	20 (17.7%)
Obesity	31 (15.3%)	27 (30.3%)	4 (3.5%)

Bioimpedance analysis revealed significant sex differences in body-fat percentage: a normal body-fat percentage was observed 27.7% more often in girls than in boys (*p* < 0.001). Conversely, boys were significantly more likely to have high (by 1.7%; *p* < 0.05) and very high (by 7.0%; *p* < 0.05) body-fat percentages.

A direct relationship has been established between overweight and the content of adipose tissue: 85.9% of overweight children had excess body fat. It is noteworthy that among girls with a normal BMI, 8% were also diagnosed with excess fat mass, which indicates hidden obesity in this subgroup.

The average total NQI scores in the subgroups of schoolchildren with different nutritional status did not significantly differ and amounted to: body weight deficit subgroup — 39.0 points, normal body weight subgroup — 46.4 points, overweight subgroup — 39.8 points, obesity subgroup — 43.1 points. However, the analysis of the individual components of the NQI revealed significant differences. Schoolchildren with a normal BMI had higher intake of dietary fiber compared with overweight peers (average score 3.6 vs. 2.7, respectively; *p* < 0.05).

When comparing the groups formed on the basis of the NQI, we found that children with "unsatisfactory" diet quality (less than 51 points) had significantly higher BMI (21.6 vs. 19.8; *p* < 0.05) and the body-fat percentage (24.7% vs. 19.2%; *p* < 0.05) compared to peers whose diet was rated as "satisfactory."

Odds ratio analysis indicated a significant association between poor nutritional quality and disorders of nutritional status (OR = 5.5; 95% CI: 2.2–13.6; *p* < 0.05). The outcome was defined as overweight or obesity (SDS BMI ≥ 1) and/or elevated body fat (> 85th percentile for age and sex). Among children with unsatisfactory NQI (*n* = 136), this outcome was observed in 48 (35.3%), whereas among children with satisfactory NQI (*n* = 66), it was observed in only 6 (9.1%).

HRV indicators reflecting the state of vegetative and neurohumoral regulation, adaptive reserves and the psycho-emotional status of the examined schoolchildren, depending on the quality of nutrition and nutritional status, are presented in the Table 4.

Table 4. Comprehensive analysis of functional health of schoolchildren ($n = 202$)

Functional health indicator	Me	[Q ₁ ; Q ₃]	Frequency of occurrence, %
Body adaptation level (A), %	62	57.9; 67.2	42.2
Vegetative regulation (B), %	63	57.5; 69.5	42.2
Neurohumoral regulation (C), %	59	54.4; 61.8	51.8
Psychoemotional state (D), %	61	56.0; 63.5	48.2
Comprehensive health indicator (H), %	64	56.6; 65.3	48.2

The analysis of HRV indicators revealed that the average values of most parameters of the regulatory systems of the examined schoolchildren are within the physiological norm, which was 60–100% on the scale used. The lowest values were recorded for the neurohumoral regulation index (C), which averaged 59.0 [54.4; 61.8]%, and the psychoemotional state index (D), which averaged 61.0 [56.0; 63.5]%. The values of the other integral indicators were also close to the lower limit of the norm, as may be indicated by the stress of adaptive mechanisms in some of the surveyed.

We assessed the balance of regulatory systems based on the ratio of indicators of the level of adaptation (A), neurohumoral (C) and psychoemotional regulation (D). The optimal range of ratios was 60–80%. It was found that the majority of schoolchildren (65.0%) had balanced and stable regulation. However, only 18.1% of children have optimal regulation. Unstable regulation and overstrain of regulatory systems were seen in 16.9% of the surveyed, which indicates depletion of the adaptive reserve.

The average value of neurohumoral regulation (C) in the sample was 59.0 [54.4; 61.8]%, while the normal range is 60–100%, which is within acceptable limits, but close to the lower threshold. The incidence of unstable neurohumoral balance and its disorders reached 30.1%. Since indicator C reflects the efficiency of the endocrine system and the state of energy resources, it can be stated that the suboptimal functioning of the endocrine system and the irrational use of energy resources are typical for 28.9% of schoolchildren.

The integral indicator of the energy balance in the examined sample turned out to be below the optimal level (the average value was 0.9 with a norm of 1.0). Low values of this indicator were registered in 67.5% of children. An imbalance between energy expenditure and recovery time was detected in 18.1% of schoolchildren, which may indicate chronic fatigue and poor quality of the recovery processes.

Based on the results of the cluster analysis, we identified four types of dietary patterns, and compared their effect on the regulatory systems using the HRV indicators. The first type of diet implied high consumption of PUFA, fiber, vegetables, fruits and low consumption of added sugar. The second type involved moderate consumption of all food groups, as well as consumption of added sugars and fat within the normal range. The third type was characterized by excessive consumption of confectionery, added sugar, saturated fatty acids, table salt and high energy value. The fourth type of diet was low in calorific value and involved low intake across all food groups. The highest HRV values, reflecting the optimal functional state of regulatory systems, were recorded in the group of schoolchildren who had the diet of the first type (16.8%). Those whose diet belonged to the second type (28.7%) exhibited good average HRV scores. At the same time, children who overconsumed critically important nutrients (the third type of diet; 20.8% of the respondents) had the worst HRV values, which was associated with dysregulation of the autonomic nervous system. Low-calorie diet (fourth type) entailed low body resources and adaptive potential; 33.7% of the participating

schoolchildren had the diet of this type. The significance of the differences in HRV indicators was confirmed at the p level < 0.001 , which indicates a significant influence of the nature of nutrition on the functional state of the regulatory systems of adolescent children.

DISCUSSION

Analysis of dietary patterns and the NQI revealed that most schoolchildren had an imbalanced intake of macro- and micronutrients: excessive saturated fat, added sugars, and sodium, and inadequate dietary fiber, high-quality protein, B vitamins, vitamin A, calcium, and magnesium. This imbalance stems from two bidirectional trends: excessive consumption of foods that are sources of fats and added sugars, and dietary shortage of bakery products, cereals, vegetables, high-grade protein, and essential amino acids (meat, fish, dairy products). Our results obtained are consistent with data from Russian and foreign studies that used other assessment tools, such as HEI-2015 and various modifications of DQI [19–23], which indicates the typicality of the identified nutritional disorders in children populations in the modern world.

Overlaying quality of the diets on the anthropometric indicators, we found that schoolchildren whose NQI was unsatisfactory were characterized by significantly higher values of BMI and body-fat percentage compared with their peers whose NQI was satisfactory. This fact confirms the role of the nutritional factor in the formation of eating disorders already in childhood.

The analysis of HRV indicators revealed the predominant role of the sympathetic division of the autonomic nervous system, which indicates the tension of regulatory mechanisms in the examined schoolchildren. According to modern concepts, HRV reflects neurohumoral effects on cardiac activity and serves as an informative noninvasive marker of the functional state of the body, the balance of sympathetic and parasympathetic divisions, as well as the activity of suprasegmental regulatory structures, including the hypothalamus and limbic system [24, 25]. The decrease in adaptive potential seen in this study (the functional status was low in 42.2–48.2% of the children) is comparable with the results of other authors [26, 27]; it indicates a high prevalence of autonomic dysfunction in the considered population.

Special attention should be paid to the fact that 28% of schoolchildren have a suboptimal level of neurohumoral regulation (indicator C), which characterizes the efficiency of the endocrine system and the use of energy resources. The observed dysregulation may be associated with an unbalanced diet, low energy intake, and protein deficiency, creating a vicious cycle: eating disorders exacerbate dysfunction of neuroendocrine axes and alterations in the immune system, which in turn can lead to complex cardiovascular dysregulation. Currently, there is increasing evidence that a decrease in HRV is a predictor of a wide range of pathological conditions, including diabetes mellitus and cardiovascular diseases, and changes recorded in childhood can predict psychological and physiological morbidity in the long term [28].

Our data show significant differences in HRV rates in children who follow a balanced diet and their peers with deficient dietary patterns ($p < 0.001$); the findings are consistent with the results of international studies. For example, Mediterranean diet, high consumption of fish, vegetables, fruits, multivitamins, and weight loss are associated with increased HRV, whereas a diet high in fat and trans fats leads to a low HRV [29]. With respect to micronutrient availability, the most convincing evidence for an effect on HRV has been obtained for vitamins D and B₁₂, although the roles of vitamins C and E, zinc, magnesium, and iron are also under discussion [30].

Thus, the identified associations between poor nutritional quality, nutritional status disorders, and low HRV among schoolchildren of Yekaterinburg fit into the global picture of the prevalence of nutrition-related disorders in pediatric population. The presented data on the health risk and the possibility of its correction through nutrition optimization can serve as a justification for the development of preventive programs and a motivational basis for the formation of healthier eating habits among parents, teachers, and schoolchildren themselves.

It should be noted that this study has a number of limitations: its cross-sectional design disallows establishing causal relationships;

the assessment of dietary patterns is based on self-reported data, which may have a systematic error; the sample is limited to one city and age group, which hinders generalization of the results; there is no data on physical activity and hereditary predisposition; the devices for bioimpedance analysis and HRV registration are not uniform in their accuracy of measuring body composition in children. Nevertheless, our results are consistent with data from other studies and can serve as a basis for further prospective observations.

CONCLUSIONS

The study confirmed that eating disorders in schoolchildren are associated with anthropometric abnormalities (obesity and underweight) and increased strain on regulatory systems. Gender-specific patterns call for targeted preventive measures: reducing sodium intake and controlling body weight in boys, and correcting micronutrient status in girls. Heart rate variability indices are proposed as markers for the hygienic assessment of the impact of nutrition on schoolchildren's health, opening up prospects for the introduction of personalized wellness strategies.

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EXPERIMENTAL ASSESSMENT OF THE EFFECT OF ANTIPSYCHOTICS BY WEDGE-SHAPED DEHYDRATION

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Recently, there has been an increase in the number of cases of unsafe use of medications, including antipsychotics, by the population. The uncontrolled use of medication leads to an increase in the rate of physical health problems and a decrease in the quality of life. Predicting the effects of substances in the body and identifying such cases are tasks of preventive medicine. The study aimed to assess the possibility to use the wedge-shaped dehydration method to determine antipsychotics (aminazine and haloperidol) in blood serum. Male outbred rats intragastrically administered aminazine and haloperidol at a dose of 35 mg/kg and 10 mg/kg, respectively, were used for the experiment. The control group was administered distilled water. Structures of blood serum facies were assessed 1, 4, 24 h after the antipsychotic administration. Parametric statistical methods were used for the analysis of comparative data ($p \leq 0.05$). Similarities of the structures of rat and human blood serum under physiological conditions were identified. The emergence of structures deviating from normal was observed in the rat facies after the haloperidol and aminazine administration. After 1 h, "silver" cracks were detected; after 4 h, rope-like structures resembling a "leaf-within-a-leaf" (following haloperidol administration) and a "double leaf" (following aminazine administration) were observed; and after 24 h, an increase in the thickness of triradiate cracks was noted. The findings demonstrated the efficacy of the wedge-shaped dehydration method in the experimental assessment of the effects of antipsychotics.

Keywords: antipsychotics, aminazine, haloperidol, wedge-shaped dehydration, experiment

Author contribution: Drugova ED — material collection and processing, manuscript writing, statistical analysis; Sheina NI — research concept and design, manuscript writing, editing; Korolik VV — research concept, manuscript editing.

Compliance with ethical standards: animal keeping and handling during the experiment were compliant with the principles of Good Laboratory Practice (GLP) and GOST 33044–2014 "Principles of Good Laboratory Practice". The study was approved by the Ethics Committee of the Pirogov Russian National Research Medical University (protocol No. 9 dated September 20, 2023. Blood collection from the volunteers, who had had submitted the informed consent, was regulated by GOST R 59778–2021 "Procedure of Venous and Capillary Blood Sampling Procedure for Laboratory Testing".

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Received: 28.11.2025 **Accepted:** 17.05.2026 **Published online:** 26.09.2026

DOI: 10.24075/rbh.2026.175

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ОЦЕНКА ВЛИЯНИЯ НЕЙРОЛЕПТИКОВ МЕТОДОМ КЛИНОВИДНОЙ ДЕГИДРАТАЦИИ В ЭКСПЕРИМЕНТЕ

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В последнее время увеличилось количество случаев небезопасного приема населением лекарственных препаратов, в том числе нейролептиков. Бесконтрольное применение лекарств приводит к увеличению нарушений физического здоровья и снижению качества жизни. Прогнозирование эффектов веществ в организме и выявление таких случаев — задачи превентивной медицины. Целью исследования было оценить возможность применения метода клиновидной дегидратации для определения нейролептиков (аминазина и галоперидола) в сыворотке крови. В эксперименте использовали беспородных крыс-самцов, которым внутривенно вводили аминазин и галоперидол в дозе 35 мг/кг и 10 мг/кг соответственно. Контрольная группа получала дистиллированную воду. Структуры фаций сыворотки крови оценивали через 1, 4, 24 ч после введения нейролептиков. Для сравнительного анализа данных использовали параметрические статистические методы ($p \leq 0,05$). Выявлено сходство структур сыворотки крови крыс и человека при физиологической норме. После введения галоперидола и аминазина в фациях крыс выявлено появление отличных от нормы структур. Через 1 ч обнаружены трещины «серебра», через 4 ч — жгутообразные структуры в виде листа в листе (после введения галоперидола) и в виде двойного листа (после введения аминазина), а через 24 ч — увеличение толщины трехлучевых трещин. Полученные результаты продемонстрировали эффективность метода клиновидной дегидратации при изучении влияния нейролептиков в эксперименте.

Ключевые слова: нейролептики, аминазин, галоперидол, клиновидная дегидратация, эксперимент

Вклад авторов: Е. Д. Другова — сбор и обработка материала, написание текста статьи, статистическая обработка данных; Н. И. Шеина — концепция и дизайн исследования, написание текста статьи, редактирование; В. В. Королик — концепция исследования, редактирование текста статьи.

Соблюдение этических стандартов: содержание животных и обращение с ними в эксперименте соответствовали правилам надлежащей лабораторной практики (GLP) и ГОСТ 33044–2014 «Принципы надлежащей лабораторной практики». Исследование одобрено этическим комитетом РНИМУ имени Н. И. Пирогова (протокол № 9 от 20 сентября 2023 г.). При отборе крови у волонтеров после подписания ими добровольного согласия руководствовались ГОСТ Р 59778–2021 «Процедуры взятия проб венозной и капиллярной крови для лабораторных исследований».

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Статья получена: 28.11.2025 **Статья принята к печати:** 17.05.2026 **Опубликована онлайн:** 26.09.2026

DOI: 10.24075/rbh.2026.175

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Recently, due to changing socio-economic conditions, such as the rise of crises in global politics and the economy, as well as various stressors, and the availability of medical information online, there has been an increase in the uncontrolled use of medications, including antipsychotics, by the general population [1, 2]. It is reported that up to 60% of the entire population suffers from depressive disorders, and 91% of prescription-based pharmacy visits involve drugs that depress the central nervous system: tranquilizers, sleeping pills, antidepressants, and antipsychotics [3].

Irrational use of medications can have serious side effects and reduce the quality of life of people, therefore timely detection of the use of narcotic and antipsychotic drugs, knowledge and adherence to the principles of information hygiene in cyberspace, implementation of health measures will contribute to maintaining the population physical, mental, and social well-being (preventive medicine). There is ongoing search for predictive models for the early detection of unsafe use of such medications.

The method of wedge-shaped dehydration has become widely used in clinical practice for diagnosing pathological processes and assessing the efficacy of drug therapy. Professor V.N. Shabalin, staff members of the Department of Gerontology at the Pirogov Russian National Research Medical University, and their followers have made significant contributions to the theory and practical application of this method [4–8]. The principle of the method lies in the formation of a film (facies) upon the drying of an open blood serum droplet on a horizontal substrate. Analysis of large clinical material made it possible to identify differences in the structure of the facies of healthy people and patients with chronic and acute diseases, which provided the basis for an atlas of biological fluids in various disorders [4, 9]. It was shown that effective drug therapy led to the reduction in the number of structural markers of pathological conditions in the facies [5, 6]. Furthermore, the wedge dehydration method was recommended for the forensic medical examination of fatal poisonings involving narcotic and potent substances [10, 11].

Numerous reports present compelling evidence that the structures formed within the facies result from changes in the molecular composition and physicochemical properties of the body's biological fluids associated with various pathological conditions, and are therefore universal [12–17]. Our study is relevant as it is based on the premise that the presence of specific structures, their combinations and quantity in the facies can also represent an integral indicator of the body's overall state upon exposure to xenobiotics. Therefore, identification of changes in architectonics and structural markers characteristic of the effects of substances possessing antipsychotic properties, i.e., antipsychotics, in blood serum facies is of both scientific and practical interest.

The study aimed to assess the possibility of using wedge-shaped dehydration to determine antipsychotics (aminazine and haloperidol) in blood serum of experimental animals.

METHODS

A total of 30 male outbred rats aged 5–6 months with the body weight of 180–200 g were used in the experiment (rats were taken from the Stolbovaya breeding nursery of the Scientific Center for Biomedical Technologies of FMBA of Russia). Animals had a standard diet throughout the experiment. The rats were housed in plastic cages on a bedding of fine wood shavings. The conditions in which the animals were kept

met the requirements of GOST 33216–2014. Three groups were formed; each statistical group consisted of 10 animals.

Rats were intragastrically administered aminazine (chlorpromazine hydrochloride) at a dose of 35 mg/kg and haloperidol (a butyrophene derivative) at a dose of 10 mg/kg—doses which, when converted to the human equivalent, corresponded to the maximum daily doses (MDD). The control group received distilled water in a volume corresponding to the volume administered to the experimental animals. Blood was collected from the sublingual vein 1, 4, and 24 h after the administration of antipsychotics; facies were prepared from the serum collected. The 20 µL biological fluid drops were applied to microscope slides using an automatic pipette. Slides were left to dry for 24 h in a room with optimal microclimatic conditions [18]. The ADF B50 digital microscope system equipped with a video camera (ADF; China) was used to view and photograph the general appearance and structures of the facies. The architectonics of the facies, the number of identical marker structures associated with pathological conditions, and the width of the zones were evaluated using the resulting images. To compare the normal facies of rats and humans, venous blood was collected from the antecubital fossa of 12 healthy volunteers, and facies were prepared using the above method.

Statistical analysis of the obtained data involved calculating the mean and standard deviation in the groups. The significance of differences between groups was determined at $p \leq 0.05$ using Student's *t*-test and Dunnett's test (q') to avoid the multiple comparisons effect. Parameters were analyzed using the BioStat software tool (Glantz; USA) [19].

RESULTS

Initially, the analysis of the facies architectonics of rat and human blood serum under physiologically normal conditions was conducted (Fig. 1).

A similarity in the facies structures of rat and human serum was noted. In both cases, the facies showed symmetry, radially diverging fractures, jointing, and concretions. The homology of facies structures corresponding to the physiologically normal conditions suggests that similar facies structures may also be found in animals and humans under certain pathological conditions and under exposure to harmful environmental factors. Furthermore, the reported similarity makes it possible to use the criteria and markers of human serum facies described in the papers by S.N. Shatokhina and V.N. Shabalin when performing morphological analysis of rat serum facies in experimental settings [4, 9].

The animals' behavior was analyzed after the aminazine and haloperidol intragastric administration. A sedative effect was observed in rats of the experimental groups one hour after the administration of aminazine and haloperidol, the presentation of which was characterized by lethargy, passivity, and reduced motor activity. The peak antipsychotic effect was observed within 4 h; no differences in clinical features between experimental and control rats were reported within 24 h.

Then the morphological analysis of the blood serum facies architecture was conducted, along with the quantitative assessment of the structures and the identification of marker structures (Table 1). One hour after the administration of aminazine and haloperidol, experimental rats showed the decrease in the width of the central zone of blood serum facies compared to the facies of the control group animals (Fig. 2, Table 1). The change was most pronounced following

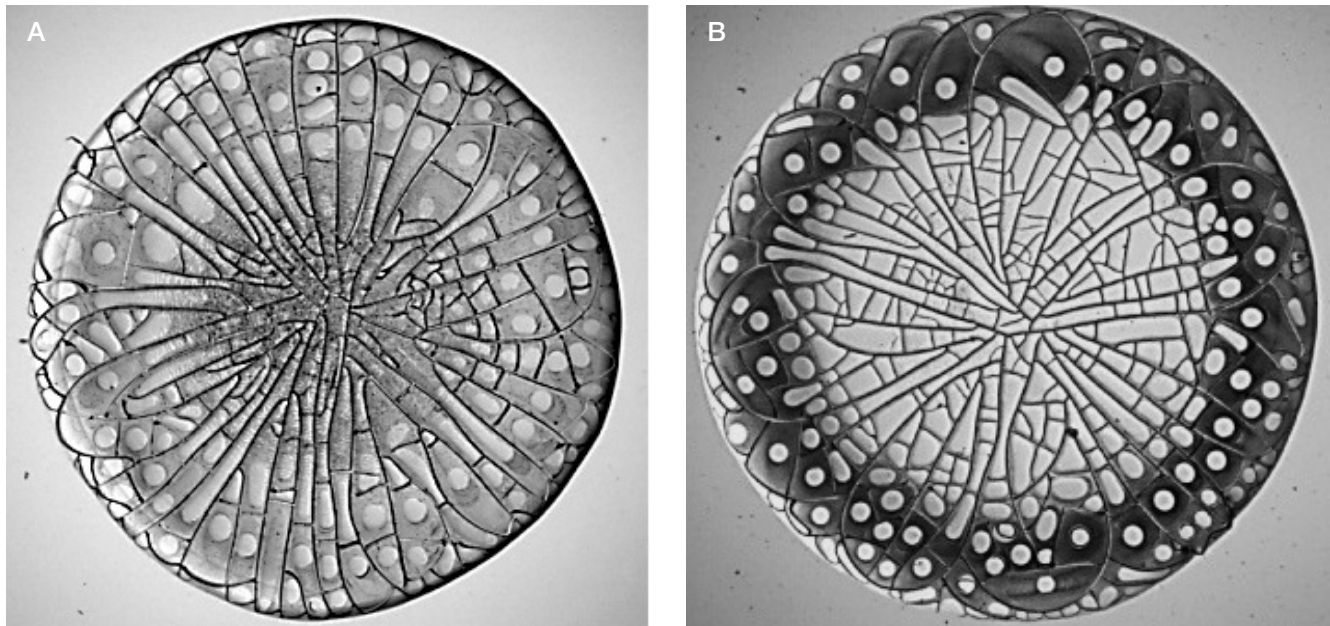


Fig. 1. Serum facies structure under physiologically normal conditions in rats and humans. **A.** Rat. **B.** Human

the aminazine administration. Assessment of the width of the facies central zone revealed a 1.3-fold decrease on average following haloperidol administration and a 2-fold decrease following aminazine administration, compared to the corresponding values of control animals.

Four hours after drug administration, leaf-like, rope-like structures were observed in the blood serum facies central zone in rats. Furthermore, rugosity was reported in this same facies zone of rat blood serum post the haloperidol administration (Fig. 3, Table 1).

Rope-like cracks were observed in the blood serum facies of rats in the experimental groups, whereas no such structures were reported in the control group animals. Furthermore, the average number of cracks of this type in blood serum facies of rats administered haloperidol was 1.9 times higher than in rats administered aminazine.

After 24 h, despite the fact that the experimental animals' behavior was back to normal and did not differ from that of the control animals, structures not found in the control group appeared in the blood serum facies of the rats administered antipsychotics. Spiral cracks were reported in the outer zone of rat blood serum facies after the haloperidol and aminazine administration (Fig. 4). The average number of spiral cracks was

significantly (1.4 times) higher in the facies of rats administered haloperidol, than in the facies of animals administered aminazine (Table 1).

It should be emphasized that such marker, as the facies surface rugosity, appeared at various times: thus, it was detected throughout the observation period after the haloperidol administration, but as late as 24 h after the aminazine administration (Table 2).

Thus, the study conducted allowed us to identify markers of antipsychotic action in rat blood serum facies, determine their quantities, and reveal similarities and differences in their effects at the levels corresponding to the antipsychotic MDDs.

DISCUSSION

The literature data suggest that the wedge-shaped dehydration method, based on fundamental processes of changes in the blood serum molecular composition and physicochemical properties is applicable in various pathological conditions and under the exposure to harmful environmental factors. In clinical trials, it is used for differential diagnosis of various diseases affecting the internal organs (of the brain, liver, ovaries, etc.), assessment of the efficacy of chemotherapy

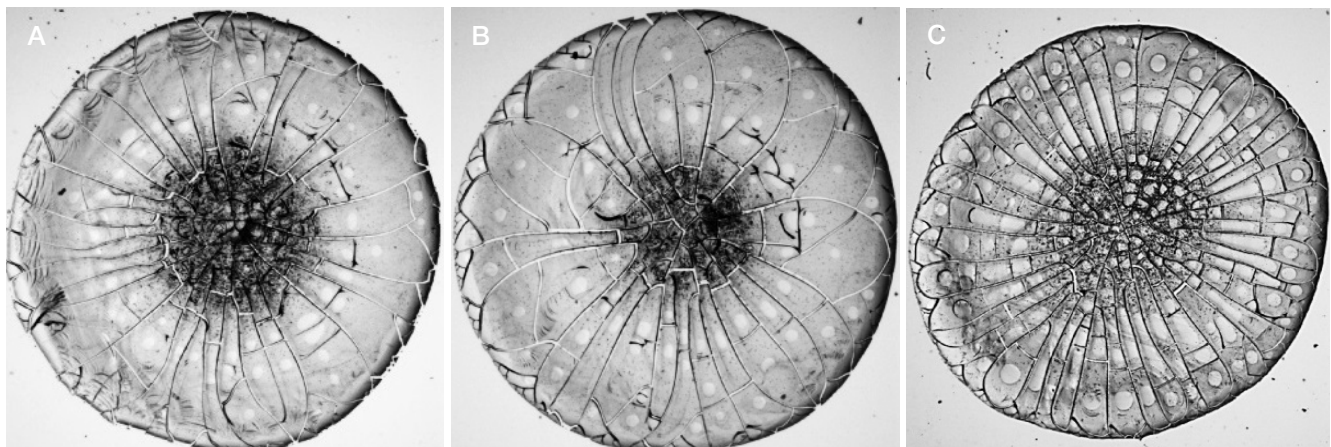


Fig. 2. Reduction in the width of the serum facies central zone in rats (general view) one hour after the administration of haloperidol (**A**) and aminazine (**B**) to rats. **C.** Control group, 12.5× magnification

Table 1. Changes in the structural markers of blood serum facies 1, 4, and 24 h after antipsychotic administration

Indicator	Groups of rats		
	Control	Haloperidol, 10 mg/kg	Aminazine, 35 mg/kg
Central zone width, % 1 h after administration	50.2 ± 4.1	37.4 ± 2.8*	24.9 ± 2.4*
Number of rope-like structures, 4 h after administration	–	5.44 ± 2.19	2.88 ± 1.71**
Number of spiral cracks, 24 h after administration	–	17.56 ± 5.01	12.50 ± 1.86**

Note: * — significant differences from the control group based on the Dunnett's test ($p \leq 0.05$); ** — significant differences from the groups of animals administered antipsychotics based on the Student's t-test ($p \leq 0.05$).

for malignant neoplasms, as well as for forensic examination of fatal poisoning by toxic substances [5–17].

The method information value is determined primarily by the early emergence of exposure markers in blood serum facies — during the period when clinical and biochemical manifestations of health problems may still be absent.

The authors aimed to compare the facies of human and animal blood serum and to attempt to substantiate an experimental model for predicting the effects of harmful substances on human health, exemplified by the effects of antipsychotics — actual substances widely used by the population as medicinal products.

There is great similarity of the general architectonics and distinct structures of the physiologically normal human and rat facies. Similarity in the architectonics of blood serum facies in humans after taking an antipsychotic and in animals after the antipsychotic administration attracts attention. Fig. 5

presents structures of the rat and young man's blood serum facies central zone 24 h after receiving/taking haloperidol: characteristic rope-like structures resembling a leaf can be seen in the blood serum facies central zone. The man had no history of chronic disorders.

The authors more thoroughly examined changes in the facies configuration and structures in the rat blood serum under the exposure antipsychotics. The study showed that the effects of aminazine and haloperidol manifest themselves in both structural similarities and differences in the facies of animal blood serum, which can probably be explained by the drug effect nature. Aminazine exerts antihistamine and anti-adrenergic effects, and a potent sedative activity. Haloperidol is a potent antipsychotic agent that blocks dopaminergic activity and possesses a moderate sedative effect [20, 21]. A sedative effect was observed in experimental rats 4 hours after administration of the drugs.

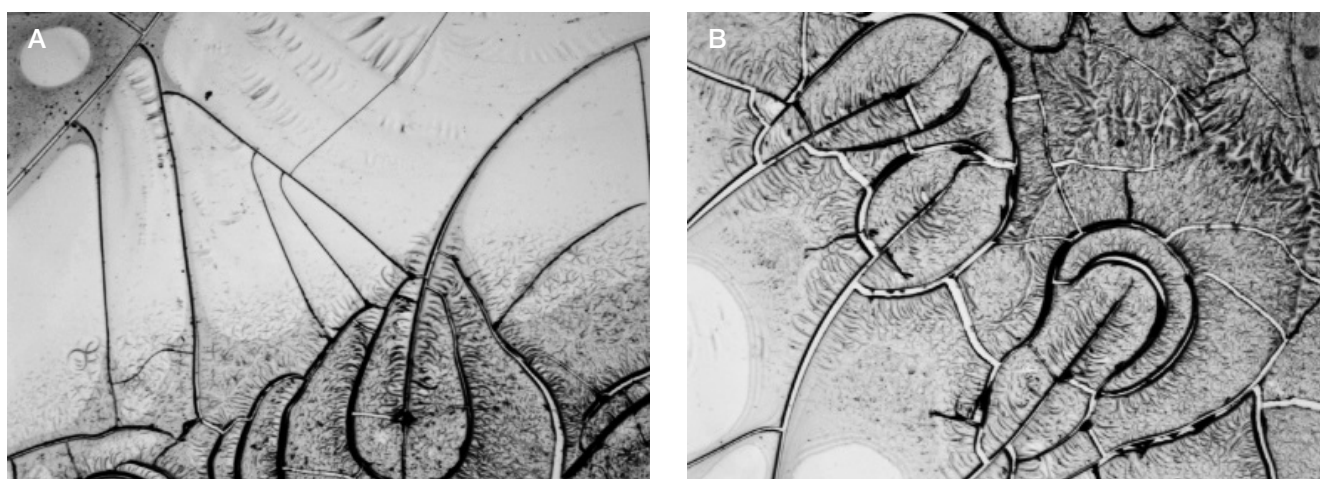
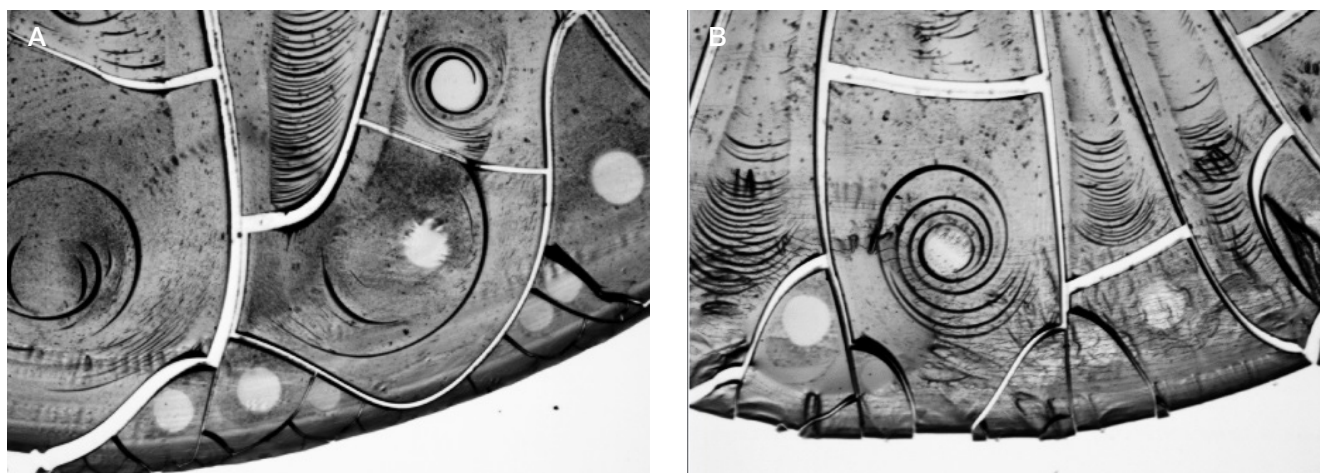
**Fig. 3.** Rope-like structures in the rat blood serum facies 4 h after the intragastric administration of haloperidol (A) and aminazine (B) to rats, 63× magnification**Fig. 4.** Spiral cracks in the rat blood serum facies 24 h after the administration of haloperidol (A) and aminazine (B) to rats, 63× magnification

Table 2. Summary table of antipsychotic markers and effects in rats at various observation time points

Antipsychotic effect	Drugs, time after administration, h								
	Haloperidol			Aminazine			Control		
	1	4	24	1	4	24	1	4	24
Behavior	+	+	—	+	+	—	—	—	—
Change in the facies general appearance	+	+	+	+	+	+	—	—	—
Rope-like structures	—	+	—	—	+	—	—	—	—
Rugosity	+	+	+	—	—	+	—	—	—
Spiral cracks	—	—	+	—	—	+	—	—	—
"Silver" cracks	+	—	—	+	—	—	—	—	—
Triradiate cracks	—	—	+	—	—	+	—	—	—

Note: + — effect; — — no effect.

The dynamic monitoring showed that "silver" cracks were found in the outer zone of the facies one hour after the administration of both drugs; the presence of those indicated impaired vascular elasticity and the blood pressure drop. These structures are presented in the atlas of human non-cellular tissues in patients with vascular abnormalities [9]. The emergence of multiple wrinkles was noted after 4 h, indicating increasing intoxication. Furthermore, after the antipsychotic administration, rope-like structures in the form of a "leaf-within-a-leaf" (after haloperidol administration) and a "double leaf" (after aminazine administration) were observed in the central zone of rat blood serum facies; the presence of those indicated hypoxia of brain cells and alterations in metabolic processes [9]. Twenty-four hours after the administration of antipsychotics, an increase in the width of triradiate cracks was observed in the central and peripheral zones; the presence of those suggested congestive phenomena in the organs. Spiral cracks were observed during this period; such cracks typically form in cases of hyperproteinemia resulting from reduced renal filtration capacity.

However, the haloperidol and aminazine effect severity and time of manifestation are different: a significantly greater number of rope-like structures and spiral cracks are reported upon administration of haloperidol; markers of intoxication appear as early as one hour after haloperidol administration and persist for 24 h. These are observed only 24 h after aminazine administration.

The authors believe that the findings and further studies will make it possible to consider the use of the wedge-shaped dehydration method in rat experiments as a prognostic

criterion for extrapolation of results to humans. This is based on the similarity of blood serum facies structures under physiologically normal conditions and the unity of mechanisms underlying the dehydration-induced self-organization of human and rat biological fluids.

In addition to the effects of antipsychotics on the animal body, the effects of other toxic substances (strychnine and arsenic oxide (V), ethanol, caffeine) possessing various biological activity and having various physicochemical properties had previously been investigated using the wedge-shaped dehydration method. It was shown that the effects of these compounds on the organism and their manifestation in the architectonics of rat blood serum facies conformed, on the one hand, to general patterns, but on the other hand, the effect had specific characteristics reflecting the biological activity of each compound [22, 23]. This confirms the scientific and practical significance of the use of this method.

It is necessary to focus on the fact that in practice, intoxication with chemical substances, including medicinal products, is determined using complex laboratory methods that require time-consuming sample preparation and expensive consumables. When considering the wedge-shaped dehydration method from an economic perspective, it is necessary to note that it has a number of advantages: it is less time-consuming allowing one to rapidly obtain preliminary results. This makes it a promising method for determining the effects of toxic substances and identifying these in preventive medicine. To ensure widespread implementation and use of the method in future, it is necessary to create a library of images of blood serum facies from experimental animals and a database of alteration post exposure to harmful chemicals.

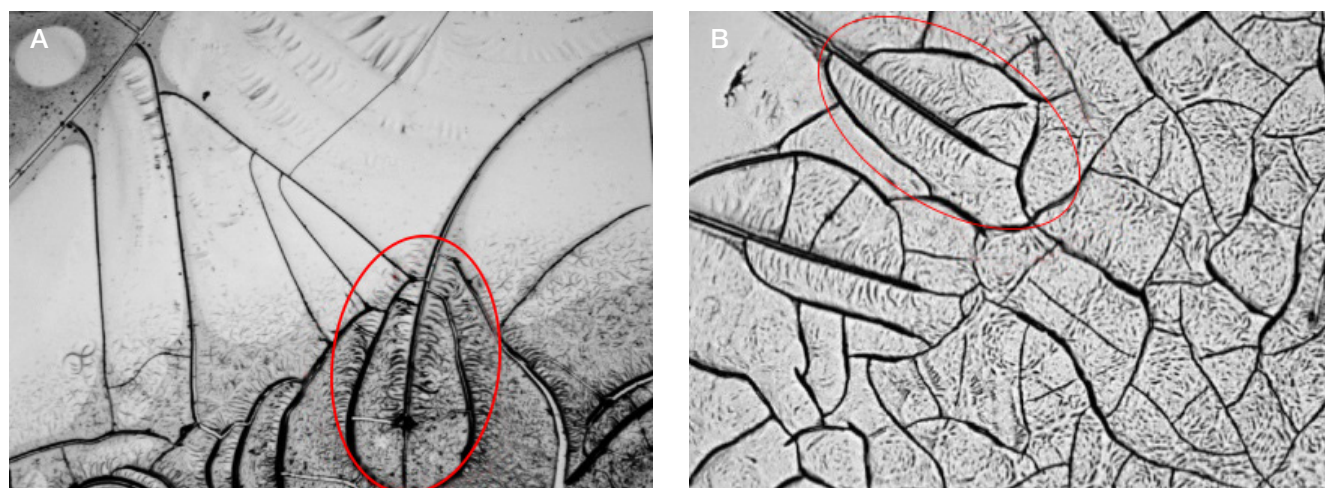


Fig. 5. Rope-like structures in blood serum facies 24 h after the haloperidol administration to the rat (A) and after the haloperidol intake in human (B) — circled in red, 63× magnification

CONCLUSIONS

Administration of antipsychotics (aminazine and haloperidol) at doses corresponding to the maximum daily doses (MDDs) caused structural changes in the dehydrated rat blood serum organization manifested as a reduction in the central zone width and the emergence of rope-like structures and spiral cracks not

found in control animals, which correlated with the experimental rats' behavioral responses. The wedge-shaped dehydration method demonstrated high sensitivity and information value in the experimental study of the antipsychotic effects. This allows us to propose it as a promising and cost-effective method for predicting the impact of chemical factors of the occupational and natural environments on humans.

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ANALYSIS OF PUBLICATION TRENDS IN THE DOMAIN OF HYGIENE EDUCATION

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To identify the most relevant directions for research in the domain of hygienic education, it is necessary to summarize and systematize the accumulated research materials and practical guidelines. This study analyzed existing scientific and practical evidence on hygienic education in various populations. The Russian Science Citation Index (RSCI) enabled analysis of the publication trends in the field of hygienic education. We considered works published from 1995 (when the first paper was added to the index) to the third quarter of 2025 inclusive. The pool included 663 publications, mostly by Russian authors. The total number of citations is 2402. The number of publications with zero citations is 278. The average number of citations per publication is 3.62 ± 1.22 . The analysis of the publication activity in the domain of hygienic education has shown that this problem is underexplored, and there is an insufficient number of fundamental guidelines and original research on topical issues, as well as dissertations covering this subject matter. There is a need for sustained dialogue between researchers and practitioners in this field in leading hygiene journals, to share scientific experience, enhance cross-citation of research, extend the use of these materials to other regions, and drive the development of new technologies for hygiene education.

Keywords: publications, hygiene education, health education, authors, citation**Funding:** the study was part of the state-supported R&D project AAAA-A19-119021890068-7 of February 18, 2019.**Author contribution:** the authors have made equal contributions to this publication.✉ **Correspondence should be addressed:** Yulia L. Tikhonova
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АНАЛИЗ ПУБЛИКАЦИОННОЙ АКТИВНОСТИ ПО ВОПРОСАМ ГИГИЕНИЧЕСКОГО ВОСПИТАНИЯ

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С учетом имеющегося накопленного научного материала и практических наработок возникла необходимость обобщения и систематизации полученных сведений для определения наиболее актуальных направлений гигиенического воспитания, подлежащих разработке. Целью исследования было выполнить анализ существующей научной и практической информации по гигиеническому воспитанию различных групп населения. Для анализа публикационной активности по вопросам гигиенического воспитания использовали Российский индекс научного цитирования (РИНЦ). Временной диапазон выхода рассматриваемых статей — от первой имеющейся в базе публикации (1995 г.) до III квартала 2025 г. включительно. Всего было 663 публикации, в основном отечественных авторов. Общее число цитирований — 2402. Число публикаций с нулевым цитированием — 278. Среднее число цитирований одной публикации — $3,62 \pm 1,22$. Анализ публикационной активности по вопросам гигиенического воспитания показал недостаточное внимание к данной проблеме, недостаток фундаментальных руководств и оригинальных исследований по злободневным проблемам, а также связанных с данной тематикой диссертационных работ. Необходимы широкий обмен мнениями работающих в этой области ученых и врачей-практиков на страницах ведущих гигиенических журналов для обмена научным опытом, перекрестное цитирование научных материалов, их активное использование в других регионах, наработка новых технологий гигиенического воспитания.

Ключевые слова: публикации, гигиеническое воспитание, санитарное просвещение, авторы, цитирование**Финансирование** исследование выполнено в рамках НИР (номер государственного учета НИОКР AAAA-A19-119021890068-7 от 18 февраля 2019 г.).**Вклад авторов:** все авторы внесли равный вклад в подготовку публикации.✉ **Для корреспонденции:** Юлия Леонидовна Тихонова
ул. Островитянова, д. 1, г. Москва, 117997, Россия; tikhonova_yl@rsmu.ru**Статья получена:** 20.05.2026 **Статья принята к печати:** 15.09.2026 **Опубликована онлайн:** 27.09.2026**DOI:** 10.24075/rbh.2026.176**Авторские права:** © 2026 принадлежат авторам. Лицензиат: РНИМУ им. Н. И. Пирогова. Статья размещена в открытом доступе и распространяется на условиях лицензии Creative Commons Attribution (CC BY) (<https://creativecommons.org/licenses/by/4.0/>).

The high demand for preventive medicine necessitates the search for the most effective forms, means, and methods of prevention. Hygienic education of various populations that factors in lifestyle, professional activity, environmental conditions, and health status is one of the relevant directions in the field of prevention. The search for the most relevant areas of hygiene education is the subject research designed to analyze the existing literature, regulations, and methodological documents. In order to identify the most relevant directions for research in the domain

of hygienic education, it is necessary to summarize and systematize the accumulated research evidence and theoretical materials.

As specified in Clause 12 of the Passport of the scientific specialty "3.2.1 Hygiene," current research in the field of hygiene involves investigation of the effectiveness of various forms, means, and methods of hygienic education, which support the development of hygienic education technology for various population groups and design of an evidence-based healthy lifestyle popularization system.

Given that the Russian healthcare system is oriented toward prevention, it is necessary to analyze publication trends in the field of health education for various population groups, considering both historical experience and the current situation.

This study analyzed existing scientific and practical evidence on hygienic education in various populations.

METHODS

The Russian Science Citation Index (RSCI; data from eLIBRARY.RU) enabled the analysis of publication activity on the problem of hygienic education; the papers for inclusion in the study were searched for among the indexed literature. We considered works published from 1995 (when the first paper was added to the index) to the third quarter of 2025 inclusive. The search included three stages. At stage 1, we limited the search scope to titles and keywords, and searched for "hygienic education." The search yielded 480 publications, mostly by Russian authors. At stage 2, with the search still limited to titles and keywords, we used the query "sanitary education," which reflects the historical development of this field in Russia. This attempt yielded 425 publications, mostly by Russian authors. At stage 3, we selected publications that were articles, monographs, textbooks, and manuals. Subsequently, we eliminated duplicate records identified in both search attempts (retaining a single copy) and excluded publications that were only indirectly related or unrelated to the review question. As a result, 663 publications were selected for further analysis.

GigaChat 2.0 neural network (<https://giga.chat>) was used to analyze the data. The results of the processing was verified and edited by the authors in accordance with modern approaches to data processing [1].

RESULTS

We established the total number of citations of the selected publications: 2402 (Fig. 1).

There were 278 publications with zero citations.

The average number of citations per publication was 3.62 ± 1.22 .

The pool of works included both translated publications, such as materials by the World Health Organization (WHO) and UNESCO, as well as original research conducted in the Republic of Belarus, the Republic of Tajikistan, the Kyrgyz Republic, and the People's Republic of China, the topics of which were addiction prevention, dental health, etc. (24 publications) [2–4].

There were 18 theses prepared for conferral of the degrees of Candidate or Doctor of Sciences in Medicine or Pedagogy. The study dedicated to dental health was the most cited: 25 citations [5]. The papers also described the organization of patient education courses for individuals with cardiovascular diseases, osteoporosis, and tuberculosis; programs aimed at preserving reproductive health; and courses promoting healthy lifestyle among students.

A large number of articles and fundamental monographs explored the history of medicine and health education in different periods of the country's development (83 publications) [6–9].

Some works investigated individual methods, forms, and means of health education, such as posters, films, and literature (14 citations) [10, 11].

Two publications analyzed the role of health education houses in the anti-epidemics efforts [12, 13].

The article with the largest number of citations (15) was published in 1995. It analyzes the historical problems of health education of the country's population and sets the tasks relevant at that time [14].

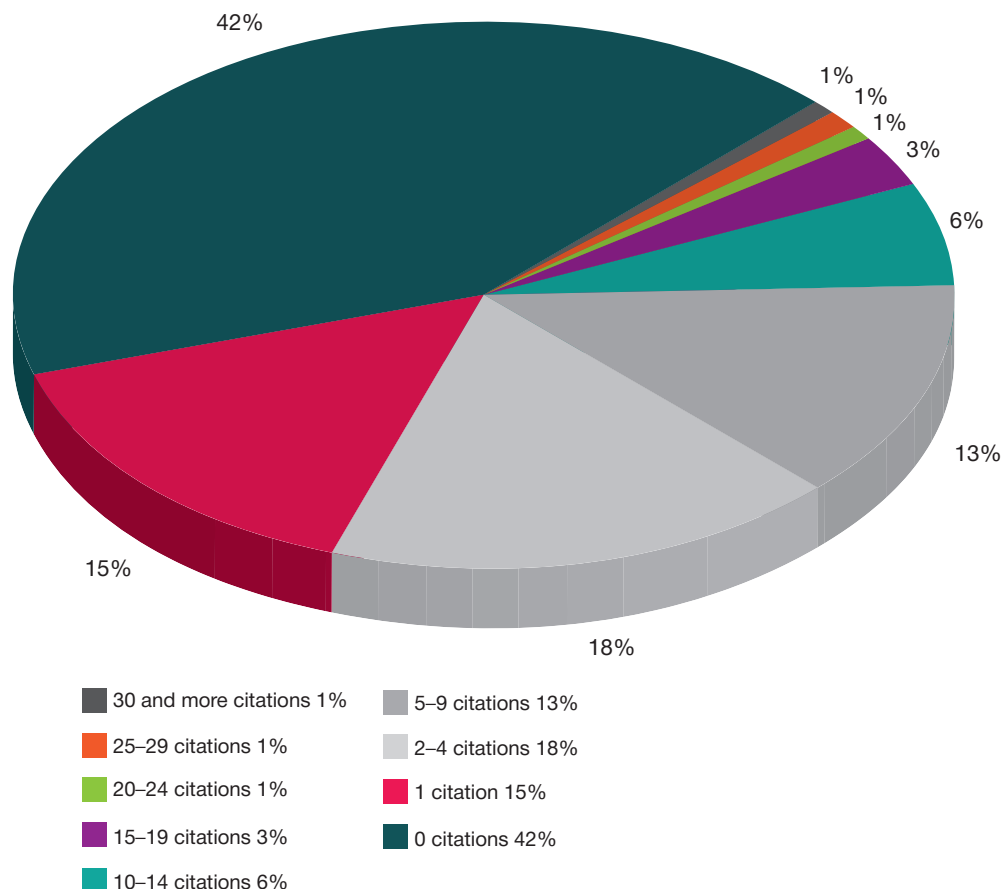


Fig. 1. Publications by the amount of received citations, %

A number of studies have examined the contributions of prominent figures in hygiene and sanitation, including N.A. Semashko, Academician of the Academy of Medical Sciences of the USSR; Professors A.V. Molokov, Z.P. Solovyov, and I.M. Sechenov; and the poet V.V. Mayakovsky [15–17].

Works dedicated to prevention of drug addiction, substance abuse, alcohol dependence, and tobacco smoking prevention (analytical papers, manuals, original research, practical guidelines) occupy a special place. They are intended for different target audiences — doctors, educators, psychologists, students, and parents. Our pool included 149 such publications. The most cited were the textbook for students of pedagogical universities (29 citations), the handbook for psychologists (28 citations), and the handbook for doctors (25 citations) [18–20].

Thirty-two publications covered protection of reproductive health, HIV and STD prevention. The most cited was a literature review (7 citations) discussing reproductive health of adolescent girls [21].

Many publications consider issues of prevention of dental diseases, including through hygienic education. There were 53 of them in the pool. The most cited (28 and 29 citations) were publications exploring approaches to the prevention of dental diseases in various population groups, including students [22, 23].

Several works focus on the need to educate tuberculosis patients (16 publications), and to organize educational programs for patients with various diseases (chronic obstructive pulmonary disease, diabetes mellitus, cardiovascular, oncological diseases, etc.) (24 publications). The most cited of them was a monograph that discusses the issues of public health

education in the context of prevention of zoonotic infections (45 citations) [24].

Twenty-nine works addressed the aspects of sanitary education of specific population cohorts — servicemen, women on maternity leave, convicts, working population, rural population, people living in the northern regions, retired, etc. The most cited work in this subpool was the one that considered sanitary and hygienic education of convicts (19 citations) [25].

A relatively small number of works — 9 publications — revolve around more current issues of hygiene education, including prevention of COVID-19, hygienic guidance for guests, athletes, and volunteers at the XXII Olympic and XI Paralympic Winter Games in Sochi [26].

A substantial subset of 95 guidelines and articles is aimed at teachers, psychologists, and students of pedagogical universities. These works cover hygienic education, healthy lifestyle formation, and health-saving technologies in institutions for children, adolescents, and young people. Here, the guidelines received the largest number of citations (36) [27].

The pool included 14 fundamental guidelines and textbooks for hygienists, medical doctors of various specialties, teachers and students of medical universities and medical colleges (mostly for undergraduates and postgraduates). A 2019 textbook by L.F. Ignatova, V.V. Stan, and H.H. Khamidulina was the most cited work in this subset. It outlined the methodology for assessing lifestyle in school-age children [28].

We reviewed the original research by doctors on the topic of hygienic education of various groups of the population and students of medical universities; the topics of these works were nutrition (9 publications), safe use of electronic devices

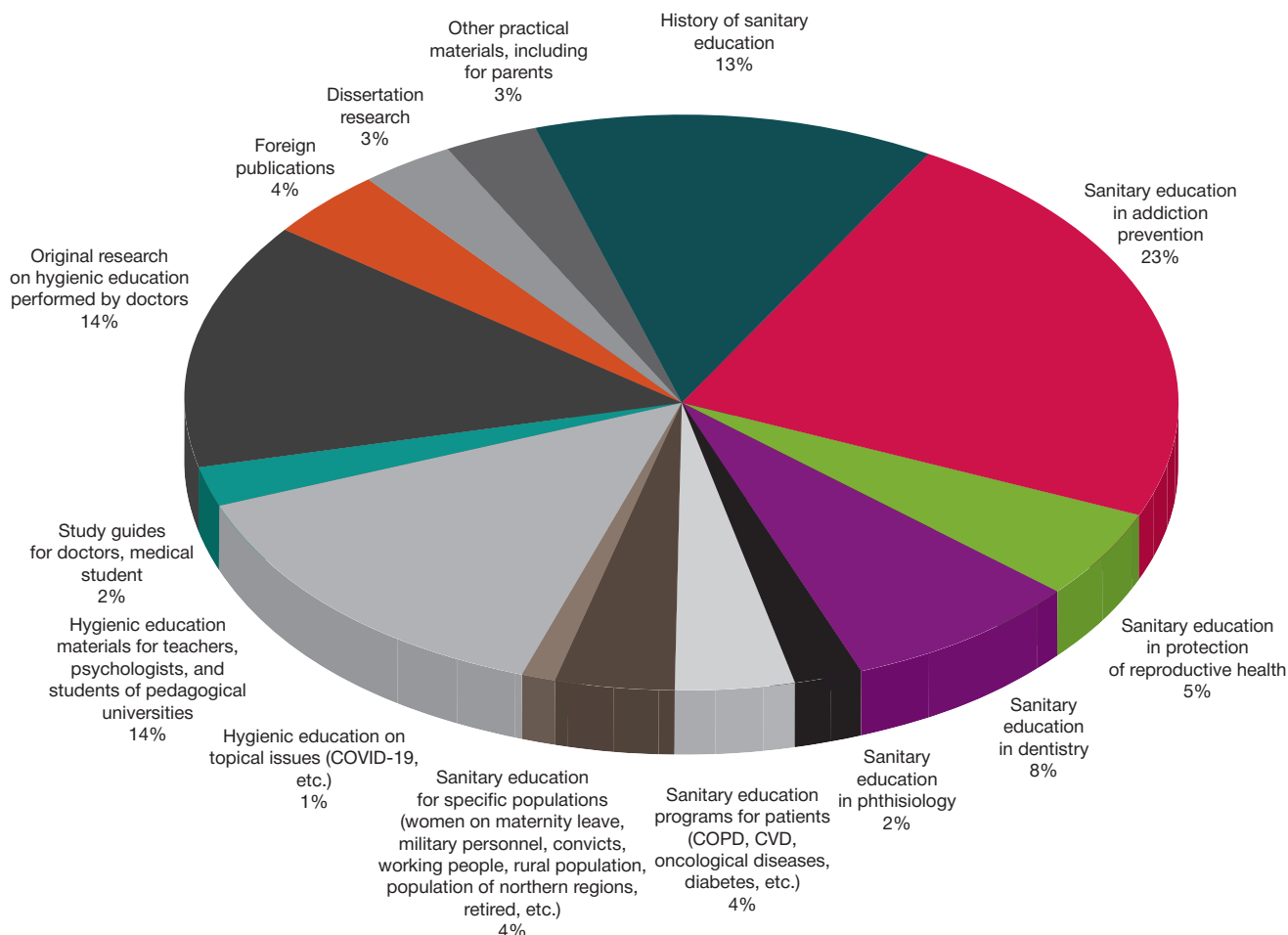


Fig. 2. Shares of publications on various topics in the domain of hygiene education (%)

Table. Distribution of publications by type (*n*, %)

Type of publication	Quantity
Textbooks and workbooks	112 (17%)
Monographs	46 (7%)
Scientific articles in journals	426 (64%)
Abstracts of dissertations	18 (3%)
Other publications	61 (9%)

(12 publications), theoretical issues and modern technologies of hygienic education (22), etc. This subset included 94 original studies published in different years.

The most cited articles were those by A.G. Sukharev, V.V. Stan, and L.F. Ignatova (2016) — 25 citations; E.G. Blinova, O.S. Bogunova, I.S. Akimova, and L.V. Demakova (2015) — 24 citations; O.Yu. Milushkina, N.A. Skoblina, Yu.P. Pivovarov et al. (2022) — 18 citations. They explore the issues of hygienic education of students [29–31].

Fig. 2 presents the proportions of each of the publication types described above.

The table below shows the overall distribution of publications.

The ratio of publications by one author (18%) versus groups of authors (82%) is 1:5.

DISCUSSION

The problems of hygienic education of the population are cross-domain, being of interest to the medical, pedagogical, and psychological communities, as evidenced by the wide variety of journals publishing the respective works. However, although a substantial number of publications have appeared since 1995, they are rarely cited; many articles have zero citations.

Since 2005, only 18 dissertations have been completed; these studies vary considerably in how deeply they examine hygienic education in different populations, with most focusing on patients..

The most common sources in this study's corpus are historical and contemporary methodological papers and guidebooks on sanitary education for various population groups, covering addiction prevention, reproductive health, tuberculosis prevention, and dental health, as well as works discussing the organization of patient education courses for people with chronic non-communicable diseases, although the range of nosologies covered is limited.

There are 28 papers presenting research on health education of specific groups of the population (women on maternity leave, military personnel, convicts, working population, rural population, population of northern regions, retired, etc.). It should be noted that these studies do not cover all target groups.

The guidelines for teachers, psychologists, and students of pedagogical universities are a special subset of the corpus. In these works, health education is considered together with the formation of a healthy lifestyle and use of health-saving technologies.

The number of hygiene education textbooks and workbooks for doctors and students of medical universities that were published within the considered period is limited. Several studies report original research but largely neglect some of the notable issues, such as vaccination and parent education during the infant's first year of life. Current research priorities include population-level health education in the context

of the COVID-19 pandemic, given that this domain remains understudied. With the spread of digitalization, new forms, methods, and tools for hygienic education are becoming increasingly relevant, necessitating further methodological development, testing, and evaluation of their effectiveness. An interesting avenue is to analyze scientific developments across departments of leading medical universities; in our pool, only four papers fell into this category.

The ratio of single-author to multi-author publications likely reflects the current trend toward collaboration in research and practice, especially in areas related to disease prevention and hygiene education, where interdisciplinary approaches and multi-domain efforts are needed.

Most of the publications are research articles, which highlights the importance of original, relevant research in the field of hygiene education and disease prevention.

As for the evolution of research and other activities in the considered field, we see the following directions.

1. Expansion of interdisciplinary cooperation. Involvement of specialists from various domains (medicine, pedagogy, psychology, and sociology) to obtain a more holistic understanding and develop effective prevention strategies.

2. Expansion of the geographical scope of research. Comparative assessment of the data obtained in different regions of Russia aimed at identifying regional specifics and adapting the applied technologies to local conditions.

3. Strengthening the practical focus of research. Transition from purely theoretical developments to the design and testing of modern methods, forms, and means of hygienic education in order to facilitate practical application of the said theoretical developments.

4. Strengthening actual links between science and practice. Close cooperation between researchers and practitioners (teachers, doctors, social workers) in the context of testing of modern methods, forms and means of hygiene education, as well as assessment of practical effectiveness of implemented technologies.

CONCLUSIONS

The analysis of publication trends in the field of hygiene education revealed that this area has received insufficient attention from researchers. We identified only a few fundamental and original studies, a narrow range of issues addressed, and very few dissertations on this topic. This field requires extensive dialogue between scientists and practitioners, active discussion of the problem in leading hygiene journals, systematic sharing of accumulated experience, cross-citation of scientific literature, adaptation of existing practices to diverse living, working, and recreational conditions and regional contexts, and the development of new approaches to hygienic education.

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HYGIENIC FEATURES OF PHYSICAL ACTIVITY AMONG MEDICAL UNIVERSITY STUDENTS

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A high risk of physical inactivity is emerging among students in the context of the high level of informatization in public life, the widespread development of online delivery services, and the growing popularity of network forms of interpersonal communication. The cross-sectional descriptive study aimed to identify the features of the medical students' physical activity and the risk factors influencing the development of physical inactivity during the period of study. We conducted an anonymous online questionnaire survey of 431 students of the Pavlov Ryazan State Medical University on the forms.yandex.ru platform using questions from the Physical Activity Level Self-Assessment Form adapted by A.V. Kabachkova (2025). The majority of students (61.95%), who took part in the study, had low physical activity. The higher prevalence of moderate, sufficient, and high physical activity was reported in male respondents compared to female ones ($\chi^2 = 20.36$; $p < 0.001$). There is a downward trend of the medical students' physical activity from the first to the third year, a significant increase in physical activity in the fourth year and a subsequent decline by the sixth year. The decrease in the proportion of students with low physical activity and the increase in the proportion of students with moderate and sufficient physical activity with decreasing time spent on electronic devices are observed ($\chi^2 = 34.5$; $p < 0.001$). Risk factors for low physical activity among medical students include studying in the third or sixth year of medical university, female gender, and significant time spent using electronic devices.

Keywords: students, physical activity, healthy lifestyle, physical inactivity prevention

Author contribution: Dementiev AA — study concept and design, statistical data processing, manuscript writing; Fadeeva MD, Soloviev DA — material collection, data processing; Tsukareva EA — data processing; all authors — approval of the final version of the article.

Compliance with ethical standards: all students submitted the informed consent to take part in the study.

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Received: 06.06.2026 **Accepted:** 16.09.2026 **Published online:** 28.09.2026

DOI: 10.24075/rbh.2026.177

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ГИГИЕНИЧЕСКИЕ ОСОБЕННОСТИ ДВИГАТЕЛЬНОЙ АКТИВНОСТИ СТУДЕНТОВ МЕДИЦИНСКОГО УНИВЕРСИТЕТА

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В условиях высокой информатизации общественной жизни, широкого развития сервисов онлайн-доставки, увеличения популярности сетевых форм межличностной коммуникации формируется высокий риск развития гиподинамии в студенческой среде. Целью кросс-секционного описательного исследования было выявить особенности двигательной активности студентов-медиков и факторов риска, влияющих на формирование гиподинамии в период обучения. Проведено анонимное онлайн-анкетирование 431 студента ФГБОУ ВО РязГМУ на платформе forms.yandex.ru с использованием вопросов «Опросника самооценки уровня двигательной активности» (Physical Activity Level Self-Assessment Form) в адаптации А. В. Кабачковой (2025). Большинство студентов (61,95%), принявших участие в исследовании, имели низкую двигательную активность. Выявлена большая распространенность средней, достаточной и высокой двигательной активности среди респондентов мужского пола по сравнению с респондентами женского пола ($\chi^2 = 20,36$; $p < 0,001$). Прослеживается тенденция к снижению двигательной активности студентов-медиков от первого к третьему курсу, существенное увеличение двигательной активности на четвертом курсе и дальнейшее снижение к шестому курсу. Наблюдаются уменьшение доли студентов с низкой и увеличение доли студентов со средней и достаточной двигательной активностью по мере снижения временных затрат на электронные устройства ($\chi^2 = 34,5$; $p < 0,001$). К факторам риска низкой двигательной активности студентов-медиков можно отнести обучение на третьем и шестом курсах медицинского университета, женский пол и значительные временные затраты на взаимодействие с электронными устройствами.

Ключевые слова: студенты, двигательная активность, здоровый образ жизни, профилактика гиподинамии

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Соблюдение этических стандартов: от всех студентов получено добровольное информированное согласие на участие в исследовании.

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Статья получена: 06.06.2026 **Статья принята к печати:** 16.09.2026 **Опубликована онлайн:** 28.09.2026

DOI: 10.24075/rbh.2026.177

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Fostering health-preserving behavior and the culture of healthy living is considered as a priority task for preventive medicine in the current context, characterized by relatively low birth rates and a progressively aging population [1–4]. Given that a significant portion of preventive work falls within the duties of medical personnel providing primary medical and social care

to the population, fostering attitudes toward a healthy lifestyle among medical students is a crucial task of higher medical education [5–8].

Adequate physical activity is an integral part of a healthy lifestyle, contributing to the maintenance of cardiovascular health and the prevention of metabolic syndrome and obesity

Table 1. Student distribution by physical activity intensity

Gender		Physical activity				Total
		High	Sufficient	Moderate	Low	
Female	<i>n</i>	3	12	71	196	282
	%	1.06 %	4.26 %	25.18 %	69.50 %	100.00 %
Мужской	<i>n</i>	4	13	61	71	149
	%	2.68 %	8.72 %	40.94 %	47.65 %	100.00 %
Male	<i>n</i>	7	25	132	267	431
	%	1.62 %	5.80 %	30.63 %	61.95 %	100.00 %

[9–13]. A high risk of physical inactivity is emerging among students in the context of the high level of informatization of public life, the widespread development of online delivery services, and the growing popularity of network forms of interpersonal communication [14–17]. In this regard, studying the hygienic features of medical university students' physical activity is highly relevant.

The study aimed to identify the features of medical students' physical activity and the risk factors influencing the development of physical inactivity during the period of study.

METHODS

The cross-sectional descriptive study was conducted at the Department of General Hygiene of the Pavlov Ryazan State Medical University of the Ministry of Health of the Russian Federation. We conducted an anonymous online questionnaire survey of 431 1st to 6th-year students of the Pavlov Ryazan State Medical University on the forms.yandex.ru platform using questions from the Physical Activity Level Self-Assessment Form adapted by A.V. Kabachkova (2025). Inclusion criteria: The respondent is a student of the Pavlov Ryazan State Medical University of the Ministry of Health of the Russian Federation, he/she has submitted the informed consent to take part in the study, he/she has answered all questions of the online questionnaire. Exclusion criteria: incorrectly filled online questionnaire. The sample size was determined using the standard formula for sampling without replacement.

Relative values were calculated when assessing the rate of various motor activity variants. Significance of differences in the frequency analysis was assessed using the chi-squares test (χ^2); pairwise comparison of relative values was performed using Student's *t*-test. The differences were considered significant at $p < 0.05$. Statistical data processing was performed in MS

Excel (Microsoft; USA) and Jasp 0.97 (University of Amsterdam; Netherlands) software packages.

RESULTS

The study showed that the majority of students enrolled (61.95%) had low physical activity (Table 1). High and sufficient physical activity was typical for a small proportion of respondents (1.62 and 5.80%, respectively), whereas other students had average levels. We revealed significant gender differences in the physical activity of medical students, reflected by the higher rate of moderate, sufficient, and high physical activity in male respondents ($\chi^2 = 20.36$; $p < 0.001$).

The study revealed significant differences in the distribution of students with varying levels of physical activity across different years of university study ($\chi^2 = 25.9$; $p = 0.039$) (Table 2).

The fact that students with high physical activity were found only in the first three years of university attracts attention, and their share was insignificant and fell within the range of 0.63–3.81%. The majority of students in all years of study had low physical activity, and their share increased from the first to the third year of study from 56.18 to 74.29%, reaching its maximum. Then, in the fourth year of study, it dropped to a minimum (52.6%), primarily due to increasing the proportion of students with sufficient and moderate physical activity to the maximum level (to 10.53 and 36.84%, respectively). However, during the next two years of study, the prevalence of low physical activity among students began to rise again: to 68.97 and 70.00%, respectively.

It should be noted that no significant effect of age or faculty on the medical students' physical activity was found.

It seems interesting to consider distinct components of the students' physical activity determining its overall score. The study has shown that 35.75% of students always use

Table 2. Student distribution by physical activity intensity depending on the year of study

Year		Physical activity				Total
		High	Sufficient	Moderate	Low	
1	<i>n</i>	2	7	30	50	89
	%	2.25 %	7.87 %	33.71 %	56.18 %	100.00 %
2	<i>n</i>	1	13	54	92	160
	%	0.63 %	8.13 %	33.75 %	57.50 %	100.00 %
3	<i>n</i>	4	0	23	78	105
	%	3.81 %	0.00 %	21.90 %	74.29 %	100.00 %
4	<i>n</i>	0	4	14	20	38
	%	0.00 %	10.53 %	36.84 %	52.63 %	100.00 %
5	<i>n</i>	0	0	9	20	29
	%	0.00 %	0.00 %	31.03 %	68.97 %	100.00 %
6	<i>n</i>	0	1	2	7	10
	%	0.00 %	10.00 %	20.00 %	70.00 %	100.00 %

Table 3. Distribution of students with various physical activity depending on the time spent on electronic devices (television, computer, tablet, smartphone)

Time		Physical activity				Total
		High	Sufficient	Moderate	Low	
More than 5 h a day	<i>n</i>	1	5	32	109	147
	%	0.68 %	3.40 %	21.77 %	74.15 %	100.00 %
3–5 h a day	<i>n</i>	1	12	64	125	202
	%	0.50 %	5.94 %	31.68 %	61.88 %	100.00 %
Less than 2 h a day	<i>n</i>	5	8	33	36	82
	%	6.10 %	9.76 %	40.24 %	43.90 %	100.00 %

the stairs instead of the elevator, while the proportion of such students among males (46.75%) is significantly higher than among females (30.13%) ($t = 3.46$; $p < 0.05$). A total of 37.50% of the students engage in high-intensity physical activity for 20 min or more, 2–3 days a week, males more often (45.45%), than females (33.34%) ($t = 2.48$; $p < 0.05$). A total of 46.93% of respondents perform strength exercises very rarely, and the proportion of such individuals among females is 54.97%, which 1.7 times higher, than among males ($t = 5.06$; $p < 0.05$). A total of 34.42% of men and 1.5 times fewer women practice physical activity of this type 2–3 days a week ($t = 2.48$; $p < 0.05$).

One in three survey participants, regardless of gender, spends more than 5 h a day in front of a television, computer, tablet, or smartphone; 46.87% of respondents spend between 3–5 h a day interacting with electronic devices, while others spend less than 2 h. At the same time, 46.93% of medical students read books for more than 2 h a day, 31.8% for 2 h, and 16.23% for about an hour. No significant gender differences were found in the distribution of students based on the time spent with books or electronic devices.

A decrease in the proportion of students with low physical activity is observed as the time spent on electronic devices decreases: from 74.15 to 43.90%, respectively ($\chi^2 = 34.5$; $p < 0.001$) (Table 3).

Reduction of the time spent using electronic devices is reflected in the increase in the fraction of respondents with sufficient or moderate physical activity: from 3.40 to 9.76% and from 21.77 to 40.4%, respectively. At the same time, the highest proportion of respondents with high physical activity was reported for the group with the least time spent using electronic devices.

DISCUSSION

The high prevalence of low physical activity among medical university students (61.95%) identified in the study is fully consistent with the results of other researchers, according to which the lack of physical activity was reported in 57–64% of students [18–20], and 48.6% of students lead a sedentary

lifestyle [21]. At the same time, there are studies with a more optimistic assessment of the medical students' physical activity. According to the results of some studies, more than half of medical students had high physical activity [22]. According to other data, only 30.9% of medical university students had physical activity levels below the norm recommended by the World Health Organization (WHO) [23]. According to our data, 37.5% of students engaged in high-intensity physical activity 2–3 times a week, which is consistent with findings from other studies [24]. The reported higher physical activity of males compared to females has been also confirmed by other authors [25]. Our study has revealed no gender differences in the distribution of students based on the time spent using electronic devices, whereas data from other authors suggest that women tend to spend more time on smartphones and using social media [16, 25]. The time spent on electronic devices has an adverse effect on students' physical activity, which is fully consistent with the findings of other authors [25].

It should be noted that insufficient physical activity being a risk factor for metabolic disorders leads to the body mass index increase [26, 27]. Encouraging physical activity among medical students is important for maintaining health and training future physicians [25].

CONCLUSIONS

The majority of medical university students (61.95%) are characterized by low physical activity, which is more prevalent among females (69.5%) than among males (47.5%) ($p < 0.001$). In general, the trend is observed toward a decrease in the medical students' physical activity from the first to the third year, a significant increase in the fourth year, and a further decline by the sixth year. A higher rate of high-intensity physical activity and strength exercises was observed among men compared to women. At the same time, nearly half of the students of both genders spent 3–5 h on electronic devices and more than 2 h a day reading. Risk factors for low physical activity among medical students include studying in the third or sixth year of medical university, female gender, and significant time spent using electronic devices.

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