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

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OCCUPATIONAL AND GENERAL SOMATIC PATHOLOGY IN HEALTHCARE WORKERS

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Today, the world medical community and the World Health Organization share an understanding of health as the most important right of every person and nation. Unfortunately, the level of occupational morbidity in healthcare significantly exceeds that in other sectors of the economy. In 2012-2017, about 30% of all the professional diseases diagnosed were registered in healthcare workers. We have searched for foreign and Russian papers covering this subject in various databases, including Scopus, Web of Science, MedLine, eLIBRARY.RU, CyberLeninka, and RSCI. During the search, we paid special attention to the PubMed database. Summarizing the current data on working conditions and health indicators of healthcare professionals published in the papers, it is necessary to identify several key areas that are particularly relevant: harmful aspects associated with professional activities as factors raising occupational morbidity; lifestyle of healthcare workers and the prevalence of non-communicable diseases; and professional burnout, with the consequences thereof for the health and mental state of the medical professionals. The topic of their health and the conditions they work in is considered urgent and relevant in the scientific circles. The conducted studies confirm that healthcare workers face unique factors that can negatively affect their health and well-being.

Keywords: working conditions, health workers' health, review, professional burnout syndrome

Author contribution:: Stepanov EG, Masyagutova LM — study conceptualization and design, data collection and processing, article authoring; Shaikhlislamova ER, Sadrtdinova GR — data collection and processing, article authoring, editing; Vlasova NV, Rafikova LA, Muzafarova AR, Valeeva LR — article authoring, selection and translation of literature; all authors — approval of the final version of the article, responsibility for the integrity of all parts thereof.

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ПРОФЕССИОНАЛЬНАЯ И ОБЩЕСОМАТИЧЕСКАЯ ПАТОЛОГИЯ У РАБОТНИКОВ ЗДРАВООХРАНЕНИЯ

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Сегодня мировая медицинская общественность и Всемирная организация здравоохранения подтверждают понимание здоровья как важнейшего права каждого человека и народа. К сожалению, профессиональная заболеваемость в здравоохранении значительно превышает уровень в других отраслях экономики. Согласно данным за 2012–2017 гг., около 30% всех заболеваний зарегистрированы у медицинских работников. Нами выполнен поиск зарубежной и отечественной литературы по данной тематике в различных базах данных, таких как Scopus, Web of Science, MedLine, eLIBRARY.RU., CyberLeninka и РИНЦ. В ходе поиска особое внимание уделяли базе данных PubMed. Обобщая приведенные в литературных источниках современные научные данные об условиях труда и показателях здоровья медицинских работников, следует выделить несколько ключевых направлений, которые являются особенно актуальными. В первую очередь, стоит обратить внимание на вредные производственные факторы, которые приводят к высокой профессиональной заболеваемости. Второе направление, которое следует рассмотреть, — это образ жизни медицинских работников и распространенность неинфекционных заболеваний. Третье направление, которое стоит упомянуть, — это синдром профессионального выгорания и его последствия для здоровья и личности медицинских работников. Тема условий труда и здоровья работников здравоохранения является насущной и актуальной в научном мире. Проведенные исследования подтверждают, что работники здравоохранения сталкиваются с уникальными факторами, которые могут отрицательно сказываться на их здоровье и благополучии.

Ключевые слова: условия труда, здоровье работников здравоохранения, обзор, синдром профессионального выгорания

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One of the most important achievements of the 20th century, which marked the transition from the era of medicine to the era of healthcare, is recognition and identification of the main patterns of development of healthcare systems both in a broad public and professional and administrative contexts at all levels, from local to global. Today, the world medical community and the World Health Organization (WHO) share an understanding of health as the most important right of every person and nation. A medical doctor, or, more broadly, a healthcare professional, was and is the main guardian of health [1].

Unfortunately, the level of occupational morbidity in healthcare significantly exceeds that in other sectors of the economy.

According to the data collected from 2012 to 2017, about 30% of all the professional diseases diagnosed were registered in healthcare workers [2].

Papers on occupational medicine show that the situation in healthcare is the direst. According to the researchers, this is the activity where the labor is very or extremely stressful due to the high psychological burden, lack of social support, workplace violence and intimidation, general dissatisfaction with work, and low appreciation thereof by society [3–6].

Currently, because of the COVID-19 pandemic, the issue of safety and health of those involved in healthcare is particularly relevant. Healthcare workers face an even greater risk of contracting and transmitting an infection. The conditions of their labor are highly stressful, the resources are limited, and the protocols and recommendations change constantly. These factors create additional challenges for their physical and psychological well-being [7].

According to the 2022 Russian Federation Sanitary and Epidemiological Status Report, occupational morbidity in various sectors of the economy is generally decreasing. However, in healthcare and social services, this indicator is 2.7 times higher than it used to be, which is a significant increase [8].

Experts from the WHO and the International Labor Organization (ILO) consider psychosocial factors, stress, and mental exhaustion as the new forces peculiar to the working environment and process; some of the most serious problems posed before occupational medicine today stem from these forces, and this is equally relevant for both industrial and non-industrial settings. According to the WHO, depression caused by stress at work is currently becoming the main health problem and the leading cause of disability [9].

This study aimed to explore foreign and Russian scientific papers, and analyze studies investigating the problems of labor conditions and their impact on the health of healthcare professionals.

For this purpose, we searched the Scopus, Web of Science, MedLine, CyberLeninka, RSCI databases for Russian and foreign literature on the subject. Special attention was paid to data from the PubMed database, the largest repository of scientific publications on medicine and healthcare, and eLIBRARY.RU, a Russian information and analytical portal giving access to a scientific library with a wide range of publications. We have also analyzed the websites of scientific journals specializing in the topic of this work.

First, the keywords reflecting the essence of the study's subject were identified. For this purpose, we analyzed the existing literature on the topic, and used dictionaries of medical terms. The keywords were selected with the aim to cover all aspects of the topic. We entered them into the search fields of Scopus, Web of Science, MedLine, CyberLeninka, RSCI, and eLIBRARY.RU. In PubMed, the search relied on MeSH (Medical Subject Headers), a standardized system of medical terminology. The resulting lists of articles were carefully studied. First of all, we selected articles published in peer-reviewed scientific journals. The articles on the subjects other than that of this work were taken off the list. In addition, relevance of the research, methodological rigor, and data quality were considered. We analyzed the citation rate peculiar to the selected articles, and, in some cases, verified the accuracy of the information provided.

Problems of mental and physical health of healthcare professionals

One of the most difficult problems was the emotional (professional) burnout syndrome, the term for which was introduced into psychology by Herbert Friedenberg, an American psychiatrist, in 1974 [10].

Burnout syndrome is usually understood as a professional deformation of those who, in the context of their work, have to communicate closely with people (the so-called "helping" or "communicative" professions). The worker grows indifferent, emotionally exhausted, shows signs of dehumanization (negative attitude towards colleagues and clients), and ultimately develops a negative self-perception [11–16].

Currently, in many countries, alcoholism and substance abuse, deterioration of mental health are major problems among doctors. Interestingly, the situation is similar for veterinarians [17–20]. According to foreign experts, doctors should ensure that their colleagues who misconduct can be suspended from their professional activities. In addition, medical professionals are required to lead a healthy lifestyle or make efforts in this direction, and to report colleagues who continue abusing alcohol and drugs and violate discipline [21, 22].

Early retirement of doctors is a worldwide problem, and every effort is being made to prolong their active professional life [23, 24].

According to the experts, the best approach to the psychosocial problems of doctors should stem from the "better too early than too late" principle. Mandatory neuropsychiatric and neuropsychological assessment should help plan optimal treatment and start social and professional rehabilitation in a timely fashion. It is also important to improve the organization of work in medical institutions, and access to legal aid [25].

Dentists of all specializations suffer from similar physiological and ergonomic stresses. They are associated with work-induced prolonged static tension of the spine muscles, and the rotated shoulder joint. Such loads, resulting from the working posture, can lead to tonic tension of the occipital and trapezius muscles. However, there are also other factors that affect the physical condition of dentists. For example, frequent use of vibrating instruments can put additional strain on the hands and wrists, which can lead to the development of carpal tunnel syndrome. In addition, a static pose maintained for a long time can translate into back and neck pains as well as limited mobility thereof. All of these factors can ultimately trigger development of chronic diseases of spine and joints [26–29].

Among dentists, the highly prevalent conditions are hand neurodermatitis and disorders of the musculoskeletal system; researchers attribute them to overweight and lack of awareness of the occupational risks [30].

The COVID-19 outbreak had a huge impact on healthcare workers. Numerous studies confirm that the COVID-19 pandemic undermined their mental health. For example, a Chinese study that involved nearly 1,300 medical professionals found that 70% of them exhibited symptoms of anxiety and depression. Another study, conducted among healthcare workers in the United States, demonstrated that 40% of them suffered from the post-traumatic stress disorder (PTSD) [31].

In the Czech Republic, a study enrolled 500 medical professionals who provided care to COVID-19 patients; this work showed that they were more likely to be diagnosed with the burnout syndrome, and the severity of this syndrome was associated with the symptoms of post-traumatic stress [7].

In a study conducted at the University Hospital of Verona (Italy), 63.2% of the participants reported a traumatic experience related to COVID-19 that they had experienced at work. In 53.8% of them, symptoms of post-traumatic distress were registered. Moreover, over half of the participants (50.1%) also

exhibited symptoms of clinically significant anxiety, and 26.6% experienced at least moderate depression [32].

The professional duties of nurses are mainly associated with moderate physical activity. Compared to doctors and junior medical staff, there are significantly more nurses who do morning exercises, sports, and walk. In addition, they regularly (during the warmer months) do physical work at home, in the countryside. Work-related back pain is the most common and "expensive" musculoskeletal system disorder reported in nurses worldwide. For example, in 1990, 57% of Chinese nurses complained thereof. Bending, turning the body around the spine, lifting something heavy, movements performed with force and strain, such as when supporting and moving patients, are risk factors for lower back pain. Approximately 70% of back pain cases in nurses originated from moving patients in orthopaedics and intensive care units. Nurses who lift patients often are 7.5 times more likely to experience lower back pain than their colleagues who do it relatively infrequently [33, 34].

The risks faced by nurses are associated with respiratory disorders caused by exposure to chemicals and intensive smoking; disorders of the nervous system caused by the intensity of the work process, nutritional disorders, alcohol consumption and job satisfaction indicators; disorders of the cardiovascular system caused by the severity of the work process and indicators of medical activity [35].

According to a study, 89.60% of neonatology nurses experienced mild burnout, while for 10.40% the burnout was moderate. However, no neonatal nurses have been reported to have severe burnout. In addition, it was found that this condition is more often diagnosed in young nurses and those with poor technical skills. Poor interpersonal relationships, irregular meals, and insufficient rest were established to significantly affect the likelihood of burnout among nurses [36].

In China, most nurses face various forms of violence from patients and their relatives. About 75.4% of the study participants confirmed that they had such an experience. The most common forms were verbal abuse (65.2%), intentionally created obstacles (54.5%), defamatory rumors (37.5%), crowd behavior (34.9%), intimidation (18.8%), physical violence (14.6%) and sexual harassment (5.9%). This study also showed that 92.4% of the participants saw compassion from their colleagues (84.9%), supervisors (67.3%), and even patients (65.3%) [37].

A survey of dentists in New Zealand produced similar results: every fifth respondent admitted cases of violence, intimidation or insults at work [38–40].

In addition to emotional burnout, healthcare professionals of many specializations can be exposed to harmful factors of the working environment and process, including biological hazards, ionizing and non-ionizing radiation, hard labor, etc.; in some cases, these factors are difficult to identify and even more difficult to quantify [41, 42].

In Russia, this fact triggered development of special requirements (conduct specifics) for the assessment of working conditions of certain categories of medical workers, which is regulated by Federal Law No. 426-FZ of December 28, 2013 "On Special Assessment of Working Conditions" [43].

In particular, this applies to healthcare professionals who directly provide emergency medical care outside a medical institution, including during medical evacuation; medical workers stationed in spaces subject to the requirements stipulating the need to maintain a special microbiological environment and to ensure stable operation of medical equipment (intensive care units, operating rooms); medical workers using medical equipment to diagnose and treat, such medical equipment potentially malfunctioning in the presence of measuring instruments used during the special assessment of working conditions. In addition, there was drawn up a list of medical equipment (devices) the normal operation of which may be affected by measuring instruments used during the special assessment of working conditions [44].

The following harmful and (or) dangerous production factors are mandatorily studied and measured at the workplaces of medical workers who directly provide emergency medical care: chemical hazards, noise, vibration, microclimate parameters in the vehicle interior, biological hazards, severity and intensity of the labor process, and workplace injury potential.

Based on the assessment, the class (subclass) of working conditions previously considered potentially hazardous is moved up a step.

In addition, the work intensity class is moved a step up based on the assessment of the said intensity in case healthcare professionals render emergency medical assistance facing time constraints, lacking information about the patient's health status, and needing to make decisions on which the life and health of this patient depend in the future.

Chemical hazards, non-ionizing and ionizing radiation, biological hazards, and the severity and intensity of the labor process are subject to mandatory assessment and measurement at stations of medical workers located in rooms that are subject to special requirements [45–50].

The class of working conditions by intensity of the labor process also increases by one degree in case of performing operations in operating rooms using surgical (microsurgical) treatment methods, including during childbirth and the postpartum period, with manipulations aimed at saving the life of a patient in a life-threatening condition, and with management of vital functions of the patient's body in intensive care units [43].

Thus, currently in Russia, federal agencies have formulated and started solving the practical issues related to quantifying the impact of dangerous and harmful factors of the working environments and labor processes peculiar to certain healthcare specializations, and in many cases the priority is given to the assessment of intensity of the labor process, which, to a certain extent, is the root cause of the burnout syndrome.

Health of medical workers: key issues

Thus, summarizing the current research of working conditions and health indicators of healthcare professionals, it is necessary to identify several key areas that are particularly relevant. First, harmful aspects associated with professional activities as factors raising occupational morbidity. These may stem from contact with infectious agents or exposure to chemicals that are present in the medical environment. Tuberculosis and allergic reactions are among the most common diseases associated with such factors. Second, lifestyle of healthcare workers and the prevalence of non-communicable diseases. As in any other profession, medical workers may have problems related to poor nutrition, lack of physical activity, and stress. Irregular work schedules and high workload can negatively affect their overall health. Therefore, it is important to pay attention to the prevention of noncommunicable diseases such as cardiovascular diseases, diabetes, and obesity, and to promote a healthy lifestyle among healthcare professionals. Third, professional burnout, with the consequences thereof for the health and mental state of the medical professionals. Constant stress, demands for high productivity, and the need to make difficult decisions can lead to burnout and poor health.

CONCLUSION

The conducted studies of the peculiarities of working conditions and health of healthcare professionals confirm the relevance of this topic for the scientific community. The data obtained can be used in the development of effective strategies and programs in this area. In addition, there is undoubtedly a need for further research and new developments aimed at improving diagnostic capabilities, treatment and prevention of the related diseases. A deeper understanding of the factors affecting the health and well-being of healthcare workers will help create more favorable working conditions and improve the overall quality of medical care.

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INTEGRAL ASSESSMENT OF DRINKING WATER QUALITY IN RESIDENTIAL DISTRICTS OF RYAZAN

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The quality of drinking water is one of the key factors defining the health of the population. The risk-based approach is one of the most effective drinking water quality assessment and control tools. This study aimed to make a comparative integral assessment of the quality of drinking water from a centralized water supply system in residential areas of Ryazan based on chemical safety indicators. We have considered organoleptic, non-carcinogenic and carcinogenic risks, and compiled an integral assessment based on MR 2.1.4.0032-11. The drinking water quality monitoring data used for the assessment came from the Center for Hygiene and Epidemiology in the Ryazan Region, and covered years 2017 through 2022. Identifying the hazards, we relied on the above-norm spikes in drinking water quality indicator values registered during the specified period. The maximum figures used to calculate the organoleptic risks had 98% confidence interval, while that for the data enabling non-carcinogenic and carcinogenic risk assessments was 95% (nonthreshold models), the said data reflecting the average long-term concentrations. The uncertainties inherent in the risk assessment stem from the limited list of indicators controlled in drinking water. In all residential districts of the city of Ryazan, the integral indicator (II) of the level of hazard of drinking water from the centralized water supply system exceeds the acceptable values, with the said level being the highest in Solotcha (II = 8.8) and Kanishchevo (II = 5.6). In all districts of the city, the indicator is largely shaped by the high organoleptic risk, which points to the need for respective mitigation measures.

Keywords: risk, drinking water, centralized water supply, integral indicator, chemical safety

Author contribution: Dementiev AA — study concept, text editing; Gavrikova AA — data collection, processing of the results, text authoring; Solovyov DA — text editing; Tsurgan AM — processing of the results; Korshunova EP — collection and processing of primary material; Paramonova VA — statistical data processing.

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ИНТЕГРАЛЬНАЯ ОЦЕНКА КАЧЕСТВА ПИТЬЕВОЙ ВОДЫ В ЖИЛЫХ РАЙОНАХ Г. РЯЗАНИ

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Качество питьевой воды является одним из ключевых факторов, определяющих здоровье населения. Рискориентированный подход является одним из наиболее эффективных инструментов количественной оценки и управления качеством питьевой воды. Целью исследования было выполнить сравнительную интегральную оценку качества питьевой воды централизованной системы водоснабжения в жилых районах г. Рязани по показателям химической безвредности. Проведена сравнительная оценка органолептических, неканцерогенных и канцерогенных рисков, а также интегральная оценка питьевой воды централизованной системы водоснабжения в жилых районах г. Рязани по показателям химической безвредности на основании МР 2.1.4.0032-11. Для оценки рисков использовали данные мониторинга качества питьевой воды санитарно-химической лаборатории ФБУЗ «Центра гигиены и эпидемиологии в Рязанской области» за 2017–2022 гг. На стадии идентификации опасности в ходе исследования использовали показатели качества питьевой воды, полученные в течение указанного периода и когда-либо превышавшие гигиенические нормативы. Для расчета органолептических рисков использовали максимальные показатели 98%-й вероятностной обеспеченности, тогда как неканцерогенный и канцерогенный риски рассчитывали по средним многолетним концентрациям 95%-й вероятностной обеспеченности по беспороговым моделям. К неопределенностям оценки риска следует отнести ограниченный перечень показателей, контролируемых в питьевой воде. Во всех жилых районах города Рязани интегральный показатель (ИП) опасности питьевой воды централизованной системы водоснабжения превышает приемлемые значения, при этом наибольшей опасностью характеризуется питьевая вода в жилом районе Солотча (ИП = 8,8), а наименьшей — в районе Канищево (ИП = 5,6). При этом основной вклад в формирование ИП опасности питьевой воды во всех районах города вносит высокий органолептический риск, что свидетельствует о необходимости реализации мероприятий по его снижению.

Ключевые слова: риск, питьевая вода, централизованное водоснабжение, интегральный показатель, химическая безвредность

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The quality of drinking water is one of the key factors defining the health of the population. In the developing countries, deviations in its qualitative composition mainly underpin epidemiological health risks, whereas in industrially developed areas, it is chemical safety indicators that are most important from the hygienic viewpoint [1–3]. According to the available data, 87% of the population are provided with high-quality drinking water, and the key goals of the Clean Water Federal Project have been fully achieved only in three quarters of the territory of the Russian Federation [4]. The common flaws of drinking water in centralized water supply systems that draw upon surface and underground sources are excessive hardness, high levels of iron, boron, cadmium, and lead [5–9]. The quality quality of drinking water is affected not only by the sanitary, hygienic and hydrological features of the source, but also by the water treatment methods; for example, chlorination of water contaminated with phenols translates into formation of chlorophenolic compounds [3].

One of the most effective approaches to the drinking water quality evaluation and control is risk assessment: it allows ranking chemical threats by their impact on public health, and helps identify and prioritize scientifically sound measures aimed at reducing health risks to acceptable levels [5, 10, 11].

In a capital of a subject of the Federation, it is particularly interesting to compare, district-wise, the chemical safety of drinking water from the centralized water supply system that draws upon different sources; such a comparison will allow identifying priorities among the efforts aimed at improvement of the quality of drinking water within given residential areas.

This study aimed to make a comparative integral assessment of the quality of drinking water from a centralized water supply system in residential areas of Ryazan based on chemical safety indicators.

METHODS

The study was conducted on the territory of Ryazan, the administrative center of the Ryazan region. The population there, as of January 1, 2024, was 520.5 thousand people. The population of the regional center receives water from a central ring-type water supply system, which draws upon the Oka River (55–60%) and the artesian waters of the Podolsk, Oka and Kashira aquifers (40–45%). Sanitary protection zones have been established for all water supply sources. In all districts of the city, the water in the system is a mixture from surface and artesian sources, with the exception of Solotcha, which receives water from the artesian wells only.

For this study, we used water quality assessments made at monitoring points of the supply network during the period from 2017 to 2022. There is one such point in each district of the city, with the exception of Oktyabrsky, where there are two monitoring points. The samples are taken monthly, i.e., 12 times a year. In total, the study relied on the results of 3,440 drinking water quality analyses that involved 720 samples. MR 2.1.4.0032-11 was the guiding document for the comparative integral assessment of chemical safety of drinking water from a centralized water supply system of the city of Ryazan [12]. To identify hazards, we specifically monitored the water quality indicators the values of which were above the relevant hygiene standards in 2017–2022. The confidence interval for the maximum values used in the calculation of organoleptic risks was set at 98%. Non-carcinogenic and carcinogenic risks were calculated based on the average long-term concentrations expressed as values with 95% confidence interval (non-threshold models) [12, 13]. The uncertainties inherent in the risk assessment stem from the limited list of indicators controlled in drinking water in the context of sanitary and hygienic monitoring.

Primary data were processed using the one factor analysis of variance with the target significance level $p < 0.05$; the software employed for the purpose was STADIA 8.0 (Informatics and Computers LLC; Russia).

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RESULTS

In the considered districts of the city, the maximum values for drinking water smell and taste (98% CI) varied from 2.9–3.4 points, which is above the hygienic norm (Table 1). The color of the water, however, was within the standard range (20°).

The given data show that the turbidity values (at $p = 0.98$) were maximum in Solotcha and Stroitel districts, where they exceeded the hygienic norm by 2.1 and 1.8 times, respectively; in other districts, this indicator was within the hygienic norm and ranged from 1.7–2.5 mg/l. The maximum concentration of iron (2+) in the drinking water was the greatest in Solotcha: it exceeded the maximum permissible concentration (0.3 mg/l) by 7.6 times. In Zheleznodorozhny, Stroitel and Oktyabrsky, this indicator was 3.5–5.2 times higher than the maximum permissible concentration, while in the remaining districts it was 1.1–2.8 times higher. Single concentrations of aluminum in the drinking water in Dyagilevo, Moskovsky, Solotcha, and Stroitel districts were below detection threshold (bdt), while its maximum concentrations in the remaining districts did not exceed the maximum permissible concentration (0.2 mg/l).

The study showed that in all districts of the city, drinking water's smell (at 20 °C) and taste values, the organoleptic indicators, amounted to 0.5, which is five times higher than the acceptable value of 0.1 (Table 2). In the city, the organoleptic risk associated with iron (2+) content in the drinking water was 2 to 8 times higher than the acceptable values, with the exception of Moskovsky and Sovetsky districts. The highest value, 0.821, was registered in Solotcha. In Oktyabrsky and Stroitel districts, iron content was six times higher, in other districts — 2-3 times higher than acceptable. It should be noted that organoleptic risks of drinking water associated with aluminum ion content and turbidity were insignificant in all the districts considered. In the overall assessment, the organoleptic risk of drinking water in Solotcha, Oktyabrsky, and Stroitel stemmed from the content of divalent iron, whereas in the remaining districts the factors shaping this risk were smell and taste, which could have various origins (increased iron content, corrosion of metal pipes, formation of microbial films of iron bacteria on the inner walls of water pipes, formation of chlorinated hydrocarbons, stagnation of water, etc.) [14–20].

The average long-term concentrations (95% CI) of the main contaminants in drinking water from Ryazan's centralized

Table 1. Maximum values of indicators affecting the organoleptic properties of drinking water, residential districts of Ryazan ($S_{av.} + t\sigma$, at $p = 0.98$)

District	Smell (20 °C), points	Taste, points	Color, °	Turbidity, mg/l (by kaolin)	Fe^{2+}, mg/l	Al^{3+}, mg/l
Dashkovo-Pesochnya	3.4	3.4	11	2.5	0.7	0.2
Dyagilevo	2.9	2.9	11	1.7	0.8	bdt
Kanishchevo	3.3	3.4	10.8	1.7	0.8	0.2
Moskovsky	3.1	3.1	10.4	1.8	0.3	bdt
Oktyabrsky	3.3	3.3	11.1	1.9	1.6	0.1
Solotcha	2.9	2.9	16.6	5.3	2.3	bdt
Sovetsky	3.4	3.4	10.9	1.9	0.5	0.2
Stroitel	3.3	3.4	12.4	4.6	1.4	bdt
Zheleznodorozhny	3.3	3.4	11.9	1.8	1	0.2

Note: bdt — below detection threshold.

Table 2. Organoleptic risk (OR) of drinking water in residential districts of Ryazan

District	Smell (20 °C)	Taste	Color	Turbidity	Fe^{2+}	Al^{3+}	OR total
Dashkovo-Pesochnya	0.5	0.5	0.005	0.009	0.2	0.043	0.5
Dyagilevo	0.5	0.5	0.005	0.005	0.3	0	0.5
Kanishchevo	0.5	0.5	0.005	0.005	0.3	0.008	0.5
Moskovsky	0.5	0.5	0.004	0.005	0.03	0	0.5
Oktyabrsky	0.5	0.5	0.005	0.006	0.6	0.002	0.6
Solotcha	0.5	0.5	0.013	0.048	0.8	0	0.8
Sovetsky	0.5	0.5	0.005	0.006	0.1	0.028	0.5
Stroitel	0.5	0.5	0.006	0.032	0.6	0	0.6
Zheleznodorozhny	0.5	0.5	0.006	0.005	0.4	0.028	0.5

water supply system did not exceed the respective maximum permissible concentrations (Table 3). The total non-carcinogenic risk was below the threshold (0.05) in all the districts; it ranged between 0.013 (Moskovsky) and 0.021 (Stroitel).

Of the chemicals presented in Table 3, only cadmium (Cd) and lead (Pb), which belong to IARC carcinogenicity groups 1 and 2B, respectively, have carcinogenic effects [15]. The study showed that only in Dashkovo-Pesochnya did the carcinogenic risk of drinking water exceed the acceptable value (1×10^{5}) and amounted to 1.25E-05; in other districts, its values ranged between 3.19E-06 (Kanishchevo) and 6.09E-06 (Stroitel) (Table 4). It should be noted that the main contributor to the total carcinogenic risk of drinking water was cadmium: in Dashkovo-Pesochnya, it supported the said risk by 93.2% (the highest), and in the Sovetsky district — by 66.8% (the smallest).

The results of the integrated assessment of hazards in the drinking water from centralized water supply system in residential districts of Ryazan are given in (Table 5).

The study showed that in all residential districts of the city of Ryazan, the integral indicator (II) of the level of hazard of drinking water from the centralized water supply system exceeds the acceptable values, with the said level being the highest in Solotcha (II = 8.8) and Kanishchevo (II = 5.6). The greatest contribution to the II of hazard of drinking water is made by the organoleptic risk.

DISCUSSION

High maximum concentrations of iron in the drinking water in Solotcha, Stroitel, and Oktyabrsky create unacceptable organoleptic risks (0.6–0.8); they may stem from a higher proportion of artesian waters (Podolsk and Kasimov aquifers) in the supplied mixture, since this element is common therein [21, 22]. The content of iron in drinking water is known to grow with the time the water spends in the supply system due to pipe corrosion. The process also increases color and turbidity indicators, and the water acquires characteristic metallic taste. The organoleptic properties of water can also deteriorate due to the proliferation of iron bacteria inside water pipes [9, 14–17, 23]. Drinking water with a high iron content increases the risk of skin and subcutaneous fat diseases in children and adolescents [11]. Other studies have shown that elevated concentrations

Table 3. Long-term average concentrations (95% CI) of contaminants in drinking water in residential districts of Ryazan ($S_{av.} + t_m$, at $p = 0.95$)

District	Boron (MPC = 0.5 mg/l)	Cadmium (MPC = 0.001 mg/l)	Nickel (MPC = 0.02 mg/l)	Lead (MPC = 0.01 mg/l)
Dashkovo-Pesochnya	0.133	0.0007	0.011	0.0024
Dyagilevo	0.108	0.0002	0.005	0.0038
Kanishchevo	0.1	0.0001	0.008	0.0024
Moskovsky	0.095	0.0002	0.005	0.0029
Oktyabrsky	0.102	0.0002	0.008	0.0018
Solotcha	0.091	0.0002	0.012	0.0034
Sovetsky	0.128	0.0002	0.009	0.0037
Stroitel	0.259	0.0003	0.005	0.0047
Zheleznodorozhny	0.106	0.0003	0.008	0.0036

Table 4. Individual carcinogenic risk (CR) of drinking water in residential districts of Ryazan

District	Cadmium	Lead	CR total
Dashkovo-Pesochnya	1.16E-05	8.54E-07	1.25E-05
Dyagilevo	3.23E-06	1.38E-06	4.60E-06
Kanishchevo	2.30E-06	8.90E-07	3.19E-06
Moskovsky	3.24E-06	1.08E-06	4.31E-06
Oktyabrsky	3.84E-06	6.70E-07	4.50E-06
Solotcha	2.78E-06	1.25E-06	4.03E-06
Sovetsky	2.74E-06	1.36E-06	4.10E-06
Stroitel	4.39E-06	1.70E-06	6.09E-06
Zheleznodorozhny	4.71E-06	1.30E-06	6.01E-06

Table 5. Integral indicator (II) of hazards in the drinking water, districts of Ryazan

District	RO/PV_o	RN/PV_n	RC/PB_c	II
Dashkovo-Pesochnya	5	0.4	1.2	6.6
Dyagilevo	5	0.3	0.5	5.8
Kanishchevo	5	0.3	0.3	5.6
Moskovsky	5	0.3	0.4	5.7
Oktyabrsky	6	0.3	0.5	6.8
Solotcha	8	0.4	0.4	8.8
Sovetsky	5	0.4	0.4	5.8
Stroitel	6	0.4	0.6	7
Zheleznodorozhny	5	0.3	0.6	5.9

Note: RO is the total risk of reflex-olfactory effects, RN is the total non-carcinogenic risk; RC is the total carcinogenic risk; PV_o is the acceptable risk of reflex-olfactory effects; PV_n is the acceptable value of non-carcinogenic risk; PV_c is the acceptable value of carcinogenic risk.

of iron in drinking water can have an adverse effect on the hematopoietic and immune systems [14, 15].

The identified high organoleptic risks of drinking water associated with the maximum values of smell and taste indicators may also be due to the formation of organochlorine compounds as a result of chlorination, which calls for preference of combined methods of disinfection [18–20]. However, the existing uncertainty stemming from the limited character of the list of substances the content f which in drinking water is controlled prevents us from confirming or disproving the above-mentioned reason in this study.

The individual carcinogenic risk above the acceptable threshold was registered in Kanishchevo only, and the reason behind this spike by 93.2% were cadmium ions, which may be related to anthropogenic pollution of the Oka River [24, 25]. The results of this study are generally consistent with the data reported by other authors, who underscore the unacceptable level of carcinogenic risk caused by the drinking water in Ryazan having lead and cadmium [26, 27].

CONCLUSIONS

The study showed that the total organoleptic risk of drinking water from the centralized water supply system of Ryazan was 5–8 times higher than acceptable in the Solotcha, Oktyabrsky, and Stroitel districts, the said risk created by the high content of divalent iron, while in other districts, the reasons behind the organoleptic risk were smell and taste.

The total non-carcinogenic risk did not exceed the acceptable values (0.05) in all the considered districts of the city; it ranged between 0.013 (Moskovsky) and 0.021 (Stroitel).

As for the carcinogenic risk, it was above the acceptable value (1×10^{5}) in Dashkovo-Pesochnya only, where this risk amounted to 1.25E-05. Throughout the city, carcinogenicity of drinking water stemmed from the content of cadmium.

In all residential districts of Ryazan, the integral indicator of the hazard of drinking water from the centralized water supply system exceeded acceptable values, mainly due to the high organoleptic risk, which necessitates development and implementation of preventive measures aimed at reducing it.

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HYGIENIC EDUCATION OF YOUNGER SCHOOLCHILDREN USING A RATIONAL NUTRITION SKILLS DEVELOPMENT PROGRAM

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Protection of health of children is the most important task before the country; preservation and strengthening of health of schoolchildren necessitates introduction of scientifically sound technologies and new methods of hygienic education. This study aimed to evaluate the effectiveness of the developed original educational program for primary schoolchildren designed to give them knowledge about rational nutrition and healthy lifestyle. From 2019 to 2020, we tested the rational nutrition and healthy lifestyle skills development program that relies on the Children and Adolescents Individual Diet Calculation and Hygienic Assessment Module. The study involved 336 schoolchildren (176 schoolchildren in the treatment group, 160 in the control group) from 4 classes of three educational institutions in Smolensk. The analysis of effectiveness of preventive measures showed that the proportion of children whose daily diet included vegetables and fruits has grown 1.5 times, and the consumption of fast food products and sugary carbonated drinks has dropped 4 and 2.5 times, respectively. Control group, where no preventive measures were implemented, exhibited no positive trends. The effectiveness of the program was confirmed by a significant decrease in the share of overweight primary schoolchildren: from 17.6% to 9.3% ($\chi^2 = 5.239$, $p = 0.023$). The results of this study allow recommending the developed nutrition and healthy lifestyle skills development program as an effective hygienic education technology for primary schoolchildren.

Keywords: primary schoolchildren, rational nutrition, educational program, information technology

Author contribution: the authors have made equal contributions to this publication.

Compliance with ethical standards: the study was approved by the Ethics Committee of the Smolensk State Medical University (protocol No. 1 of October 24, 2017). Each participant signed a voluntary informed consent form. The study conformed to the principles of biomedical ethics and did not endanger the participants.

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ГИГИЕНИЧЕСКОЕ ВОСПИТАНИЕ МЛАДШИХ ШКОЛЬНИКОВ С ИСПОЛЬЗОВАНИЕМ ПРОГРАММЫ ПО ФОРМИРОВАНИЮ НАВЫКОВ РАЦИОНАЛЬНОГО ПИТАНИЯ

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Охрана здоровья детского населения остается важнейшей государственной задачей. Сохранение и укрепление здоровья учащихся диктуют необходимость внедрения научно-обоснованных технологий и новых методов гигиенического воспитания. Целью работы было оценить эффективность разработанной оригинальной образовательной программы по гигиеническому воспитанию младших школьников в вопросах рационального питания и здорового образа жизни. С 2019 по 2020 г. в динамике апробировали программу по формированию навыков рационального питания и здорового образа жизни с применением информационной технологии «Модуль расчета и гигиенической оценки индивидуального рациона питания детей и подростков». В исследовании приняли участие 336 школьников (176 школьников — основная группа, 160 школьников — группа сравнения) 4-х классов трех общеобразовательных учреждений г. Смоленска. Анализ эффективности проводимых профилактических мероприятий показал, что в 1,5 раза увеличилась доля детей, в ежедневный рацион которых входили овощи и фрукты. В 4 и 2,5 раза соответственно снизилось потребление продукции «фаст-фуда» и сладких газированных напитков. В группе школьников, где не проводили профилактические мероприятия, положительная динамика не наблюдалась. Подтверждением эффективности программы стало значимое снижение доли младших школьников с избыточной массой тела с 17,6% до 9,3% ($\chi^2 = 5,239$, $p = 0,023$). Полученные результаты позволяют рекомендовать разработанную нами программу по формированию навыков рационального питания и здорового образа жизни как эффективную технологию гигиенического воспитания младших школьников.

Ключевые слова: младшие школьники, рациональное питание, образовательная программа, информационная технология

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The most important guideline for modern healthcare and education is to strengthen the health of the nation and protect that of children. Decree of the President of the Russian Federation No. 204 of May 7, 2018 sets a specific task: develop a system motivating citizens to lead a healthy lifestyle, including in the aspects of nutrition and physical culture [1]. Implementation of the state projects aimed at strengthening public health is inextricably linked with hygienic education and introduction of innovative health-saving programs [2, 3].

Nutrition, with its age-dependent specifics, is a key factor influencing growth and development of a child's body [4]. Nutrition's quantitative and qualitative attributes shape the processes of the organism's physical development and functioning, and determine its adaptive resistance to adverse environmental factors [5, 6].

Increasing the awareness of all social strata, including children, about fundamental, scientifically proven nutrition-related knowledge is an effective way to strengthen public health

[7–9]. Children and adolescents are the most promising target audience, since childhood is the period when fundamental information is learned, and stereotypes that most often persist throughout life are formed [10].

Health-saving programs are effective in prevention of many social problems and remedying drawbacks of the public health protection system [11, 12]. The World Health Organization (WHO) and other international institutes are actively working on the development and implementation of health protection and promotion programs in educational establishments [13, 14].

Deployment of educational programs aimed at development of rational nutrition and healthy lifestyle skills in schools can expand children's knowledge in this area, which makes schools a viable platform for such programs [15, 16].

The purpose of this study was to evaluate the effectiveness of the original educational program for primary schoolchildren designed to give them hygienic knowledge and promote their motivation to adopt rational nutritional patterns and lead a healthy lifestyle.

METHODS

The study was conducted in 2019–2020. Schoolchildren from three secondary schools in Smolensk (Secondary School No. 8, Secondary School No. 26, Secondary School No. 35) were involved in the evaluation of the effectiveness of the original educational program aimed at development of rational nutrition and healthy lifestyle skills. The participants (n = 336, studying in the fourth grade) were divided into two groups, 176 schoolchildren in the treatment group, where preventive measures were implemented, and 160 schoolchildren in the control group, where no such measures were deployed. Inclusion criteria: 4th grade (ages 9.5–10.5 years); voluntary consent to participate in the study; informed consent form signed by parents (legal representatives) allowing to collect and process the survey data the children participate in. Exclusion criteria: different age category; status other than schoolchild; lack of the signed informed consent form; severe hereditary and congenital diseases affecting nutritional status (4th and 5th health status groups).

To establish the degree of maturity of the rational nutrition skills and the level of awareness of the schoolchildren about the key components of healthy lifestyle, we surveyed the participants using the specially developed questionnaire. It included 10 questions seeking to uncover the features of the diet, eating behavior, and lifestyle (habitual level of physical activity, daily routine). The participants were surveyed twice: once before the implementation of the preventive program and again six months afterward. The effectiveness of the preventive measures was assessed by examining the change in the proportion of overweight schoolchildren, an indicator that was monitored before and 12 months after the start of the program.

We used MyOffice package (New Cloud Technologies; Russia) for statistical analysis of the data collected. In the context of sample comparison, the chi-squared (χ^2) test and the Fisher's exact test were used. The differences were considered significant at $p < 0.05$.

RESULTS

In 2017–2019, pilot of the School Medicine federal project by the Russian Ministry of Health was conducted in the Smolensk Region. In the context of this project, specialists from the General Hygiene Department of Smolensk State Medical University studied the prevalence of overweight and obesity among primary schoolchildren of Smolensk, and established these conditions in a significant proportion (25.3%) of the said children [17]. The excessive nutrition risk factors were identified in in-school and daily life routines; they were used as the basis for the original educational program aimed at development of the rational nutrition and healthy lifestyle skills.

The aim of the program is to make primary schoolchildren highly motivated to practice healthy eating and healthy lifestyle. Its key objectives were to teach schoolchildren the basics of nutrition; to give them proper nutrition patterns; to motivate them to be more physically active, and to do sports; and to involve parents of schoolchildren, their teachers, educators, and school psychologists in the process of development of healthy lifestyle skills in this population.

The preventive program had three directions: organizational and methodological, educational, and scientific. The organizational and methodological direction involved development of methodological recommendations, manuals, and reference materials for schoolchildren and their parents, teachers, school psychologists, and medical and preventive specialists, with the respective materials factoring in the specifics of the target audience.

Educational activities utilized modern tools in hygiene education and information technology. The latter took form of the Children and Adolescents Individual Diet Calculation and Hygienic Assessment Module, a specially developed computer program (Computer Program State Registration Certificate No. 2020616752 of 22.06.2020; hereinafter referred to as the Module).

The scientific direction implied a complex of actions designed to provide scientific support to the preventive measures and to enable assessment of their effectiveness.

Methodologically, the rational nutrition and healthy lifestyle skills development program consisted of five lessons of 40 minutes each. Each lesson included informational and practical parts. During the former, schoolchildren were given the rules of healthy eating and explained the importance of the main components of food in plain terms. One lesson was dedicated to educating the children about the importance of regular physical activity, the need to keep it at the optimal level, and the process of drawing up a rational daily routine. There was also a lesson for the parents, where they learned new information about organization of rational nutrition for their children, and ways to encourage adoption of a healthy lifestyle. During the practical part of the lessons, schoolchildren absorbed the given theoretical knowledge in the context of games. The Module, used by children and their families, was also a component of the practical part.

The module allows calculating the energy value (caloric content) of food in the diet; determine the individual daily need for basic nutrients and energy depending on age and gender; build an optimal diet for the child that factors in modern hygienic requirements and standards. The module includes a reference block of theoretical material for children and parents, providing comprehensive information on compiling healthy diets based on current Russian hygiene requirements and WHO recommendations (Fig. 1).

In the context of the integrated approach, the lessons were co-hosted by child and adolescent hygiene specialists, pediatricians, teachers, and school psychologists. Fig. 2 provides th details of the educational program.

To analyze the effectiveness of our comprehensive approach to hygienic education based on the original educational program designed to develop rational nutrition and healthy lifestyle skills in primary schoolchildren, we evaluated the results of the survey these children took.

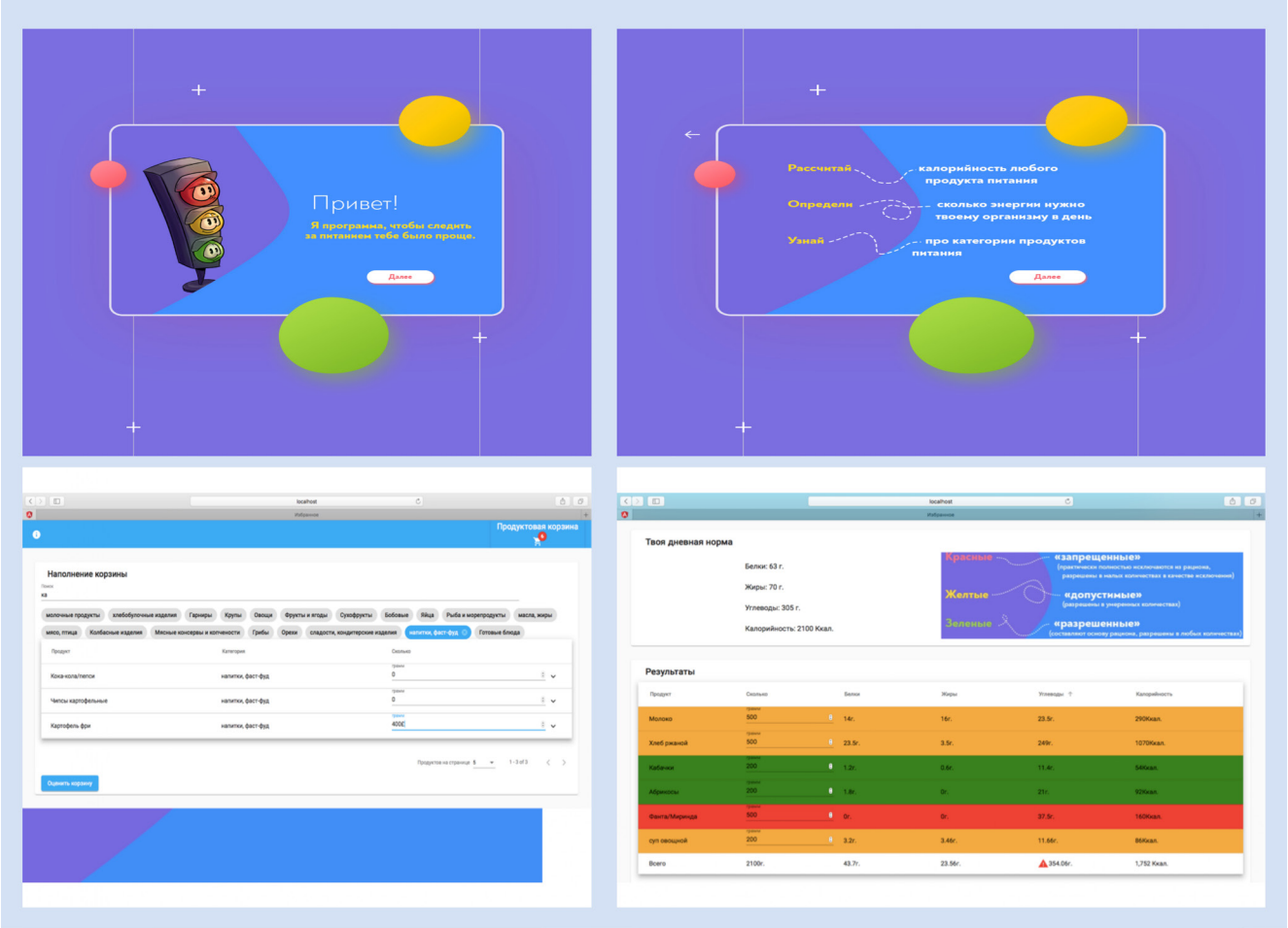

Fig. 1. Interface of the Children and Adolescents Individual Diet Calculation and Hygienic Assessment Module

The following notions were introduced for the comparative analysis:

– treatment group (n = 176): TG — schoolchildren of the treatment group during the initial diagnosing; TG^+ — schoolchildren of the treatment group during diagnosing 6 months after the start of the preventive program;

– control group (n = 160): CG — schoolchildren of the control group during the initial diagnosing; CG^+ — schoolchildren of the control group during diagnosing after 6 months.

A comparative analysis of the survey results showed a significant positive trend in indicators reflecting the development of rational nutrition skills and certain elements of a healthy lifestyle (Fig. 3–4).

For example, the program increased the share of children who have breakfast every day from 71.6% to 90.3% (φ^*_{emp} = 4.62; $p < 0.01$). There were significantly more schoolchildren with positive nutritional changes in the treatment group (TG^+) than in the control group (CG^+): 90.3% and 70.6%, respectively ($p < 0.01$).

The share of schoolchildren in the treatment group who often snack right before bedtime decreased 1.8 times, from 19.3% to 10.8% (φ^*_{emp} = 2.26; $p < 0.05$). Participants from the treatment group (TG^+) consumed food significantly less often before bedtime than their peers from the control group (CG^+): 10.8% and 26.9%, respectively ($p < 0.01$).

As for the nutritional preferences and foods eaten, the results were as follows: in the treatment group, the number of schoolchildren consuming (daily) food that includes vegetables and fruits increased from 46.6% to 70.5% (φ^*_{emp} = 4.59; $p < 0.01$); in the control group, there was no significant effect registered. Second diagnosing confirmed that the share of treatment group schoolchildren (TG^+) who regularly consume vegetables and fruits (70.5%) was significantly higher than that seen in the control group (CG^+), where the figure was 45% ($p < 0.01$).

In treatment group, the habitual consumption of fast food products decreased from 4.5 to 1.1% (φ^*_{emp} = 1.68, $p < 0.05$), and sugary carbonated drinks — from 14.7 to 5.7% (φ^*_{emp} = 2.89; $p < 0.01$). Comparing these indicators, we established that in the treatment group, there were significantly fewer schoolchildren prone to eating fast food and consuming sugary drinks than in the control group.

As for the daily routine and lifestyle, the following significant changes were registered in the treatment group: the share of schoolchildren actively spending leisure time outdoors increased 63.1 to 77.8% (φ^*_{emp} = 3.06; $p < 0.01$); the share of children doing sports increased from 35.8 to 52.3% (φ^*_{emp} = 3.13; $p < 0.01$). A comparative analysis of the data collected in two groups at the stage TG^+ and GC^+ stage showed that the proportion of schoolchildren who regularly engage energetic leisure activities outdoors and do sports is significantly higher in the treatment group.

Before deployment of the preventive program, 37.5% of schoolchildren in the treatment group noted that it was most difficult for them to give up playing games on a computer (tablet, smartphone); after the deployment, this figure went down to 27.3% (φ^*_{emp} 2.06; $p < 0.05$). A comparison of the data at the TG^+ and CG^+ stage has shown that there are significantly fewer treatment group participants affected by this than in the control group: 27.3% vs. 41.3%, respectively (φ^*_{emp} = 2.71; $p < 0.01$).

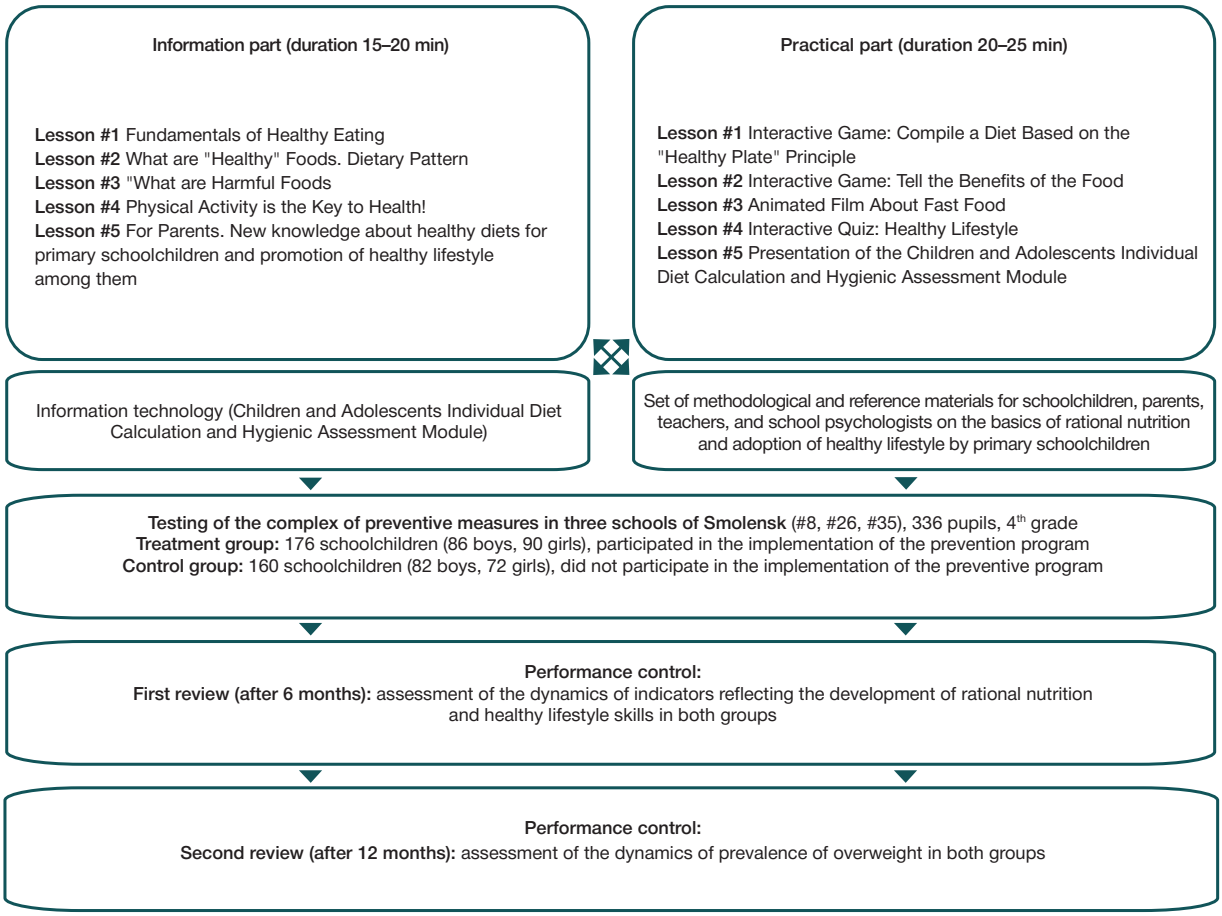

Fig. 2. The algorithm of the rational nutrition and healthy lifestyle skills development program

The effectiveness of the program and the included preventive measures designed to develop rational nutrition and healthy lifestyle skills in schoolchildren was confirmed by significant changes registered through the study. Specifically, in the treatment group, the participants from which stayed in the program for 12 months, the proportion of overweight children decreased from 17.6 to 9.6%, which is a statistically significant result ($\chi^2 = 5.239$, $p = 0.023$). In the control group, which was not in the program, the respective proportion changed in the opposite direction during the same period of time: from 16.9 to 19% ($p > 0.05$).

These data confirm that the implemented program of preventive measures has had a positive impact on the health of primary schoolchildren. The program employed various methods of hygienic education that helped form a conscious attitude to diet and lifestyle in the children. Participating in the respective events, they not only learned new information about healthy nutrition, but also changed their eating habits. Such changes were positive for preservation and strengthening of the children's health, and mitigated the risks of overweight and obesity.

The experience of deploying the original rational nutrition and healthy lifestyle skills development program for primary schoolchildren has found application in practical healthcare. The materials resulting from the study are used in the work of the Children's Health Center of the Smolensk Children's Clinical Hospital and the Smolensk Regional Children's Clinical Hospital.

DISCUSSION

Despite the measures taken in our country to strengthen the health of the child population, the trend reflecting the status of somatic and mental health of schoolchildren is downward [18].

The environment of school is natural for children and adolescents. It is a place where they spend a significant portion of their time, so the matter of adoption of a healthy lifestyle should be part of the educational process. The specific traits of schoolchildren, however, add complexity to the respective efforts, since they may not see elementary hygiene skills that are appropriate for their age as a natural part of life, including maintenance of the proper daily routine with balanced work and rest, alternating of mental and physical activity, practicing regular and rational nutrition, receiving adequate sleep, getting age-appropriate physical activity, doing adequate outdoor activities, and using gadgets rationally [19–21].

In recent years, there has been published an increasing number of works describing various methodological approaches and technologies of hygienic education for schoolchildren. These reports note that successful development of healthy lifestyle skills in children and adolescents is a long process that involves consistent exposure to health-preserving programs and technologies [15, 22]. One example of a non-standard approach to hygienic education of this population relies on habit trackers and checklists [23].

The testing of the the original educational program and information technology developed by us, the Children and Adolescents Individual Diet Calculation and Hygienic Assessment Module, has shown its high efficiency in the formation of rational nutrition skills and adoption of basic elements of a healthy lifestyle among primary schoolchildren. An integrated approach to hygiene education based on the analysis of the key excessive eating risk factors in this population helped reduce the likelihood of development of overweight and obesity.

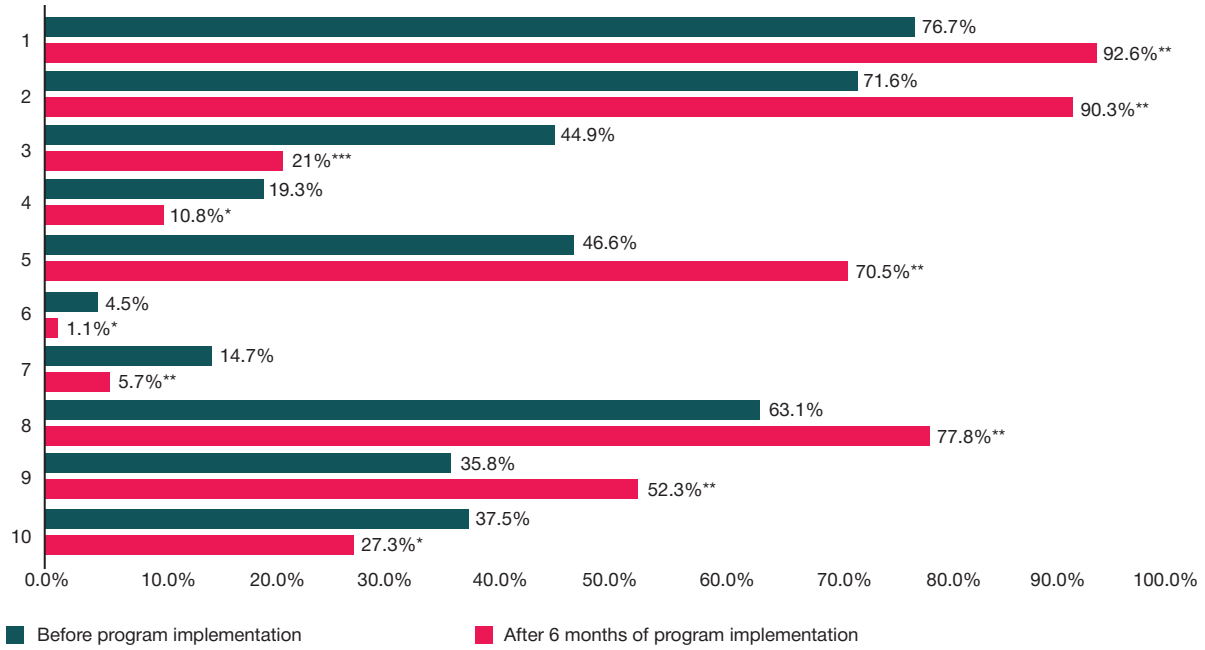

Fig. 3. Indicators of the treatment group schoolchildren
Note: 1 — the share of schoolchildren eating regular meals; **2** — the share of schoolchildren regularly having breakfast at home; **3** — the share of schoolchildren regularly snacking between meals; **4** — the share of schoolchildren regularly snacking before bedtime; **5** — the share of schoolchildren regularly adding fresh vegetables and fruits to their diet; **6** — the share of schoolchildren regularly consuming fast food products; **7** — the share of schoolchildren regularly consuming sugary carbonated drinks; **8** — the share of schoolchildren practicing energetic leisurely activities outdoors every day; **9** — the share of schoolchildren doing extracurricular sports; **10** — the share of schoolchildren preferring to spend their free time using a computer/tablet. The significance of the differences between the groups (Fisher z-transformation): * — $p < 0.05$; ** — $p < 0.01$; *** — $p < 0.001$.

CONCLUSIONS

The positive results of the study that involved deployment of the original nutrition and healthy lifestyle skills development program allow recommending it for inclusion in the hygienic education curricula for primary schoolchildren. The developed program was proven to be highly effective, and can be considered as an element of primary prevention in relation to the correction of the nutritional status of primary schoolchildren.

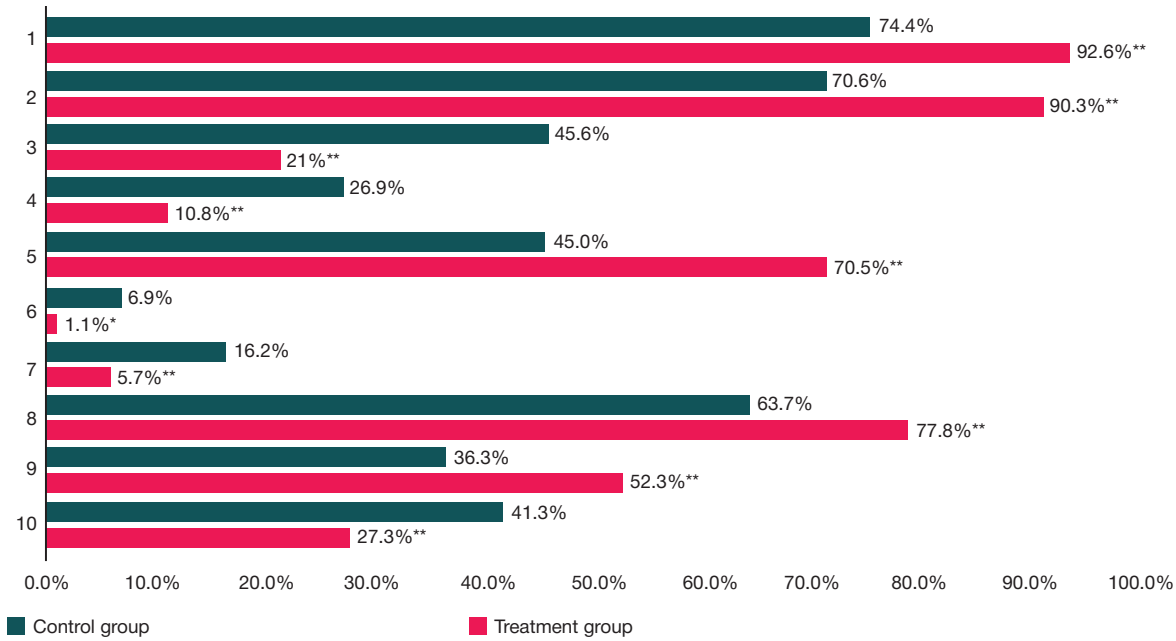

Fig. 4. Indicators of schoolchildren from the treatment group and the control group
Note: 1 — the share of schoolchildren eating regular meals; **2** — the share of schoolchildren regularly having breakfast at home; **3** — the share of schoolchildren regularly snacking between meals; **4** — the share of schoolchildren regularly snacking before bedtime; **5** — the share of schoolchildren regularly adding fresh vegetables and fruits to their diet; **6** — the share of schoolchildren regularly consuming fast food products; **7** — the share of schoolchildren regularly consuming sugary carbonated drinks; **8** — the share of schoolchildren practicing energetic leisurely activities outdoors every day; **9** — the share of schoolchildren doing extracurricular sports; **10** — the share of schoolchildren preferring to spend their free time using a computer/tablet. The significance of the differences between the groups (Fisher z-transformation): * — $p < 0.05$; ** — $p < 0.01$; *** — $p < 0.001$.

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SPECIFICS OF THE DYNAMICS OF OVERWEIGHT AND CONCOMITANT CHRONIC DISEASES IN VORONEZH OBLAST

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Overweight and obesity are some of the global problems faced by the civilization characterized by the growing prevalence and the development of concomitant diseases. This study aimed to assess the mid- and long-term incidence and dynamics of these disorders in various age groups of the population of Voronezh Oblast, including the mentioned concomitant chronic diseases, and to compare the learned data to the mean figures registered in the Central Federal District (CFD) of the Russian Federation and the country in general. From 2016 to 2020, in Voronezh Oblast, the values of the indicators reflecting the prevalence of overweight were profoundly influenced by the regional specifics; in all the age groups, these values were significantly higher than the mean figures recorded in the Central Federal District and Russia on the whole ($p < 0.05$). As for the concomitant diseases, the incidence of the disorders of endocrine system, mental and behavioral disorders, urolithiasis was high, showing an upward trend, whereas in the country in general and CFD in particular, the respective indicators tend to decrease. The results of this study indicate the need for further exploration of this subject, including investigation of the potential risk factors defining the specifics of the prevalence in the region in question, some of which are the features of the nutritional patterns, the content of vitamins and minerals in the general diet in particular, and factors not connected to nutrition, such as chemical composition of water and features of the soil.

Keywords: obesity, overweight, general morbidity, risk factors

Author contribution: Novikova II — statement of the goal and th tasks, analysis of the data obtained, manuscript authoring, article editing, literature review; Lobkis MA — analysis of literature, analysis of the data obtained; Mingazov IF — statistical processing, analysis of the data obtained; Sorokina AV — analysis of literature, analysis of the data obtained; Popov VI — editing and approval of the final version of the manuscript.

Compliance with ethical standards: the study was approved by the Ethics Committee of the Novosibirsk Research Institute of Hygiene of Rospotrebnadzor (Minutes #2 of April 21, 2022).

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ОСОБЕННОСТИ ДИНАМИКИ ЗАБОЛЕВАЕМОСТИ ОЖИРЕНИЕМ И СОПУТСТВУЮЩИМИ ХРОНИЧЕСКИМИ ЗАБОЛЕВАНИЯМИ СРЕДИ НАСЕЛЕНИЯ ВОРОНЕЖСКОЙ ОБЛАСТИ

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Проблема избыточной массы тела и ожирения — одна из глобальных проблем цивилизации, которая характеризуется как прогрессирующим ростом этой формы патологии, так и развитием хронических заболеваний, сопутствующих ожирению. Целью исследования было оценить среднемноголетние уровни и динамику показателей заболеваемости в различных возрастных группах населения Воронежской области, в том числе заболеваемости ожирением и обусловленными им хроническими заболеваниями в сравнении со средними показателями по Центральному федеральному округу (ЦФО) и Российской Федерации (РФ) в целом. В Воронежской области регистрируемые показатели распространенности ожирения в период с 2016 по 2020 г. имели ярко выраженные региональные особенности и были существенно выше по сравнению со средними показателями по РФ и ЦФО ($p < 0,05$) во всех возрастных группах. Зарегистрированы более высокие показатели заболеваемости для заболеваний эндокринной системы, психических расстройств и расстройств поведения, мочекаменной болезни, демонстрирующие направленность к росту при общей тенденции к снижению в целом по РФ и ЦФО. Полученные результаты свидетельствуют о необходимости продолжить исследование и детально изучить потенциальные факторы риска, определяющие специфику заболеваемости на этой территории, к которым относятся характер питания, в частности особенности витаминно-минерального состава пищевых продуктов основной группы потребления, а также факторы, не связанные с особенностями питания, такие как химический состав воды, особенности состава почвы.

Ключевые слова: ожирение, избыточная масса тела, общая заболеваемость, факторы риска

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The problem of overweight and obesity is one of the global problems of civilization [1]. Its prevalence on the scale of entire populations stems primarily from unhealthy eating behavior, characterized by increased consumption of high-calorie foods and dishes with excessive sugar content [2, 3]. Insufficient physical activity also aggravates the risk of overweight, as well as type 2 diabetes mellitus, cardiovascular disease, and other conditions caused by obesity [4]. The list of general significant risk factors includes eating disorders (overeating and night eating syndrome), sleep deficiency, and hypodynamia [5]. Thus,

those who sleep for less than 8 hours are 3.1 times more likely to be overweight than those who sleep for at least 10 hours [6]. There are also specific risk factors, which basically determine regional features of overweight; being primarily of chemical nature, they slow down metabolic processes [7].

Adipose tissue, as a metabolically active endocrine organ, influences immunity, glucose levels, lipid metabolism, angiogenesis, and metabolic rate. Against the backdrop of obesity and overweight, the body increases the production of pro-inflammatory and atherogenic cytokines, experiences oxidative stress, and faces heightened risks of insulin resistance, dyslipidemia, hypertension, and orthopedic issues [8].

Recent studies indicate that overweight and obesity are risk factors for cardiovascular diseases, with their prevalence continuing to rise [9–13] not only among adults but also among children [14]. The pattern of distribution of adipose tissue in the body is considered one of the key drivers behind cardiovascular pathologies in obese individuals; it particular, the respective conditions are associated with the predominance of visceral fat [15, 16]. There are about 230 complications that obesity contributes to. In addition to the mentioned cardiovascular system disorders, the list includes type 2 diabetes mellitus, diseases such as dyslipidemia, obstructive sleep apnea syndrome, chronic kidney disease, non-alcoholic fatty liver disease, and some cancers [17, 18]. There is evidence that obesity promotes the development of polycystic ovary syndrome [19], and reports describing cases of otorhinolaryngological diseases [20] and inflammatory bowel conditions [21] in obese individuals. Many patients with obesity are more prone to developing respiratory diseases [22]. Studies point to a link between obesity and certain cognitive impairments due to the development of cerebrovascular pathology, which is one of the most common disorder of the nervous system. Thus, published research positions obesity as a global problem, describing it as both a progressing pathology and a risk factor for concomitant diseases that significantly reduce the quality and duration of life. The urgency of this problem substantiated conducting a study within the framework of the Demography national project [23].

This study aimed to assess the mid- and long-term incidence and dynamics of obesity and the diseases associated therewith in various age groups of the population of Voronezh Oblast, and to compare the collected data to the mean figures registered in the Central Federal District (CFD) of the Russian Federation (RF) and the country in general.

METHODS

We analyzed the official statistical data of the Ministry of Health of the Russian Federation (report form #12 "Information on the number of diseases reported in patients living in the service area of the medical organization" and the national statistical books on the general morbidity of children (0–14 years old), adolescents (15–17 years old) and adults (18 years and older)). The analysis covered different age groups; the data described years 2011 through 2020.

We used parametric and nonparametric statistical methods to process the results in MyOffice Standard 3 package (New Cloud Technologies; Russia). The tests employed to check the normality of the distribution and the equality of variances were the Shapiro-Wilk test and Levene's test, respectively. Since the parameters studied exhibited normal distribution, we used parametric methods. The Student's *t*-test enabled the comparison of numerical data between two independent groups. The differences were considered significant for $p < 0.05$.

RESULTS

The analysis of obesity prevalence in the Voronezh region during the past decade has revealed an upward trend across all considered age groups, including children (0–14 years old), adolescents (15–17 years old), and adults (18 years and older). From 2016 to 2020, the incidence rates recorded there exhibited pronounced specific features characteristic of the region, and were significantly higher than the average for the RF and the CFD ($p < 0.05$) (Fig. 1).

From 2011 to 2020, the incidence of obesity among children (0–14 years old) in the Voronezh Region was significantly higher than in the RF, with the mean being 35.8% (from 23.7 to 48.7%) ($p < 0.05$). Compared to the CFD, the figures for the Voronezh Region were higher by 35.0% on average (from 8.1 to 61.5%), which is significant ($p < 0.05$) (Fig. 1A). Compared to the RF, the incidence of obesity was significantly higher ($p < 0.05$) than the country mean among adolescents (15–17 years old) and adults (18 years old and older), too. Specifically, the figures for adolescents were, on average, 54.4% (from 31.2 to 80.8%) greater than country means, and 51.7% (from 12.3 to 71.3%) greater than the means registered in the CFD (Fig. 1B). As for adults, the average values were higher than in the RF by 26.1%, and significant differences were recorded from 2016 on, ranging from 34.3 to 61.9%. Compared to the CFD, with the prevalence dynamics stable, the considered indicator within the studied period was 90.5% higher in the Voronezh Region, and since 2016, the incidence rates there have been more than twice as high as in the CFD (Fig. 1C).

Thus, during the period in question, the rates of obesity in all age groups were significantly higher in the Voronezh Region than in the RF ($p < 0.05$). A similar trend was observed for mental disorders, behavioral disorders, and urolithiasis (Tables 1, 2).

The analysis of morbidity among adults (18 years and older) revealed a significantly higher incidence of digestive system diseases, including gastric and duodenal ulcers, as well as a significant prevalence of diseases with long latency periods, including diseases of the circulatory system, hypertension in particular [9–13]. According to available literature, they may be etiologically linked to obesity (Table 2).

In the Voronezh Region, diseases of the endocrine system (type 2 diabetes mellitus), digestive disorders, and urolithiasis are in the rise among children and adolescents, whereas in the RF and the CFD, the direction of the trend for these ailments is opposite (Fig. 2).

Against the backdrop of a general upward trend in the incidence of diabetes among adolescents, in the Voronezh Region (Fig. 2B), the prevalence of this disease was dropping from 2013 to 2016, followed by a significant spike in the period from 2019 to 2020. The situation is similar for the digestive diseases: in 2011, the incidence thereof in the Voronezh District was lower than in the RF in general, but from 2014 on, the trend for such diseases in the said region is upward and stable (Fig. 2C). As for urolithiasis, in child population (0–14 years old), a significant increase in the incidence thereof was revealed during the observed period, with the prevalence significantly higher than in the CFD and nationwide (Fig. 2A). In adolescents, while the general incidence of urolithiasis was on the rise, in the Voronezh Region, this disease was diagnosed less often that in the RF and the CFD, but from 2017 to 2019, the situation changed to the opposite.

DISCUSSION

Along with the increased incidence of obesity in various age groups of the Voronezh Region population (compared to those

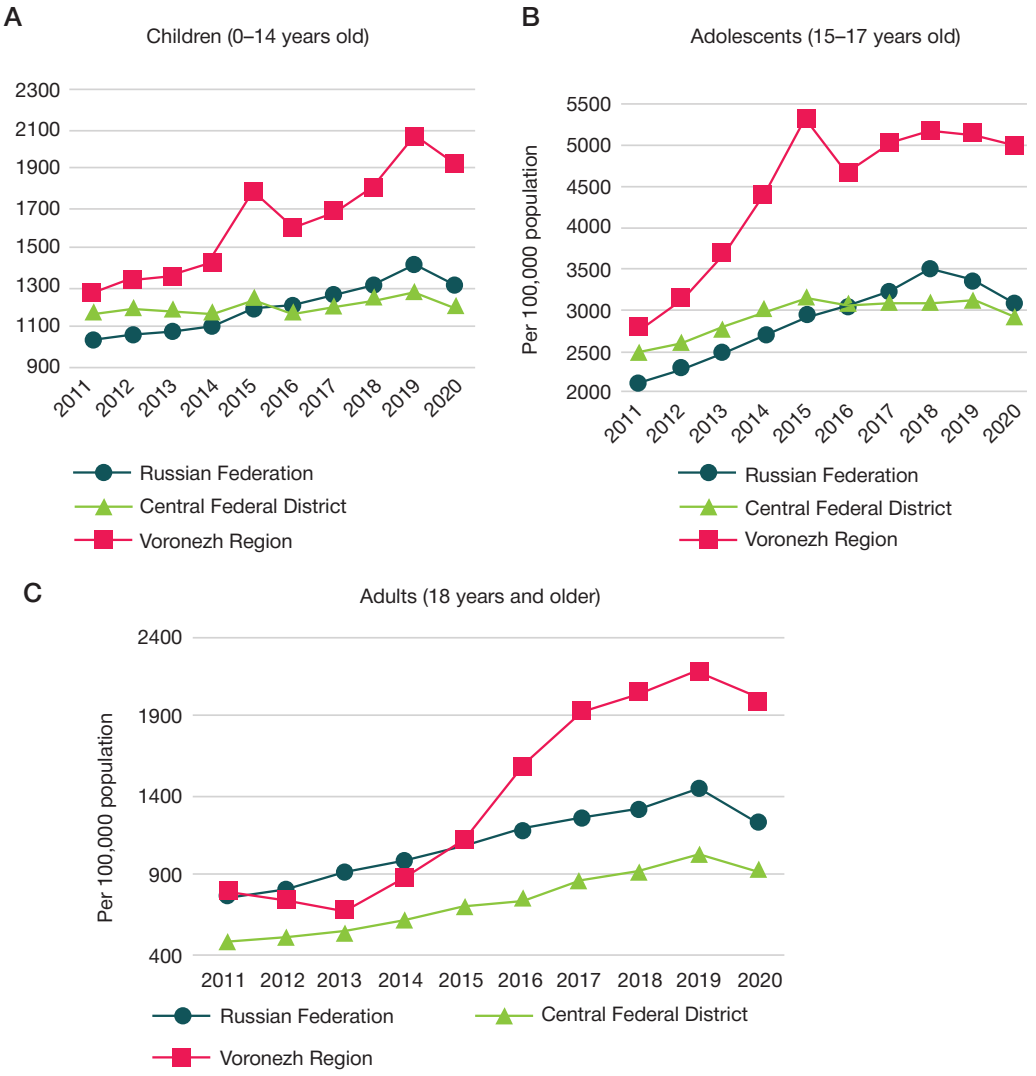

Fig. 1. Trends in obesity per 100,000 population (according to official data from the Ministry of Health of the Russian Federation)

registered in the CFD and Russia in general), we have found high prevalence of mental and behavioral disorders that may be associated with obesity, the said association shown in a study [24] that reported the set of obesity-related factors to influence cognitive well-being. The high incidence of urolithiasis requires further study to determine additional factors unrelated to dietary patterns. For the diseases with a long latency period (those of the circulatory and digestive systems), the morbidity rates in the adult population of the Voronezh Region were significantly higher, which may be a consequence of a long-term persistent high level of obesity in children and adolescents, which is also consistent with the available literature [7,11–14, 21].

CONCLUSIONS

Thus, in the Voronezh Region, we found significantly higher obesity indicators across all age groups, with a stable trend over time. Among the specifics elated to this morbidity in the considered territory are the upward trends for the endocrine system (type 2 diabetes mellitus), digestive diseases (gastritis

Table 1. Groups of diseases with significantly higher mid- and longterm prevalence in the Voronezh Region, children and adolescents, per 100,000 population

Groups of diseases	Children (0–14 years old)			Adolescents (15–17 years old)		
	VR	CFD	RF	VR	CFD	RF
V. Mental and behavioral disorders	4580	2475.6	2874.6	7823.6	5256.3	6016.5
Gastritis and duodenitis (XI. Diseases of the digestive system)	2310.2	1667.3	1891.2	6620.8	5602.6	6182.2
Obesity (IV. Endocrine, nutritional and metabolic diseases)	1629.6	1206.8	1199.9	4431	2921.6	2870.6
Diseases of the thyroid gland (IV. Endocrine, nutritional and metabolic diseases)	136.8	131.6	112.4	347.5	310	274.7
Urolithiasis (XIV. Diseases of the genitourinary system)	49.5	19	24.5	167.1	79.2	90.2
Cystic fibrosis (IV. Endocrine, nutritional and metabolic diseases)	12	10.5	9.2	9.1	7.7	6.8
IV. Endocrine, nutritional and metabolic diseases	4107.3	3580.3	4045.4	12429.9	8528.6	9555.3

Note: VR — Voronezh Region; CFD — Central Federal District; RF — Russian Federation.

Table 2. Groups of diseases with significantly higher mid- and longterm prevalence in the Voronezh Region, adults, per 100,000 population

Groups of diseases	Adults (18 years and older)		
	Voronezh Region	Central Federal District	Russian Federation
Obesity (IV. Endocrine, nutritional and metabolic diseases)	1397	733.2	1108.2
V. Mental and behavioral disorders	5728.4	4398.5	4669
Urolithiasis (XIV. Diseases of the genitourinary system)	912.1	712.9	709.9
IX. Diseases of the circulatory system	37067	28293.2	28979.4
Hypertension (IX. Diseases of the circulatory system)	18553.9	11558.9	2239.7
Stomach ulcer and duodenal ulcer (XI. Diseases of the digestive system)	1299.5	1027.6	1065.2

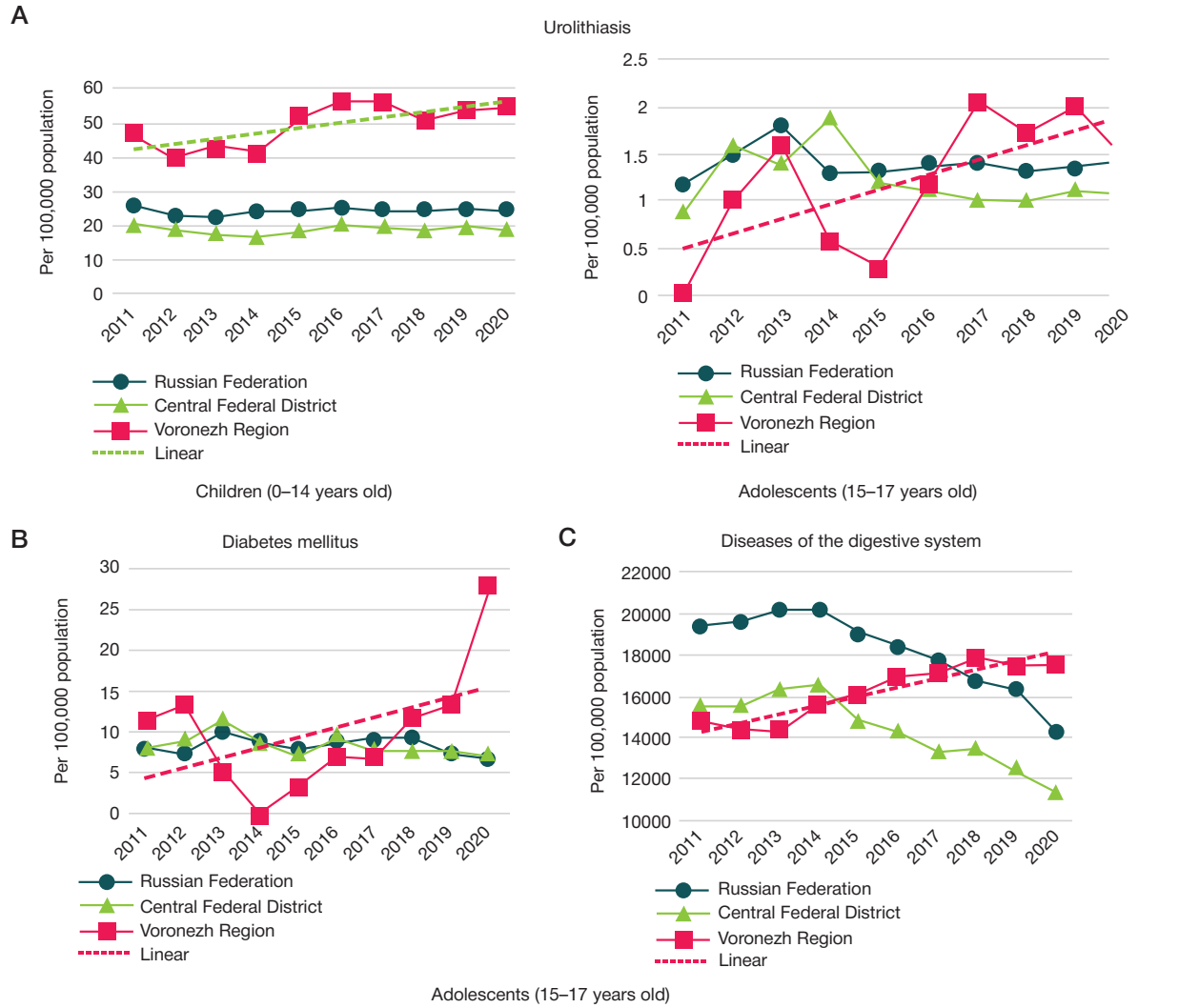

Fig. 2. The dynamics of morbidity in children and adolescents, 2011 to 2020; the Voronezh Region, the Russian Federation, and the Central Federal District compared

and duodenitis), and urolithiasis in children and adolescents, while the situation registered on the level of the nation in general for these diseases is downward in the respective population cohorts. The results of this study support the need to continue research and investigate the potential risk factors that determine the specifics of morbidity in the given area, including the vitamin and mineral content in the mainstay foods, and factors unrelated to nutrition, such as the chemical composition of drinking water and soil composition.

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THE STATE OF HEALTH OF 1ST-, 2ND-, AND 3RD-YEAR STUDENTS OF A MEDICAL UNIVERSITY

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Today, preserving the health of medical students, who constitute the labor pool for Russia's healthcare system, is a strategically important task for both the state and society. The purpose of this work was to investigate the status of health of 1st-, 2nd-, and 3rd-year students of Pacific State Medical University of the Ministry of Health of the Russian Federation. The students underwent a comprehensive examination at the beginning and at the end of the academic year. All in all, we examined 698 people in 2022 and 516 people in 2023. The examination was physical, focusing on the functional state of the cardiorespiratory system, and also assessed the participants' mental health. Primary medical documentation was used as a source of information to assess the incidence of temporary disability and chronic non-communicable diseases of students. Data comparison was done using nonparametric statistical methods. The differences were considered statistically significant at $p < 0.05$. We revealed a downward trend for the students' health indicators, which confirms their allocation into health status groups. At the beginning of the academic year, the 1st group was the largest, and by its end, the share of those reallocated to the 3rd group was significant, with the group including 33.1% of make participants and 36.8% of female participants. This study substantiates the need for continued monitoring of the health status of students. The resulting data enable assessment of the students' health status and identification of priority preventive measures to be developed to preserve their health.

Keywords: students, physical development, mental health, morbidity with temporary disability, chronic non-communicable diseases, health groups

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Author contribution: Trankovskaya LV — study planning and organization, article editing; Shestera AA — study conducting, data collection, analysis, and interpretation, preparation of the final version of the article.

Compliance with ethical standards: the study was conducted in accordance with the Helsinki Declaration of the World Medical Association and approved by the Interdisciplinary Ethics Committee of the Russian Ministry of Health (protocol No. 7 of March 27, 2023). All participants have voluntarily signed informed consent forms.

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СОСТОЯНИЕ ЗДОРОВЬЯ СОВРЕМЕННЫХ СТУДЕНТОВ МЛАДШИХ КУРСОВ МЕДИЦИНСКОГО ВУЗА

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В современных социально-экономических условиях проблема сохранения здоровья студентов-медиков как основного резерва кадров системы здравоохранения Российской Федерации имеет стратегическое значение, как для государства, так и для общества в целом. Целью работы было исследовать здоровье студентов ФГБОУ ВО ТГМУ Минздрава России 1–3 курсов. Выполнена комплексная оценка состояния здоровья студентов младших курсов в начале и в конце учебного года. Всего обследовано 698 человек в 2022 г. и 516 человек в 2023 г. Оценено физическое развитие студентов. Изучены показатели функционального состояния кардиореспираторной системы, а также состояние их психического здоровья. Для оценки показателей заболеваемости с временной утратой трудоспособности и хронической неинфекционной заболеваемости студентов в качестве источника информации использована первичная медицинская документация. Сравнительный анализ полученных данных проводили с применением методов непараметрической статистики. Статистическая значимость различий определялась при $p < 0,05$. Выявлена тенденция к ухудшению показателей, характеризующих состояние здоровья студентов, что подтверждает распределение их по группам здоровья. Если в начале учебного года преобладали обучающиеся с первой группой здоровья, то в конце учебного года процент студентов с третьей группой значительно возрос и составлял 33,1% у юношей, 36,8% у девушек. Проведенное исследование указывает на необходимость дальнейшего наблюдения за показателями состояния здоровья студентов. Полученные данные позволяют оценить состояние здоровья студентов и определить приоритетные направления разработки профилактических мер для сохранения их здоровья.

Ключевые слова: студенты, физическое развитие, психическое здоровье, заболеваемость с временной утратой трудоспособности, хронические неинфекционные заболевания, группы здоровья

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Соблюдение этических стандартов: исследование проведено в соответствии с Хельсинской декларацией Всемирной медицинской ассоциации и одобрено междисциплинарным комитетом по этике ФГБОУ ВО ТГМУ Минздрава России (протокол № 7 от 27 марта 2023 г.). Все участники подписали добровольное информированное согласие на участие в исследовании.

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Today, preserving the health of medical students, the labor pool for Russia's healthcare system, is a strategic task for both the state and society [1–5]. Receiving a medical education involves significant mental efforts, labor inputs, exposure to potentially hazardous factors of hospital environments, all of which affect organisms of students, with all the anatomical and physiological specifics of a young age [6–8].

Health status has a direct effect on the students' performance, grades, motivation, and the quality of learning the professional skills. This is most relevant for those in the 1st, 2nd, and 3rd

years, since they often struggle with mastering general cultural and professional competencies [6, 9–10].

Recent studies have revealed that the health of medical students is generally deteriorating: the prevalence of chronic diseases and functional abnormalities is increasing, while indicators of physical development and fitness are declining [6, 7, 11]. Researchers report that mental conditions are on the rise; up to 54% of them are nosological, concomitant neurotic reactions with discernible symptoms [7]. The number of students signed up to the special physical culture curriculum because of poor health is increasing every year [1, 4], and in some universities, it reaches almost 50% of all those attending the classes [12].

The health status of students is an objective indicator that allows assessing the effectiveness of the already implemented hygiene measures and formulates the directions of further activities [13]. Annual medical examinations that show how healthy the students of the country are support overall health preservation efforts designed for this population.

The purpose of this work was to investigate the status of health of 1st-, 2nd-, and 3rd-year students of Pacific State Medical University of the Ministry of Health of the Russian Federation.

PATIENTS AND METHODS

Using the "Methodological recommendations for a comprehensive assessment of students' health based on the results of medical examinations" [13], we assessed the health of 1st-, 2nd-, and 3rd-year students of Pacific State Medical University, collecting the data twice, at the beginning and at the end of the academic year. There were 698 participants (25.5% males, 74.5% females) in 2022 (beginning of the academic year) and 516 participants (31.2% males, 68.8% females) in 2023 (end of the academic year). Height (body length) and weight were measured against regional regression scales to assess the level of physical development (PD) [14]. In addition, we analyzed the functional state of the cardiorespiratory system: vital lung capacity (VC), heart rate (HR), blood pressure (BP), Myocardium and Rhythm indices. Using the Hamilton Depression Rating Scale (HDRS) and Khanin's adaptation of Spielberg state-trait anxiety inventory [15, 16], we have also evaluated the mental health status of 176 1st-year students (30.1% males, 69.9% females). In addition, medical reports (form 025-TsZ/u) were analyzed with the aim to establish values of the indicators reflecting the incidence of temporary disability (TD) and chronic non-communicable diseases (CNCD) among students of the 1st, 2nd, and 3rd years.

For statistical analysis of the data, we used StatTech v.4.7.3 (StatTech; Russia). Categorical data are given as absolute values and percentages. For comparative analysis, we used nonparametric statistical methods. Pearson's chi-squared test (χ^2) was used to compare percentages in multifield conjugacy tables, and Holm method for multiple comparisons. The differences were considered statistically significant at $p < 0.05$.

RESULTS

The collected data indicate that 46.1% of male participants had harmonious PD at the beginning of the academic year, and by the end thereof, this figure dropped to 43.8%. Through the academic year, the share of male participants with disharmonious PD (body weight deficiency) decreased by 8.1%, which is significant ($p = 0.05$), but the proportion of male students whose PD was sharply disharmonious due to body weight deficiency has grown by 6.6% ($p = 0.06$), which was not significant but very close to the threshold value. At the same time, disharmonious and sharply disharmonious PD due to overweight was registered in 23.0% of young men at the beginning and 26.9% at the end of the academic year. The share of female participants whose PD was harmonious remained virtually unchanged through the academic, and was 56.4% at the beginning and 52.5% at the end of thereof. Body weight deficiency as a reason of disharmonious PD was 4.5 times more common than overweight. By the end of the academic year, the proportion of overweight female students (varying severity) increased only slightly, from 15.4% to 18.8%.

External respiration is one of the most important health characteristics. It was found that the vast majority of 1st-, 2nd-, and 3rd-year students (91.6% of males and 88.1% of females) had normal VC, and this indicator did not change through the academic year.

The cardiovascular system (CVS), which provides all organs and systems with oxygen and nutrients, largely determines the adaptive capabilities of the whole organism. Heart rate is an important indicator of the functioning of both the cardiovascular and nervous systems. The majority of the examined students (60.0%) had normal heart rate, and one third exhibited tachycardia. Bradycardia was diagnosed in 9.6% of males and 3.3% of females. While the number of male students with normal indicators and various deviations from the norm remained unchanged through the academic year, the number of female students with bradycardia increased significantly to 7.6% ($p = 0.003$).

At the end of the academic, blood pressure was within the physiologically normal range in 87.5% of male and 82.9% of female participants. In males, it did not change significantly throughout the study period; by the end of the of the academic year, hypotension-type blood pressure deviations amounted to 3.8% of cases for SBP and 1.3% for DBP, while for the hypertension-type blood pressure deviations the respective figures were 8.8% for SBP and 9.4% for DBP. In the female cohort, by the end of the academic year, the share of participants with normal SBP dropped from 89.6% to 82.9% ($\chi^2 = 8.58$; $p < 0.01$), that with normal DBP — from 88.9% to 83.4% ($\chi^2 = 5.37$; $p = 0.02$). At the same time, the proportion of female students with hypertension-type SBP disorders rose from 3.7% to 8.2% ($\chi^2 = 8.59$; $p < 0.01$) same type DBP disorders — from 10.0% to 14.6% ($\chi^2 = 4.29$; $p = 0.04$). It is noteworthy that by the end of the academic year, the frequency of registration of hypotension-type SBP deviations in males was 2.4 times lower than in females ($\chi^2 = 4.61$; $p = 0.03$).

Examinations under the Myocardium and Rhythm indices revealed a significant decrease of the number of students with normal indicators for the former index, 44.9% to 32.5% in the male cohort ($p = 0.02$), and from 41.7% to 32.6% in the female cohort ($p = 0.01$). The functional state of the cardiovascular system was borderline in more than half of the participants at the beginning of the academic year, and it increased to over 60.0% by the end thereof in both sex cohorts.

During the academic year, the number of male participants who had the Rhythm index indicators verging upon being abnormal increased significantly, from 4.5% to 13.1% ($p < 0.01$). In addition, the proportion of female participants whose Rhythm indicators deviated from the norm slightly increased significantly (from 62.1% to 69.4% ($p = 0.03$)), while the number of girls with normal values of this index decreased (from 30.0% to 21.6% ($p < 0.01$)). It should be noted that by the end of the spring semester, normal Rhythm index was registered

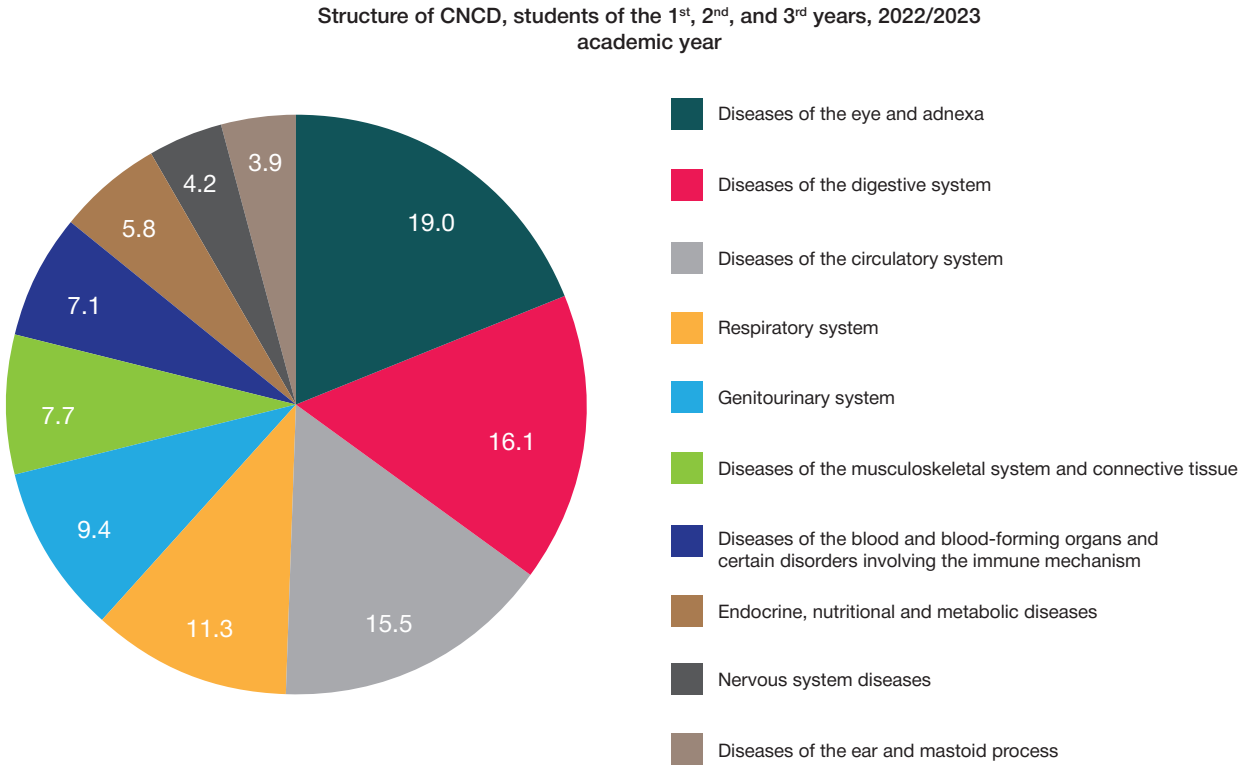

Fig. Structure of CNCD, students of the 1st, 2nd, and 3rd years (%)

only in 23.8% of male and 21.6% of female participants. In the female cohort, slight deviations from the normal values of this index were detected thrice as often as in the male cohort.

In the 2022/2023 academic year, 14.5 cases per 100 participants (mean) involved ailments causing TD, with the respective figure among the 3rd-year students being 17.5 cases, that among the 2nd-year students — 13.6 cases, and among the 1st-year students — 12.5 cases. Respiratory diseases, including acute respiratory viral infections, were the main reason for medical absences. Overall, the number of academic days skipped because of them was 73 per 100 students. The average duration of a sick leave was 8.9 days. It was also revealed that male students (all years) were less likely to seek medical assistance in a clinic than female students (44.0% and 56.0%, respectively; $\chi^2 = 4.5$; $p = 0.05$).

As for the structure of incidence of TD-causing ailments, the most common nosology was respiratory diseases, including acute respiratory viral infections (ARVI): 56.3%. The second most common reason were disorders of the musculoskeletal system (12.3%), the third — digestive system diseases (10.9%).

As for CNCD, in the 2022/2023 academic year students of the 1st, 2nd, and 3rd years most often suffered from the diseases of the eye and adnexa, digestive organs and circulatory system (Fig.).

The results of the comparative assessment of mental health of 1st-year students revealed that depressive disorder was 1.6 more common in females than in males ($p = 0.02$). Moderate trait anxiety was found to affect 54.7% of male and 56.1% of female 1st-year students, low trait anxiety — only 22.6% of males and 14.6% of females, and high trait anxiety — 77.4% of males and 85.4% of females. At the same time, about one in four first-year students exhibited symptoms of moderate reactive anxiety, and high reactive anxiety was registered only in 6.5% of the participating girls.

Based on the results of medical examination, 1st-, 2nd-, and 3rd-year students of Pacific State Medical University were distributed into health status groups (Table 1).

According to the data, at the beginning of the academic year, the majority of 1st-, 2nd-, and 3rd-year students were classified in the first health status group. However, by the end of the academic year, the proportion of healthy students decreased significantly: by 29.2% among male participants ($\chi^2 = 29.76$; $p < 0.01$), and by 24.7% among female participants ($p < 0.01$). We have registered a growing number of those reclassified into second and third health status groups, with the amount of students meeting the criteria of the third group being significant among both boys and girls ($p < 0.01$).

Table 1. Distribution of students into health status groups

Health status groups	Males				*p*-value	Females				*p*-value
	Academic year start		Academic year end			Academic year start		Academic year end		
	Abs.	%	Abs.	%		Abs.	%	Abs.	%	
First	102	57.3	45	28.1	< 0.001	298	57.3	116	32.6	< 0.001
Second	50	28.1	58	36.3	0.1	154	29.6	107	30.1	0.89
Third	23	12.9	53	33.1	< 0.001	67	12.9	131	36.8	< 0.001
Fourth	3	1.7	4	2.5	0.62	1	0.2	2	0.6	0.34
Fifth	–	–	–	–	–	–	–	–	–	–

Note: * — differences in indicators are statistically significant ($p < 0.05$).

Table 2. Classification of students into health status groups, by year (%)

Year	Period	*n*	Health status groups			
			First	Second	Third	Fourth
1	Start	368	54.3	32.3	13.0	0.3
	End	295	36.6	29.8	32.2	1.4
	χ^2		20.98	0.49	35.77	2.53
	p-value		< 0.001*	0.48	< 0.001*	0.11
2	Start	180	56.7	28.3	14.4	0.6
	End	104	26.9	33.7	38.5	1
	χ^2		23.38	0.9	20.9	0.17
	p-value		< 0.001*	0.34	< 0.001*	0.68
3	Start	150	65.3	22.7	10.7	1.3
	End	117	21.4	35.9	41.9	0.9
	χ^2		50.17	5.57	34.17	0.13
	p-value		< 0.001*	0.02*	< 0.001*	0.72
p-value	Academic year start		$p1_{\text{year 1 – year 3 (HSG I)}} = 0.02^*$; $p1_{\text{year 1 – year 3 (HSG II)}} = 0.03^*$			
	Academic year end		$p1_{\text{year 1 – year 3 (HSG I)}} = 0.003^*$			

Note: * — significant differences ($p < 0.05$).

A comprehensive assessment of the health status of 1st-, 2nd-, and 3rd-year students showed that even within one academic year, it deteriorates to the point of reclassification (Table 2).

At the beginning of the academic year, there were significantly more 1st-year students in the first and second health status groups ($p = 0.02$ and $p = 0.03$, respectively) than 3rd-year students. However, there were no significant differences in distribution of 2nd- and 3rd-year students into health groups. At the end of the academic year, the number of 3rd-year students belonging in the first health status group decreased significantly, while the number of 3rd-year students classified into the second and third health status groups increased significantly.

DISCUSSION

The results of previous studies indicate that the majority of students have harmonious PD. However, the percentage of students with disharmonious and sharply disharmonious PD remains fairly high [17]. For example, 17.0% of students of Pirogov Russian National Research Medical University have disharmonious PD, and 9.0% — sharply disharmonious [18]. At the same time, our study has shown that by the end of the academic year, 56.3% of boys and 47.5% of girls have abnormal PD.

According to the collected data, various functional disorders of hemodynamics were detected in students both at the beginning and at the end of the academic year. For example, by the end of the year, hypertension-type SBP deviations were registered in 8.8% of male participants and 8.2% of female participants, and hypertension-type DBP deviations — in 9.4% of boys and 14.6% of girls. For comparison, the assessment of blood pressure indicators of students of the Medical Faculty of Kabardino-Balkarian State University revealed hypertension only in 3.1% of cases [19].

Our work has also confirmed the data from other studies indicating that 1st-, 2nd-, and 3rd-year students most often seek medical help with respiratory diseases [20]. The prevailing chronic pathologies among the Pacific State Medical University students were diseases of the eye, digestive, and cardiovascular systems. At the same time, according to the literature, students of the Russian medical universities most often suffer from "respiratory diseases, accounting for about 18.0%, followed by the musculoskeletal system diseases and diseases of the eye and are in second place, and diseases of the eye and adnexa [21].

In our work, we observed a tendency towards developing depressive disorders of varying degrees, as well as high levels of trait and reactive anxiety among students; these findings are consistent with reports from other researchers [22–24]. For example, a study conducted in Voronezh State Medical University named after N.N. Burdenko revealed that in the fall semester, 6.0% of students had low state anxiety, 51.0% were classified as having a moderate version thereof, and 43.0% of the respondents had high state anxiety. As for trait anxiety, only 24% of the participants had it at a high level, and 76.0% experienced moderate trait anxiety [23].

Our work revealed a gradual deterioration of health indicators of 1st-, 2nd-, and 3rd-year students of Pacific State Medical University, which is confirmed by their distribution into health status groups. At the beginning of the academic year, the first health status group was the largest, but at the end of the academic year, the percentage of students with chronic diseases in the compensation stage, which puts them into the third health status group, increased significantly and amounted to 33.1% for boys and 36.8% for girls. Thus, over the course of the study, the number of practically healthy students decreased twofold. For comparison, we give data on classification of students of a medical academy into health status groups: first group — from 23.8 to 30.0%, second group — from 32.8 to 40.0%, third group — from 30.0 to 43.4%" [25].

This study substantiates the need for continued monitoring of the health status of students. The resulting data enable assessment of the students' health status and identification of priority preventive measures to be developed to preserve their health.

It is particularly important to identify students belonging in the first (practically healthy) and second (various functional or morphological changes) health status groups, since the former may be in a borderline condition, between being healthy and ill. Diagnosing, preventing, and curing these states is the most important task of medical science and practical healthcare. Moreover, timely implementation of several preventive and remedial

measures can facilitate the transition of students from the second group to the first one.

CONCLUSIONS

The comprehensive examination of health status of 1st-, 2nd-, and 3rd-year students of a medical university revealed negative trends. More than half of the students (50.2%) have disharmonious and sharply disharmonious physical development, mainly due to body weight deficiency. By the end of the academic year, their cardiovascular system deteriorates functionally, with the number of students scoring within the normal range of Myocardium and Rhythm indices decreasing significantly ($p < 0.01$). The prevalence of diseases causing TD was established as high, and female students are more likely to seek medical help (56.0% vs. 44.0%, $\chi^2 = 4.5$; $p = 0.05$). The most common of such diseases are those of the respiratory system (56.3%), musculoskeletal system (12.3%), and digestive system (10.9%). As for CNCD, the leading ailments were diseases of the eye and adnexa (19.0%), digestive organs (16.1%), and circulatory system (15.5%). The level of trait anxiety was found to be high in 77.4% of boys and 85.4% of girls, and 12.9% of boys and 20.7% of girls had depressive disorders. The proportion of those belonging in the first health status group was significantly higher among 1st-year students compared to their 3rd-year fellows ($p = 0.003$). Movement through the years is associated with a significant growth of the number of students classified into the third health status group ($p < 0.01$). The data resulting from this study form the basis for the development of targeted preventive measures aimed at preserving and strengthening the health of students.

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ANALYSIS OF BODY MASS INDEX FORMATION IN CHILDREN AND ADOLESCENTS OF THE RUSSIAN FEDERATION

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To prevent health problems in pediatric population, the Russian Federation (RF) is implementing the Complex of measures to combat obesity in children under 18 years of age, approved on December 1, 2023, No. 18824-P12-TG. The study aimed to consider body mass index (BMI) formation in Russian children and adolescents in the regional aspect. As part of the all-Russian monitoring of the physical development of children and adolescents in 2021–2024, BMI of 258,611 boys and 252,629 girls living in 50 constituent entities of the RF was studied. Big data analysis has shown that in most regions there is a harmonious development of the child population and the indicators fit into the BMI 25th–75th centile for the RF as a whole, which is 19.6–22.9 kg/m^2 in boys aged 17 and 18.7–22.3 kg/m^2 in girls. At the same time, there is an influence of socio-economic factors. The analysis of the regional features of BMI formation in children and adolescents aged 7–17 years has shown that BMI has a higher value, the lower the place of the subject of the RF in terms of gross regional product.

Keywords: children, adolescents, body mass index, regions, monitoring, physical development

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АНАЛИЗ ФОРМИРОВАНИЯ ИНДЕКСА МАССЫ ТЕЛА У ДЕТЕЙ И ПОДРОСТКОВ РОССИЙСКОЙ ФЕДЕРАЦИИ

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Для профилактики нарушения здоровья детского населения в Российской Федерации (РФ) осуществляется исполнение Комплекса мер по борьбе с ожирением у детей до 18 лет от 1 декабря 2023 г. № 18824-П12-ТГ. Целью работы было рассмотреть формирование индекса массы тела (ИМТ) у российских детей и подростков в региональном аспекте. В рамках проведения общероссийского мониторинга физического развития детей и подростков в 2021–2024 гг. был изучен ИМТ 258 611 мальчиков и 252 629 девочек, проживающих в 50 субъектах РФ. Анализ *big data* показал, что в большинстве регионов имеет место гармоничное развитие детского населения и что показатели укладываются в ИМТ в зоне 25–75-го центиля для РФ в целом, который у мальчиков 17 лет составляет 19,6–22,9 кг/м^2, а у девочек — 18,7–22,3 кг/м^2. В то же время присутствует влияние социально-экономических факторов. Анализ региональных особенностей формирования ИМТ у детей и подростков 7–17 лет показал, что ИМТ имеет тем более высокое значение, чем ниже место субъекта РФ по показателю валового регионального продукта.

Ключевые слова: дети, подростки, индекс массы тела, регионы, мониторинг, физическое развитие

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

Соблюдение этических стандартов: исследование одобрено этическим комитетом РНИМУ имени Н. И. Пирогова (протокол № 239 от 15 апреля 2024 г.).

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The issue of overweight and obesity is relevant for pediatric population all over the world [1–5].

Currently, the Russian Federation (RF) is implementing the Complex of measures to combat obesity in children under 18 years of age, approved by T.V. Golikova, Deputy Chairman of the Government of the Russian Federation, on December 1, 2023, No. 18824-P12-TG. As part of the screening assessment within the framework of the check-up aimed to allocate groups of overweight children and adolescents at risk, calculation of body mass index (BMI) with estimation is performed in accordance with the guidelines of the World Health Organization (WHO) and clinical guidelines "Obesity in Children" of the Ministry of Health of the RF [6].

Consideration of BMI formation in Russian children and adolescents in the regional aspect taking into account growth and development patterns seems to be a relevant task.

The study aimed to consider BMI formation in children and adolescents of the RF in the regional aspect.

METHODS

When conducting all-Russian monitoring of physical development of children and adolescents in 2021–2024, a cross-sectional study of physical development indicators (body length, body weight) was performed in children and adolescents aged 7–17 years with subsequent BMI (kg/m^2) calculation in 50 constituent entities of the RF. Considering the growth and development patterns, we selected the regions that were different in climate and geographic conditions, ethnic composition of the population, socio-economic and other factors. The sample was calculated using the method by K.A. Otdelnova (95.0%, $p \leq 0.05$): each gender and age group in the studied constituent

entity of the RF was represented by 100 children. The data on body length and body weight of 258,611 boys and 252,629 girls were selected for statistical analysis to calculate BMI (Table 1).

Statistical processing of the data obtained was performed using the Microsoft Office Excel (Microsoft; USA) and Statistica 13.0 (StatSoft; USA) software packages. When processing the results of physical development assessment, the data were tested for normality using the Kolmogorov–Smirnov, Lilliefors, and Shapiro–Wilk tests. The quantitative data acquired were normally distributed, which is in line with the literature data on assessing physical development indicators. We used parametric statistical methods involving the use of the mean (M), error of the mean (m), and standard deviation (σ). To assess significance of differences in mean values, the Bonferroni adjusted Student's *t*-test was used. The differences were considered significant at the significance level not exceeding 0.05.

The data on socio-economic indicators in constituent entities of the RF at the midpoint of the observation period (main economic indicators in 2022: per capita income (per month), average monthly nominal accrued wages of the employees of organizations (per month), gross regional product in 2021, agricultural products, retail trade turnover; place occupied by the constituent entity based on the major socio-economic indicators in the RF in 2022: per capita gross regional product in 2021, agricultural products, per capita retail trade turnover) were taken from official sources [7].

Correlations between BMI of children and adolescents aged 7–17 years and socio-economic indicators were assessed using the Spearman's rank correlation coefficient, since the distribution of socio-economic indicators was non-normal.

RESULTS

BMI formation in children and adolescents of the RF in the regional aspect was considered based on the gender and age BMI curves (Fig. 1–8).

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the CFD are provided in Fig. 1.

Fig. 2 presents gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the NWFD.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the SFD are provided in Fig. 3.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the NCFD are provided in Fig. 4.

Fig. 5 presents gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the VFD.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the UFD are provided in Fig. 6.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the SFD are provided in Fig. 7.

The gender and age curves of BMI formation in children and adolescents aged 7–17 years living in the constituent entities of the FEFD are provided in Fig. 8.

The analysis of gender and age BMI curves shows that in the majority of regions there is a smooth increase in BMI with age in both boys and girls — usually without crossovers, which is in line with such biological patterns, as directionality, gradualism, irreversibility and heterochrony. Indicators of boys are superior to that of girls, which is consistent with such pattern, as sex-specific growth and development (sexual dimorphism). In general, harmonious development is observed in the majority of regions.

There are regional BMI differences observed by growth termination. Thus, the following maximum and minimum BMI values are reported for the CFD: in boys aged 17 years living in the Kursk Region, the value is 21.97 ± 0.17 kg/m^2, while in boys aged 17 years living in the Ivanovo Region it is 20.95 ± 0.34 kg/m^2, i.e. the difference is 1.02 kg/m^2 (Student's *t*-test: 2.68; $p = 0.007746$). In girls living in the Oryol Region, BMI is 21.51 ± 0.39 kg/m^2, while in those living in the Kursk Region it is 20.55 ± 0.39 kg/m^2, i.e. the difference is 0.96 kg/m^2 (Student's *t*-test: 2.19; $p = 0.029425$).

No significant differences are reported for the NWFD ($p > 0.05$).

The following maximum and minimum BMI values are reported for the SFD: in boys aged 17 years living in the Republic of Kalmykia, the value is 22.57 ± 0.59 kg/m^2, while in boys aged 17 years living in the Krasnodar Krai it is 21.41 ± 0.06 kg/m^2, i.e. the difference is 1.16 kg/m^2 (Student's *t*-test: 2.00; $p = 0.005000$). In girls living in the Republic of Kalmykia, the value is 21.34 ± 0.34 kg/m^2, while in those living in the Rostov Region it is 20.16 ± 0.14 kg/m^2, i.e. the difference is 1.18 kg/m^2 (Student's *t*-test: 2.34; $p = 0.018815$).

The following maximum and minimum BMI values are reported for the NCFD: in boys aged 17 years living in the Republic of North Ossetia–Alania, the value is 21.98 ± 0.15 kg/m^2, while in boys aged 17 years living in the Karachayevo-Circassian Republic it is 21.16 ± 0.21 kg/m^2, i.e. the difference is 0.82 kg/m^2 (Student's *t*-test: 3.18; $p = 0.001600$). In girls living in the Karachayevo-Circassian Republic, BMI is 21.80 ± 0.23 kg/m^2, while in those living in the Chechen Republic it is 20.25 ± 0.29 kg/m^2, i.e. the difference is 1.55 kg/m^2 (Student's *t*-test: 4.19; $p = 0.000042$).

The following maximum and minimum BMI values are reported for the VFD: in boys aged 17 years living in the Republic of Mordovia, BMI is 21.68 ± 0.32 kg/m^2, while in boys aged

Table. Size of samples to form big data for analysis by the constituent entities of the Russian Federation, *n*

Federal District	Observations, boys, *n*	Observations, girls, *n*	Total observations, *n*
Central Federal District (CFD)	42 042	40 003	82 045
Northwestern Federal District (NWFD)	13 401	12 911	26 312
Southern Federal District (SFD)	66 935	64 923	131 858
North Caucasus Federal District (NCFD)	19 110	17 290	36 400
Volga Federal District (VFD)	51 535	48 769	100 304
Urals Federal District (UFD)	27 902	26 493	54 395
Siberian Federal District (SFD)	14 593	19 443	34 036
Far Eastern Federal District (FEFD)	23 093	22 797	45 890
Total observations, *n*	258 611	252 629	511 240

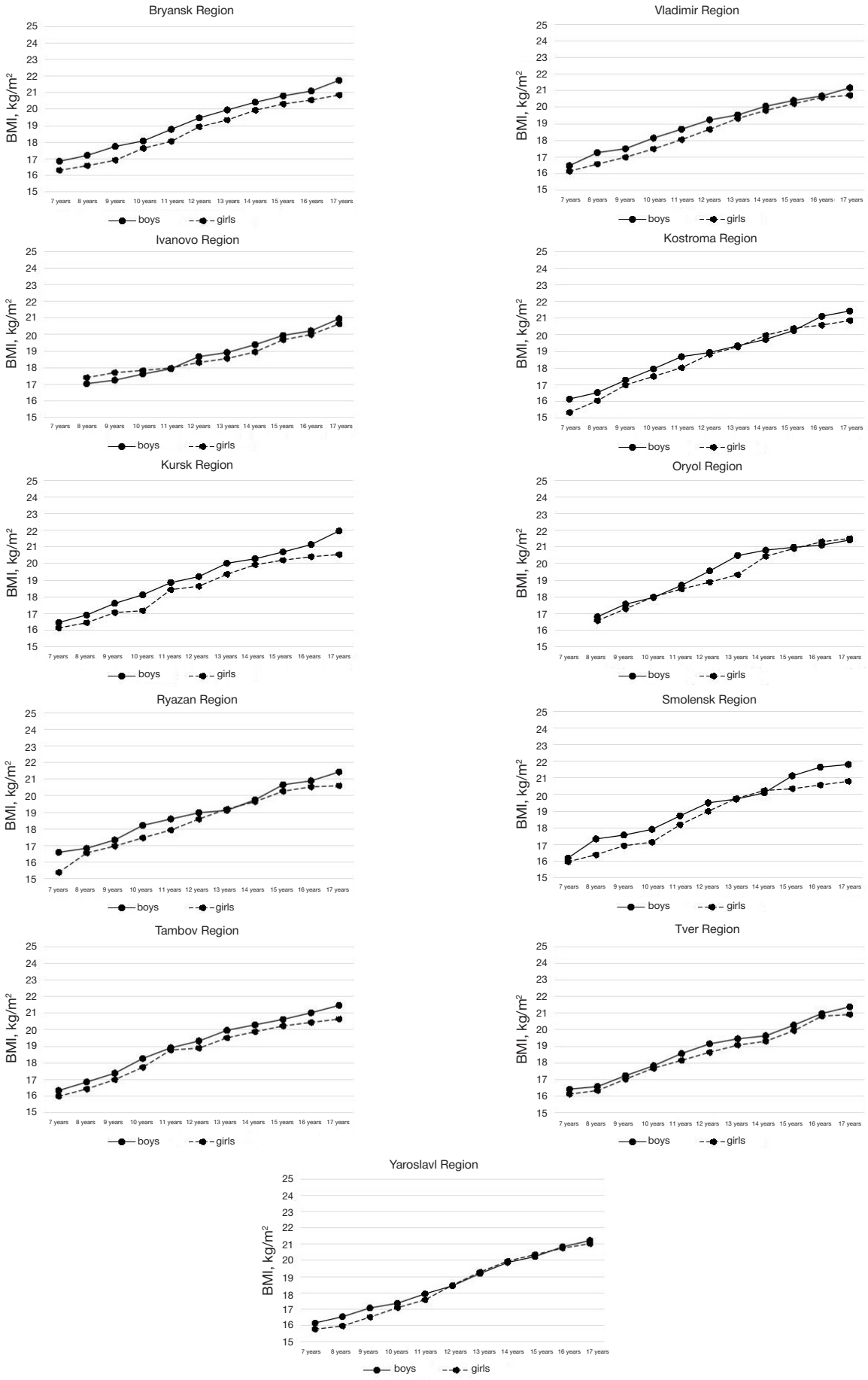

Fig. 1. Body mass index (BMI) formation in children and adolescents of the Central Federal District (CFD), kg/m^2

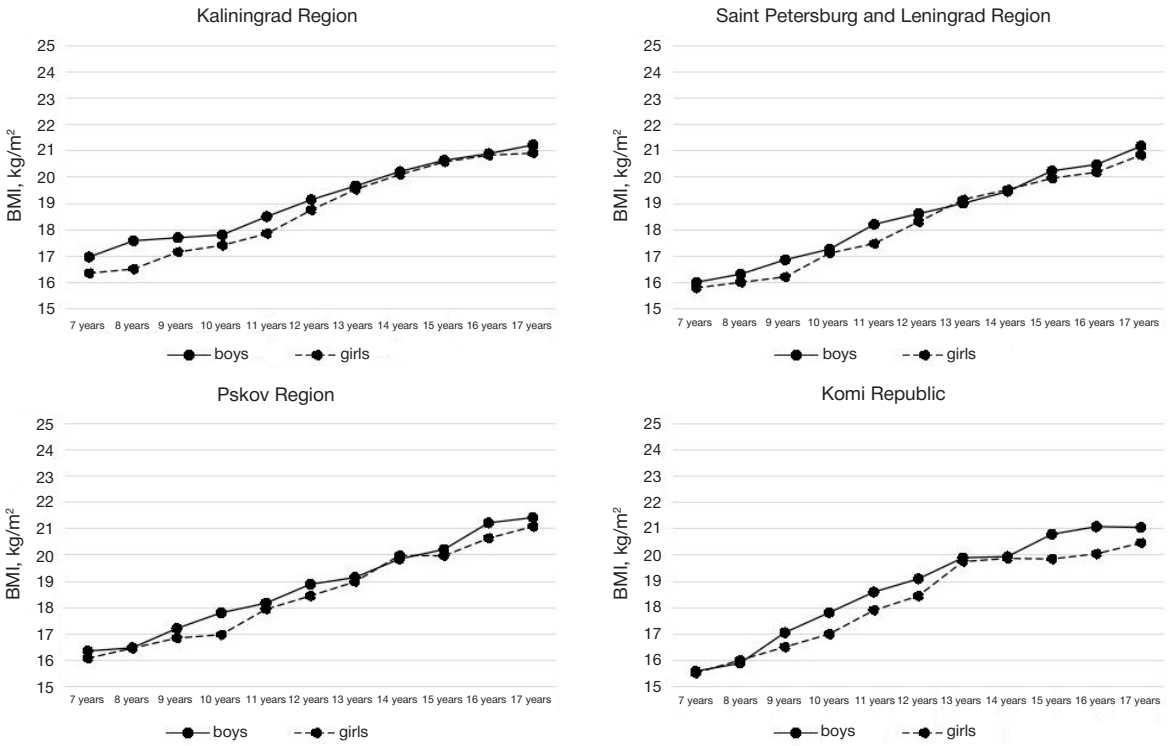

Fig. 2. Body mass index (BMI) formation in children and adolescents of the Northwestern Federal District (NWFD), kg/m^2

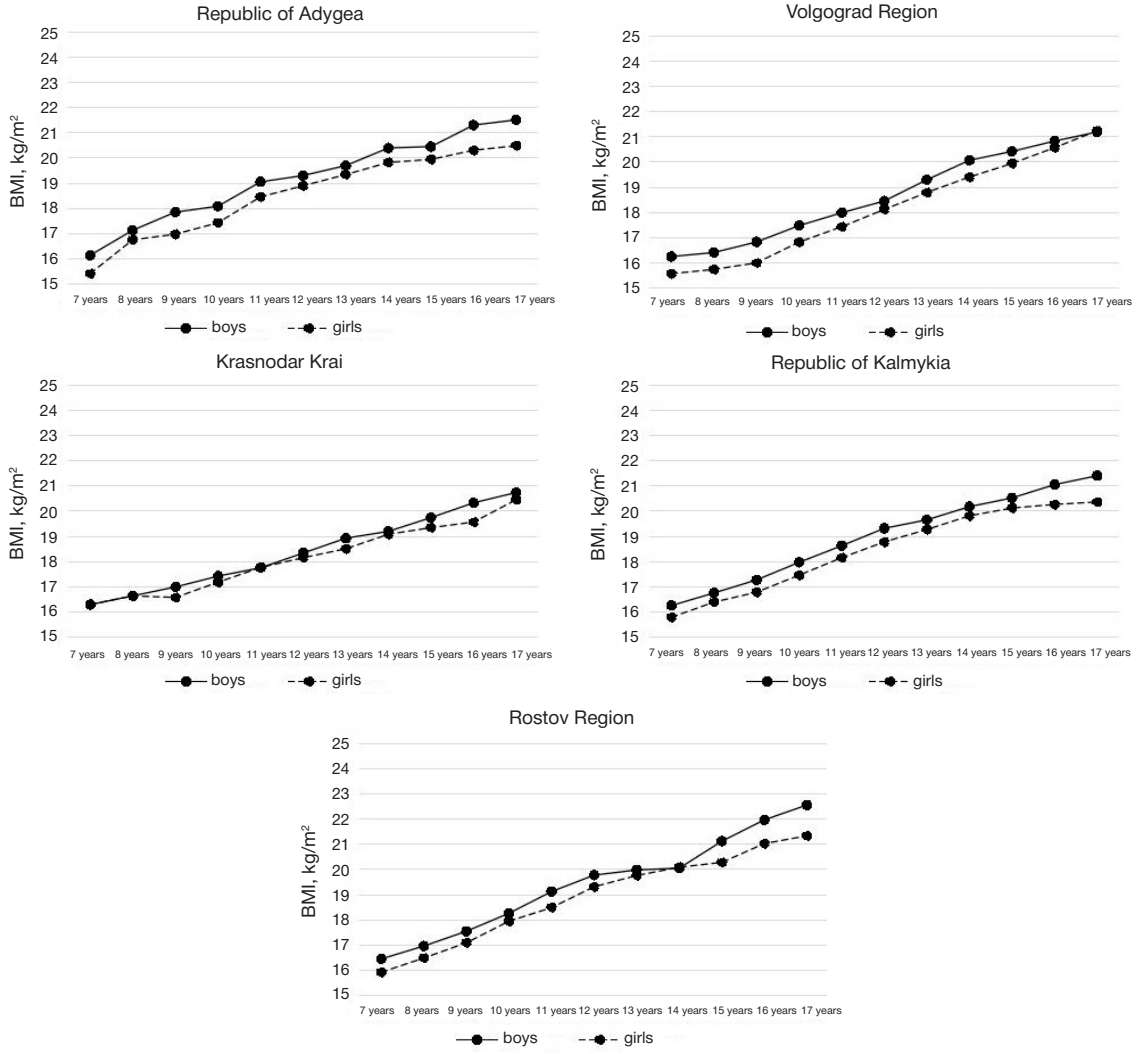

Fig. 3. Body mass index (BMI) formation in children and adolescents of the Southern Federal District (SFD), kg/m^2

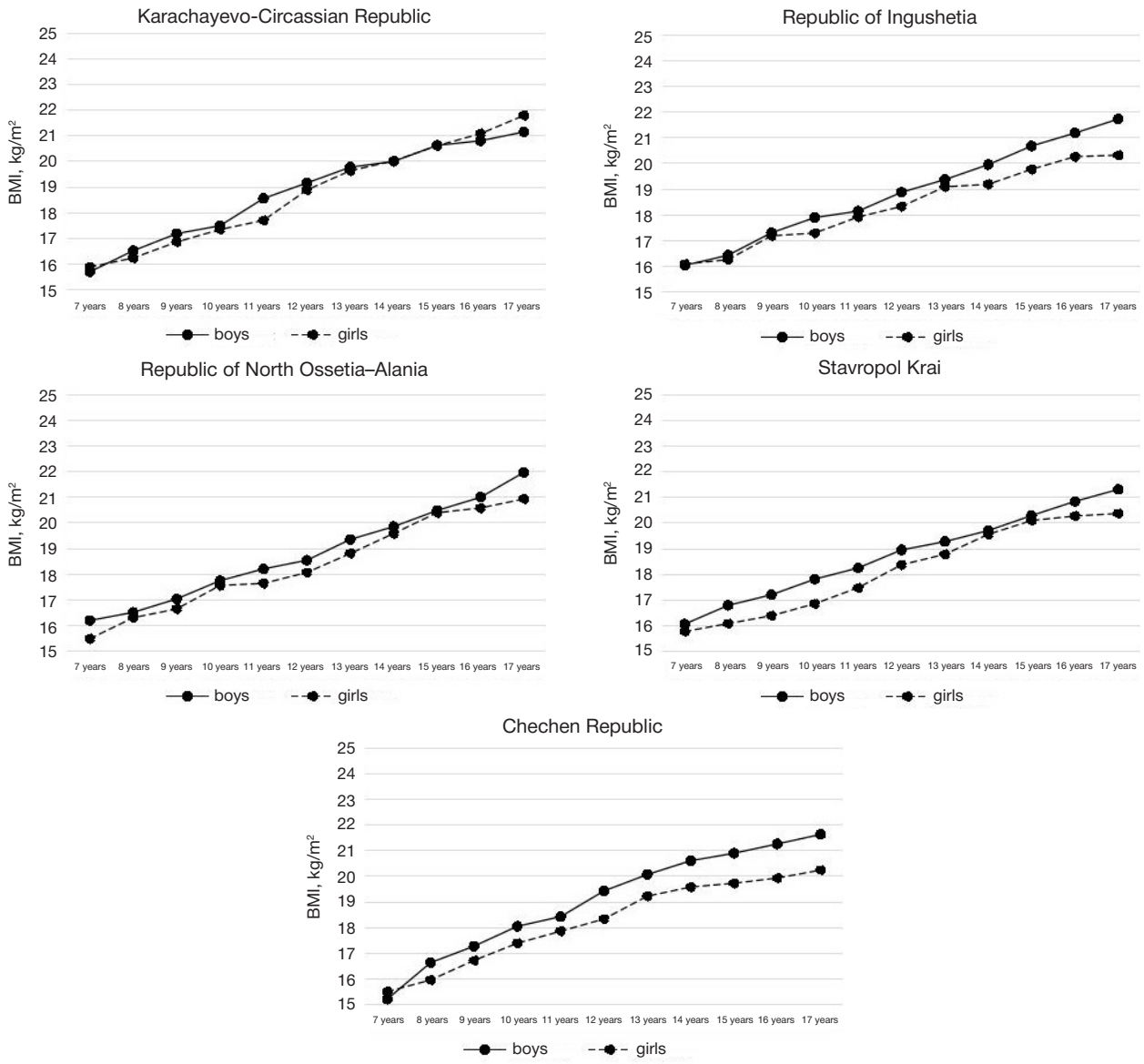

Fig. 4. Body mass index (BMI) formation in children and adolescents of the North Caucasus Federal District (NCFD), kg/m²

17 years living in the Chuvash Republic it is 20.49 ± 0.14 kg/m², i.e. the difference is 1.19 mg/m² (Student's *t*-test: 3.41; *p* = 0.000708). In girls living in the Chuvash Republic, BMI is 21.46 ± 0.34 kg/m², while in those living in the Republic of Tatarstan it is 19.79 ± 0.15 kg/m², i.e. the difference is 1.67 kg/m² (Student's *t*-test: 4,49; *p* = 0.000011).

The following maximum and minimum BMI values are reported for the UFD: in boys aged 17 years living in the Kurgan Region, the value is 21.74 ± 0.22 kg/m², while in boys aged 17 years living in the Tyumen Region it is 20.03 ± 0.18 kg/m², i.e. the difference is 1.71 kg/m² (Student's *t*-test: 6.02; *p* = 0.000001). In girls living in the Yamalo-Nenets Autonomous Okrug, BMI is 21.34 ± 0.25 kg/m², while in those living in the Tyumen Region it is 20.37 ± 0.21 kg/m², i.e. the difference is 0.97 kg/m² (Student's *t*-test: 3.28; *p* = 0.001182).

The following maximum and minimum BMI values are reported for the SFD: in boys aged 17 years living in the Altai Krai, BMI is 21.95 ± 0.39 kg/m², while in boys aged 17 years living in the Omsk Region it is 20.82 ± 0.14 kg/m², i.e. the difference is 1.13 kg/m² (Student's *t*-test: 2.73; *p* = 0.006711). In girls living in the Irkutsk Region, BMI is 21.53 ± 0.20 kg/m², while in those living in the Omsk Region it is 20.33 ± 0.15 kg/m², i.e. the difference is 1.20 kg/m² (Student's *t*-test: 4.80; *p* = 0.000002).

The following maximum and minimum BMI values are reported for the FEFD: in boys aged 17 years living in the Amur Region, the value is 21.61 ± 0.24 kg/m², while in boys aged 17 years living in the Khabarovsk Krai it is 20.85 ± 0.22 kg/m², i.e. the difference is 0.76 kg/m² (Student's *t*-test: 2.33; *p* = 0.020329). In girls living in the Amur Region, BMI is 20.95 ± 0.27 kg/m², while in those living in the Khabarovsk Krai it is 20.18 ± 0.17 kg/m², i.e. the difference is 0.77 kg/m² (Student's *t*-test: 2.41; *p* = 0.016486).

In general, the following maximum and minimum BMI values have been revealed in the regional aspect: in boys aged 17 years living in the Republic of Kalmykia, BMI is 22.57 ± 0.59 kg/m², while in boys aged 17 years living in the Tyumen Region it is 20.03 ± 0.18 kg/m², i.e. the difference is 2.54 kg/m² (Student's *t*-test: 4.02; *p* = 0.000077). In girls living in the Karachayevo-Circassian Republic, BMI is 21.80 ± 0.23 кг/м², kg/m², while in those living in the Republic of Tatarstan it is 19.79 ± 0.15 kg/m², i.e. the difference is 2.01 kg/m² (Student's *t*-test: 7.32; *p* = 0.000001).

Assessment of the impact of socio-economic indicators in the constituent entities of the RF on BMI formation in boys and girls aged 7–17 years in the regional aspect has shown that integral indicators of the subject of the RF were significant, i.e.

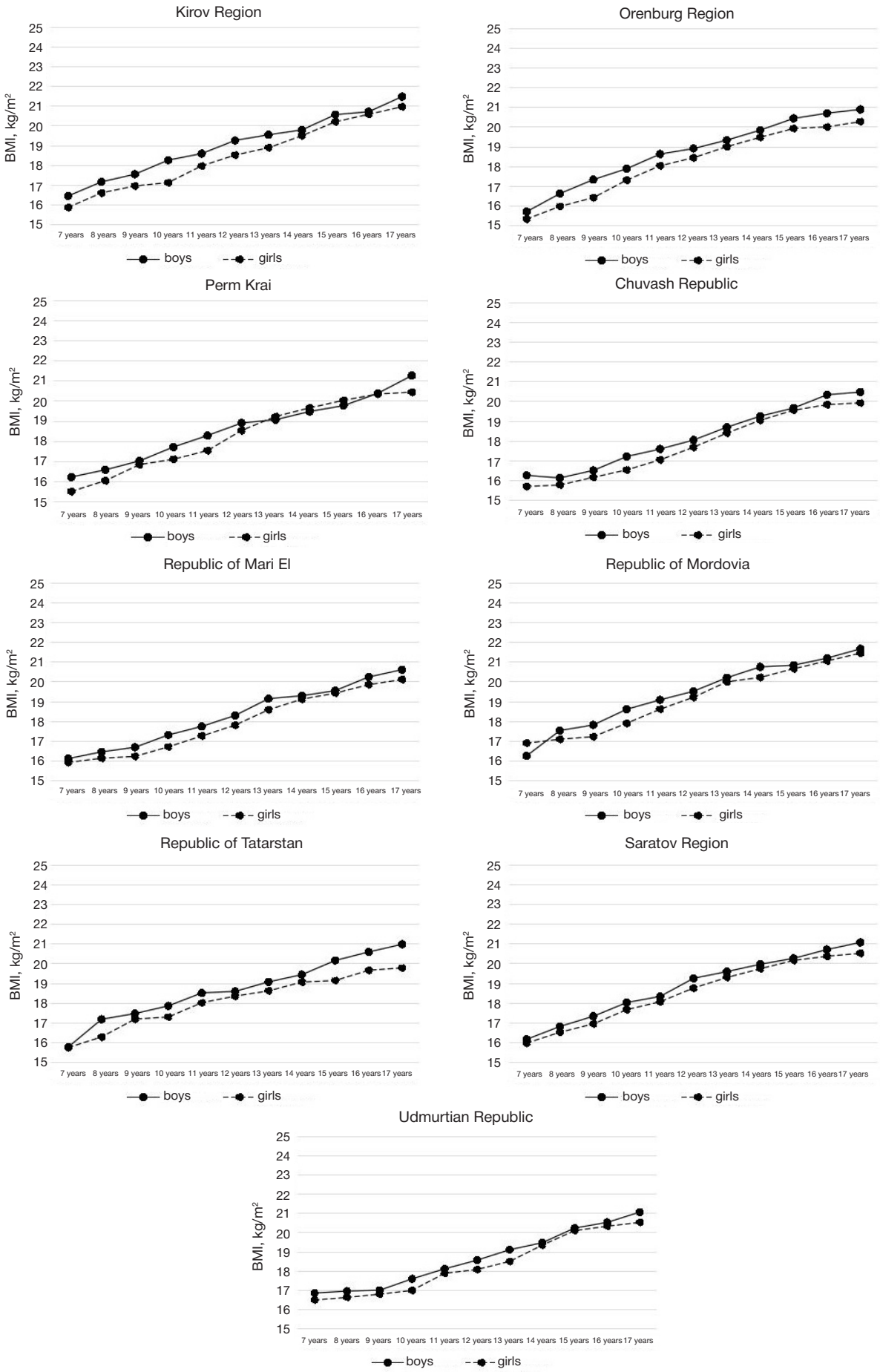

Fig. 5. Body mass index (BMI) formation in children and adolescents of the Volga Federal District (VFD), kg/m²

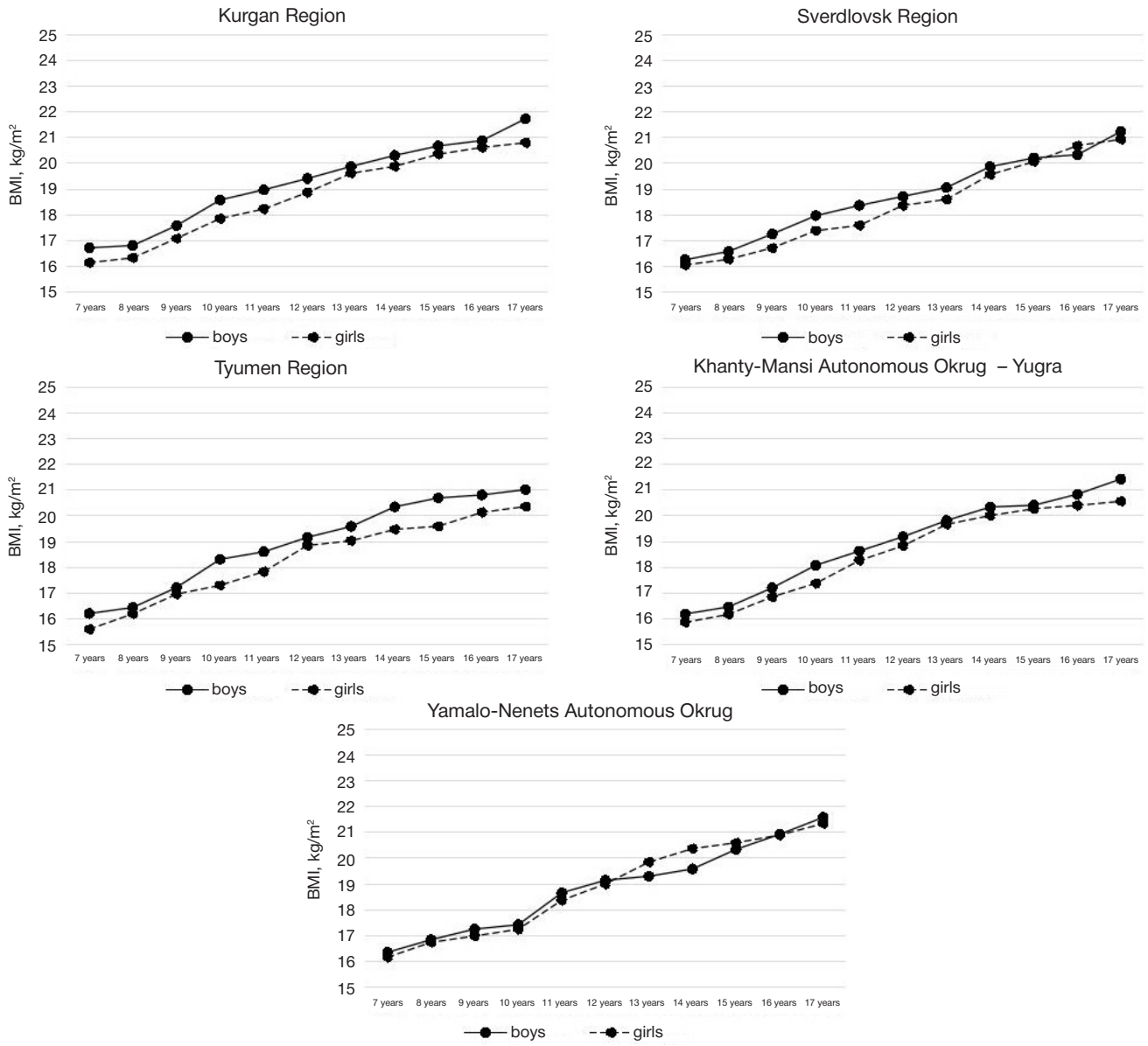

Fig. 6. Body mass index (BMI) formation in children and adolescents of the Urals Federal District (UFD), kg/m^2

per capita gross regional product, by which all the constituent entities were ranked in descending order (moderate correlation based on the Spearman's rank correlation coefficient: 0.519; $p \leq 0.05$), and the related indicators, such as supply of agricultural products 0.659 ($p \leq 0.05$) and per capita retail trade turnover 0.577 ($p \leq 0.05$).

DISCUSSION

Assessment of BMI formation in children and adolescents performed based on big data analysis has shown that there is harmonious development of pediatric population in the majority of regions, and the regional indicators of boys and girls fit into the BMI 25th–75th centile for the RF as a whole, which is 19.6–22.9 kg/m^2 in boys aged 17 years and 18.7–22.3 kg/m^2 in girls. At the same time, there are effects of socio-economic factors and, probably, climate and geographic, ethnic, and other factors.

The impact of climate and geographic factors and the regional differences in indicators of physical development of children and adolescents have been previously reported by many researchers [8–10]. There are earlier reports showing the effects of socio-economic factors on physical development of children and adolescents, as well as BMI [11].

The Pearson correlation coefficient calculated for the BMI of schoolchildren and the distribution of the number of children, who spent their summer vacations in children's recreation and health organizations in the year preceding the study, was –0.68 ($p \leq 0.05$) [12].

It has been also shown that Pearson correlation coefficients for BMI in schoolchildren aged 11 and 15 years and the value of availability of physicians and nurses per 10,000 population were –0.63 and –0.39 ($p \leq 0.05$) [13].

Our study has shown that BMI has a higher value, the lower the place of the subject of the RF in terms of gross regional product. The regions that require special attention are the Republic of Kalmykia (66th place) and Karachayevo-Circassian Republic (82nd place).

To date, the numerically significant data have been accumulated: 511,240 observations acquired at once over a short time that make it possible to develop national nomograms for gender-and-age-based assessment of BMI in pediatric population, as well as to update the previously developed standards of this kind [14].

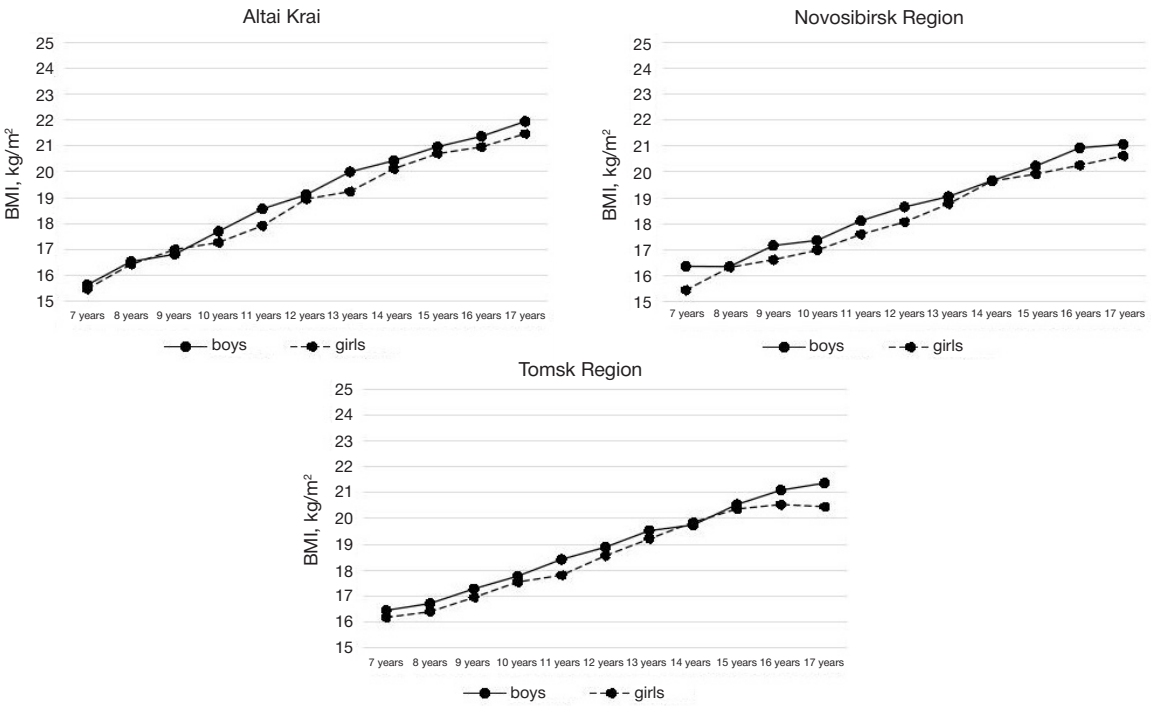

Fig. 7. Body mass index (BMI) formation in children and adolescents of the Siberian Federal District (SFD), kg/m²

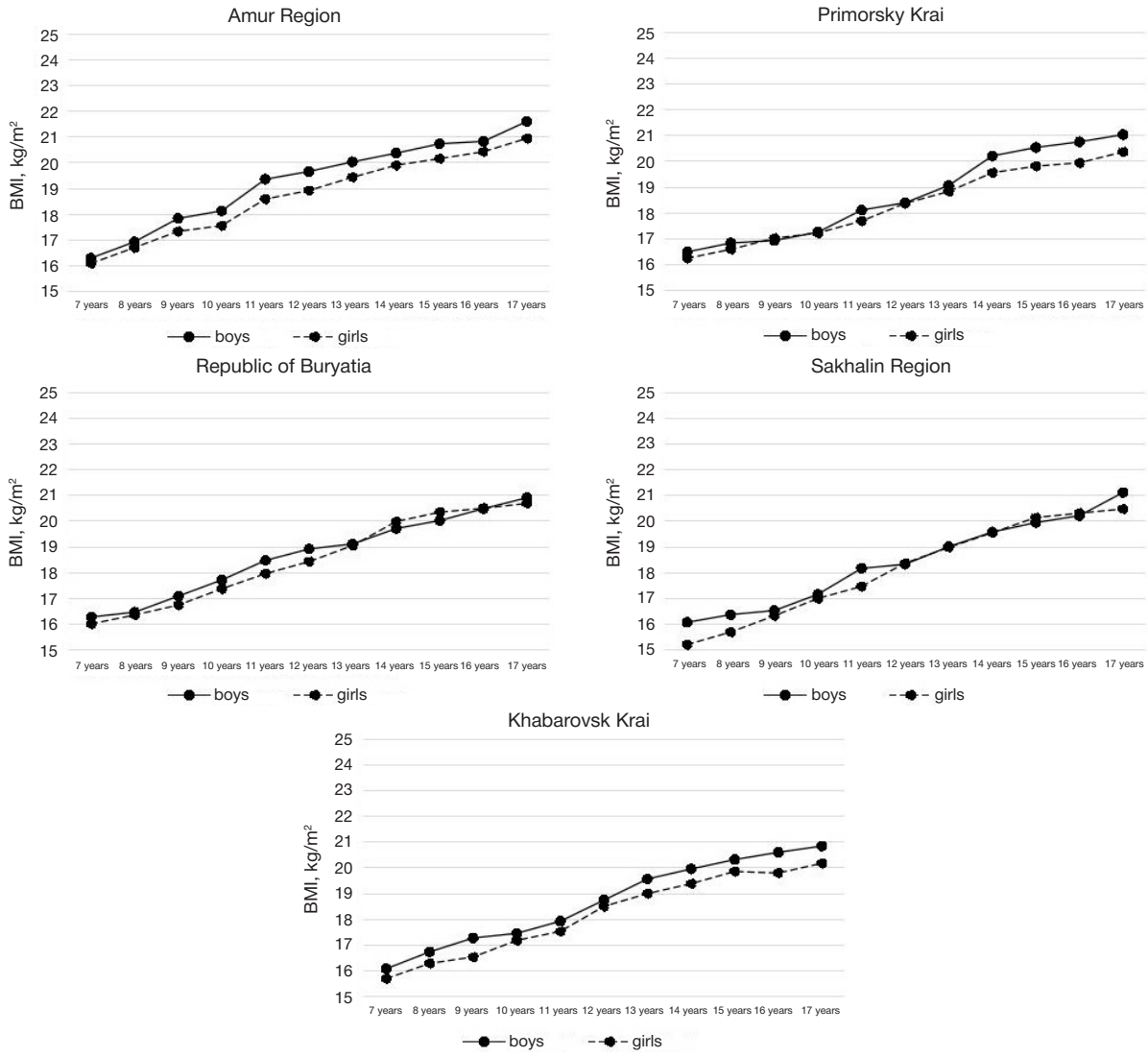

Fig. 8. Body mass index (BMI) formation in children and adolescents of the Far Eastern Federal District (FEFD), kg/m²

CONCLUSIONS

During the study the regional features of body mass index (BMI) formation in children and adolescents aged 7–17 years have been considered for the first time based on the big data analysis in 50 constituent entities of the Russian Federation (RF). It has been shown that BMI has a higher value, the lower the place of the subject of the RF in terms of gross regional product.

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THE STRATEGY FOR SCIENTIFIC SUPPORT IN IMPLEMENTING STATE POLICY ON OPTIMIZING POPULATION NUTRITION

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The article presents the authors' opinion on ways to optimize the nutrition of the population of the Russian Federation. It shows that the dietary patterns currently common in the country are still far from optimal, as they underdeliver on vegetables, fruits, and dairy products, and provide excessive amounts of sugar, salt, foods rich in animal fat, and trans fats. Inadequate dietary patterns compromise health and nutritional status, leading to an increase in diet-related diseases such as cancer, cardiovascular diseases, type 2 diabetes, obesity, gout, and osteoporosis, which are major contributors to mortality in economically developed countries, including Russia. According to the authors, there are several aspects that are crucial in the matter of overall health improvement and extension of active longevity: optimization of the dietary patterns in Russia, popularization of the principles of rational nutrition and healthy lifestyle; introduction of measures to decrease the incidence of socially significant non-communicable diseases (atherosclerosis, cardiovascular diseases, hypertension, type 2 diabetes mellitus, nutritional obesity, and others); acceleration of adoption of innovative health protection technologies in healthcare, including early diagnosis of non-communicable diseases of an alimentary nature, their targeted prevention and treatment.

Keywords: nutrition optimization, nutritional status, health care, alimentary-dependent diseases, nutriome

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Author contribution: Tutelyan VA — article concept, editing, approval of the final version thereof; Nikityuk DB — article concept, design, editing; Tarmayeva IYu — article authoring, ensuring its integrity; Pogozheva AV — authoring of the article and annotations, preparation of the final version thereof.

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СТРАТЕГИЯ НАУЧНОГО ОБЕСПЕЧЕНИЯ РЕАЛИЗАЦИИ ГОСУДАРСТВЕННОЙ ПОЛИТИКИ В ОБЛАСТИ ОПТИМИЗАЦИИ ПИТАНИЯ НАСЕЛЕНИЯ

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Федеральный исследовательский центр питания, биотехнологии и безопасности пищи, Москва, Россия

В статье изложено мнение авторов о путях оптимизации питания населения Российской Федерации. Продемонстрировано, что в настоящее время традиционная структура питания населения страны все еще далека от оптимальной, что связано с недостаточным содержанием в рационе овощей и фруктов, молочных продуктов на фоне избыточного количества сахара, соли, продуктов, богатых животным жиром и трансжирами. Нарушение структуры питания приводит к негативным последствиям для здоровья, пищевого статуса, постоянному прогрессированию числа алиментарно-зависимых заболеваний, таких как онкологические, сердечно-сосудистые, сахарный диабет 2-го типа, ожирение, подагра, остеопороз и др., которые являются основными причинами смертности населения экономически развитых стран, в том числе и России. Для повышения уровня здоровья и качества жизни, продления периода активного долголетия, по мнению авторов, наиболее важное значение имеют следующие аспекты: оптимизация питания населения России, внедрение принципов рационального питания и здорового образа жизни в общественную практику; снижение заболеваемости социально значимыми неинфекционными заболеваниями (атеросклероз, сердечно-сосудистые заболевания, артериальная гипертония, сахарный диабет 2-го типа, алиментарное ожирение и др.); ускорение внедрения в практику здравоохранения инновационных здоровьесберегающих технологий, включая раннюю диагностику неинфекционных заболеваний алиментарной природы, их направленную профилактику и лечение.

Ключевые слова: оптимизация питания, пищевой статус, здоровьесбережение, алиментарно-зависимые заболевания, нутриом

Финансирование: исследование выполнено в рамках государственного задания FGMF-2023-0002.

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Optimization of nutrition of the population is one of the priorities in the Russian Federation's state health preservation policy.

Unfortunately, the dietary patterns currently common in the country are still far from optimal, as they underdeliver on vegetables, fruits, and dairy products, and provide excessive amounts of sugar, salt, foods rich in animal fat, and trans fats [1].

Recent research revealed that inadequate dietary patterns compromise health and nutritional status, leading to an increase in diet-related diseases such as cancer, cardiovascular diseases, type 2 diabetes, obesity, gout, and osteoporosis, which are major contributors to mortality in economically developed countries, including Russia [2].

The analysis of data from epidemiological studies conducted at the Federal Research Center for Nutrition, Biotechnology and Food Safety allows identifying several factors that hinder the development of a conscious need to eat properly:

– continuity of improper dietary patterns in the families and society in general;

– insufficient knowledge about proper nutrition;

– unreliable, incorrect, contradictory information about nutrition given by the media;

– active advertising, availability and a wide range of foods with improper content of critically important nutrients.

Given the current situation, it is necessary to boost the scientific efforts supporting popularization of proper nutrition and spread of information about it; these efforts are also aligned with the goals set by the Decree of the President of the Russian Federation of 25.04.2022 No. 231 "On Declaring the Decade of Science and Technology in the Russian Federation", the Demography national project, Order of the Ministry of Health of the Russian Federation of 15.01.2020 No. 8 "On Approval of the Strategy for Promotion of Healthy Lifestyle in the Population, Prevention and Control of Non-Communicable Diseases up to 2025" [3–5].

According to the Decree of the President of the Russian Federation of 18.06.2024 No. 529 "On Approval of Priorities and the List of the Most Important High-End Technologies," one of the main directions for scientific and technological evolution of Russia involves development of "preventive and personalized medicine, ensuring healthy longevity," which is further supported by the goal of preserving the people of Russia and developing human potential of the country, formulated as a strategic national priority. The implementation of these plans and the achievement of this goal primarily involve establishing a foundation for sustainable natural population growth in the Russian Federation and increasing life expectancy. Thus, the main purpose of the Long and Active Life national project is to increase the average life expectancy of the Russian population to 78 years by 2030 and to 80 years by 2036.

Currently, the following aspects are most important for improving health and quality of life of the population, as well as prolonging active longevity therein:

– optimization of the dietary patterns practiced by the Russian population, implementation of the principles of rational nutrition and healthy lifestyle;

– reduction of the incidence of socially significant non-communicable diseases (atherosclerosis, cardiovascular diseases, hypertension, type 2 diabetes, nutritional obesity, etc.);

– acceleration of adoption of innovative health-saving technologies in healthcare, including early diagnosis of non-communicable diseases of alimentary nature, their targeted prevention and treatment.

Federal Research Center for Nutrition, Biotechnology and Food Safety conducted fundamental, exploratory, and applied research in this area, and achieved the results described below.

First-ever formalization of the concept of nutriome as a set of nutritional factors necessary to maintain a dynamic balance between humans as an evolution-shaped biological species and the environment, with the purposes thereof being the support of vital activity, procreation and preservation of the species, maintenance of the body's adaptive potential, antioxidant defense system, apoptosis, metabolism, and the immune system function [6, 7].

Clarification of the human being's need for energy and nutrition, with the updated knowledge underpinning the newly formulated methodological recommendations "Standard Physiological Need for Energy and Nutrition among Various Population Cohorts of the Russian Federation" (MR 2.3.1.0253-21), which became the basis for the development of a new edition of the Decree of the Ministry of Health of Russia No. 614 "Rational Standards of Food Consumption Meeting Current Healthy Nutrition Requirements (Recommendations)" [8, 9].

Identification of the fundamentally new mechanisms of interaction of biologically active substances and their effect on the body, as well as proving their essential properties (L-carnitine, dihydroquercetin, polyunsaturated fatty acids, polyphenols, flavonoids, vitamins, etc.) [10, 11].

In progress: metagenomic studies of the intestinal microbiome as it relates to the features of nutrition, including in case of alimentary-dependent diseases [1].

We formalized a fundamentally new scientific field of medicine: anthroponutriology. It emphasizes the leading role of nutritional factors in physical development and enables personalized optimization of nutrition and lifestyle, accounting for the parameters of basic metabolism, muscle function, which generally determine the risk factors for cardiovascular, endocrine, gastroenterological diseases, diseases of the musculoskeletal system (depending on the somatotype). We conducted a comprehensive examination of the nutritional status and functional capacity of top tier athletes, discovered basic-level flaws in the structures of their diets, and suggested personalized remedial measures. The effectiveness of immunity boosting biologically active substances (L-carnitine, coenzyme Q10, anthocyanins, capsaicin, ginsenosides, etc.) was proven in experiments that involved athletes practicing various sports, with their current professional activity phase factored in [12–14].

Development of an interdisciplinary approach to early prevention of obesity based on the knowledge of nutritional factors triggering obesity in childhood, including in breastfed children; the approach was incorporated into methodological recommendations "Early Prevention of Obesity in Children." The results of the respective research are included in the "Program of Optimization of Feeding of Children in the First Year of Life in the Russian Federation" and the "Program of Optimization of Nutrition of Children Aged 1 to 3 years in the Russian Federation." There were developed approaches to dietary therapy of epilepsy for children based on the ketogenic diet, which are included in the clinical recommendations "Glut1 deficiency syndrome." Studies of the eating behavior of schoolchildren and the factors that determine it are the basis of methodological recommendations MR 2.4.0312-22 "Additional Nutrition in Educational and Health Organizations for Children." Long-term studies of the nutrition of women during pregnancy and breastfeeding formed the basis of the monograph "Nutrition of Pregnant and Lactating Women. Breastfeeding" [15–17].

Investigation of the risk factors for development of osteoporosis in children with chronic liver diseases, including concomitant pathologies, drug therapy associated with the development of osteoporosis, decreased physical activity, and insufficient intake of calcium and vitamin D with food [18].

Investigation of the allergens that cause food allergies in children and adolescents. There were suggested methods of step-by-step diet therapy that promote the formation of oral tolerance, and developed formulations of alternative food products for patients with food allergies that enable diet therapy personalization and malnutrition prevention; The research efforts also studied the biomarkers of immune inflammation that predict the development of severe clinical manifestations of food allergy [19–21].

The analysis of single nucleotide polymorphisms that enabled molecular-level examination of the role played by nutrition in maintaining health or developing various diseases; together with clinical, molecular biological and epidemiological studies, it is important to the matter of nutrition optimization. The use of nutrigenomics methods allowed understanding the significance of interaction of genes and food components in the etiology and pathogenesis of obesity, which is a significant risk factor for cardiovascular diseases, type 2 diabetes, etc. Differences in the frequency of occurrence of gene

polymorphisms associated with obesity have been established for the regions of the Russian Federation. Studies have shown the role of the said polymorphisms in the development of nutritional deficiencies, including those associated with insufficient amounts of vitamins (in particular, vitamin D). There were established the diagnostically valuable features of gene polymorphism in obese patients, including those with type 2 diabetes; low vitamin D availability, anxiety and depression have been discovered in patients with obesity and degenerative spinal diseases [1, 22].

Study of the nutritional risk factors for non-alcoholic fatty liver disease, with description of the characteristic nutritional patterns that increase the risk of the disease, and design of innovative specialized food products to correct the said patterns that enable effective treatment and prevention of non-alcoholic fatty liver disease and its complications [23].

The results of 10 years of research on chemical composition of Russian-made food products conducted by the Federal Research Center for Nutrition, Biotechnology and Food Safety are summarized in the 4th edition of the "Chemical Composition of Russian Food Products" reference book. The book was developed and prepared for publication as part of the implementation of the "Public Heath Reinforcement" federal project of the Demography national project, with the participation of the Federal Service for the Oversight of Consumer Protection and Welfare (Rospotrebnadzor). Industry research institutes and unions of manufacturers of various food products also took part in the work on the reference book. For the first time, a printed publication provides data on the composition of specialized food products present on the Russian consumer market; the new edition also contains significantly reviewed and updated data on the composition of bread, fish and fish products, dairy products, fruits and vegetables [24].

The "Strategy for Improving the Quality and Safety of Food Products in the Russian Federation until 2030", approved by Decree of the Government of the Russian Federation of 29.06.2016 No. 1364-r (hereinafter referred to as the Strategy), along with the action plan for its implementation approved by Decree of the Government of the Russian Federation of 19.04.2017 No. 738-r, promote healthy dietary patterns in different Russian population cohorts. The strategy is focused on providing adequate nutrition, preventing diseases, increasing the duration and improving the quality of life, stimulating the development of production and sales of food products of proper quality on the market.

There were developed and implemented methodological recommendations MR 2.3.0122–18 "Color Coding Food Labels for Consumer Information"; they contain unified approaches to colors used on food labels depending on the content of critically important substances in it, including added sugar, salt, saturated fatty acids, and transisomers of fatty acids (measured against the recommended daily intake), which allows raising the consumers' awareness and enables them to make an informed and correct choice of foods for a healthy diet [25].

One of the most important tasks of the state policy is to saturate the consumer market with high-quality food products to ensure proper nutrition of the population, prevent diseases, and stimulate the development of production.

In order to optimize the provision of micronutrients to the Russian population and prevent vitamin deficiency, it is advisable to legislate fortification with vitamin D and B vitamins of mass-consumption foods such as bread and milk. Fortification of the diet is a strategy that is safe and effective in prevention or minimization of micronutrient deficiencies. There have been developed several approaches to this practice [26, 27].

Biofortification involves increasing the micronutrient value of food products through plant or animal breeding, use of genetic engineering, agronomic techniques relying on fertilizers or protective agents, and the enrichment of farm animal feed with micronutrients. Under this approach, the micronutrient, entering the animal's body, goes through biotransformation, and is ultimately consumed by humans in its natural form, which negates the arguments of opponents of the use of synthetic vitamins.

In high-income countries, along with application of this approach, the food has been artificially fortified for more than 100 years now: essential micronutrients (vitamins and mineral salts) are added thereto during production. Large-scale fortification means the mandatory or voluntary addition of micronutrients that are scarce in the usual diet of a given population, with the target foods being those most commonly consumed. The purpose of large-scale fortification is to reduce the frequency and severity of micronutrient deficiency and correct micronutrient-related disorders in the general population. The effectiveness of mandatory food fortification depends on the initial saturation of the population with micronutrients, the incidence of deficiency-related conditions, the correct choice of the product to be fortified, which depends on its share in the diet structure, habits of the population and its availability thereto, effectiveness of quality control, degree of fortification, and regular monitoring and evaluation of consumption of the fortified products.

There is scientific and practical evidence that the use of fortified mass-produced foods increases the amount of micronutrients consumed (their blood serum content grows), and reduces the incidence of anemia, goiter, and the likelihood of neural tube defects. According to the "Fundamentals of Russia's State Policy in the Field of Healthy Nutrition," the proportion of foods fortified with vitamins and minerals should be 50% of the total output of bread, but until recently, the share of bakery products high in vitamins and minerals was insignificant. Expanding the range and increasing the produced volume of fortified foods will improve micronutrient consumption in the country, provided the consumers make informed choices of micronutrient-rich products.

Increasing the market share of foods with preventive properties, which have a special chemical composition, will help to solve the micronutrient deficiency problem, reduce calorie counts, and improve the nutritional density of the diet both in organized groups and in individual consumption. In recent years, the range of such products has grown significantly, but they are often designed without regard to the preventive goals and lacking the necessary medical and biological justification of the composition and declared properties. The range of vitamin-like and minor food components with antioxidant properties used in the formulation is expanding. There are foods with processed fruit and berry materials (pomace, black currant berries, etc.) that combine the properties of two types of substances, dietary fiber and antioxidants, as functional components [28].

It is necessary to implement measures aimed at explaining to the population the importance of micronutrients and consumption of vitamin-mineral supplements and fortified foods. There is an obvious need for a state-level integrated approach to the design of fortified mass-consumption and specialized products. It is important to develop a system of recommendations for the food industry that defines

the priorities in the field of forming healthy diets and providing the population with all essential nutrients, with an emphasis on micronutrients.

In this area, a serious problem is the virtually lacking domestic production of food ingredients and substances (protein isolates and concentrates, amino acids, vitamins, food additives, enzyme preparations, biologically active substances, starter cultures, and probiotic microorganisms). The nation still depends on imports of vitamin-mineral polyunsaturated fatty acids, premixes, long-chain nucleotides, and prebiotics (oligosaccharides). One of the solutions to the problem of import substitution in this sector of the food industry is the restoration of the domestic biotechnological industry [25].

We believe that implementation of "Health for Everyone" federal project would benefit from measures seeking to develop and deploy high-end technologies for personalized, therapeutic, and functional nutrition designed for health preservation, which would be directly related to the creation of innovative food products and their mass production.

In 2021, devised by the Presidium of the Russian Academy of Sciences and the Federal Research Center for Nutrition, Biotechnology and Food Safety, there was launched the "Health Preservation, Nutrition, Demography" consortium, which is an effective tool creating conditions needed to fully commercialize and mass-produce the newly developed foods for personalized and functional nutrition. It is a comprehensive, full-cycle R&D project that includes activities from fundamental and exploratory research in the field of specialized food products for all groups of the Russian population to large-scale production and saturation of the country's consumer market with them. This project is being implemented under the leadership of the Russian Academy of Sciences with the support of the Russian Ministry of Education and Science, the Russian Ministry of Health, and Rospotrebnadzor. Its direct participants as industrial partners are domestic producers of fortified and specialized food products, as well as raw materials components.

The number of industrial partners of Consortium increases every year, which indicates a growing interest the Russian business has towards research and innovative activities in the field of high-end technologies for personalized, therapeutic, and functional nutrition products for health preservation.

CONCLUSION

Thus, the problem of optimizing the nutrition of the Russian population and ensuring the quality of domestic food products is intersectoral and interdisciplinary. It has to do with implementation of the state policy in the field of food safety and public health, and finding the right solution thereto requires an integrated approach and interdepartmental interaction of the Russian Academy of Sciences with the Ministry of Education and Science of the Russian Federation, the Ministry of Health of the Russian Federation, Rospotrebnadzor, and other interested federal executive authorities, with the participation of the Federal Research Center for Nutrition, Biotechnology and Food Safety and other specialized research centers.

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ASSESSING TOXICITY AND HAZARD OF AGIDOL-1, THE VITAMIN E SYNTHETIC ANALOGUE

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Agidol-1 belongs to non-enzymatic antioxidants and represents a synthetic vitamin E analogue, it is widely used in chemical and food industries, livestock production, cosmetology, perfumery and pharmaceutical production. The increase in its production is a prerequisite for creating optimal working conditions for employees and developing the currently not existing hygienic standard of the tentative safe exposure level (OBUV) in workplace air. The study aimed to develop and substantiate agidol-1 OBUV in workplace air through experimental study of toxicity and hazard. We studied toxicity, irritant, skin-resorptive effects and hazard of agidol-1 concentrations of 24.7 and 67.8 mg/m^3 after a single inhalation. Integrated indicators and functional indicators of some organs and systems were assessed in rats after inhalation. It has been shown that based on toxicometry data (DL_{50}) after a single intragastric injection to mice agidol-1 is a moderately dangerous substance (hazard class 3), while when administered to rats it is a slightly dangerous substance (hazard class 4). The substance has no irritant effect on the rabbit ocular mucosa and skin, it does not possess skin-resorptive or cumulative activity. Inhalation of agidol-1 concentrations of 24.7 and 67.8 mg/m^3 has no toxic effect on the nervous, carviovascular, and respiratory systems, it does not alter peripheral blood composition and biochemical parameters of blood serum and urine. The lack of agidol-1 harmful effects in the study, availability of MPC levels in ambient air for the Agidol brand substances with the chemical composition similar to that of agidol-1 and hygienic standards for agidol-1 in different countries have made it possible to substantiate OBUV for production facilities of 10 mg/m^3, aerosol, hazard class 4.

Keywords: agidol-1, toxicity, hazard, hygienic standardization

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Compliance with ethical standards: the experimental study was compliant with the necessary legal acts (Declaration of Helsinki 2013, GOST 33044-2014 “Principles of Good Laboratory Practice”; Order of the Ministry of Health of the RF No. 188n of 01.04.2016 “Rules of Good Laboratory Practice”). The study was approved by the Ethics Committee of the Pirogov Russian National Research Medical University (protocol No. 10/23 dated 15 May 2023).

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ИЗУЧЕНИЕ ТОКСИЧНОСТИ И ОПАСНОСТИ АГИДОЛА-1 — СИНТЕТИЧЕСКОГО АНАЛОГА ВИТАМИНА Е

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Агидол-1 относится к неферментным антиоксидантам и является синтетическим аналогом витамина Е, он широко используется в химической и пищевой промышленности, животноводстве, косметологии, парфюмерной промышленности и фармацевтике. Увеличение объемов его производства является предпосылкой для создания оптимальных условий труда работников и разработки отсутствующего в настоящее время гигиенического норматива — ориентировочный безопасный уровень воздействия (ОБУВ) в воздухе рабочей зоны. Целью работы было разработать и обосновать ОБУВ агидола-1 в воздухе рабочей зоны посредством экспериментального изучения токсичности и опасности. Изучены токсичность, раздражающее, кожно-резорбтивное действие и опасность агидола-1 в концентрациях 24,7 и 67,8 мг/м^3 после однократной ингаляции. После ингаляции у крыс оценивали интегральные показатели и функциональные показатели отдельных органов и систем. Установлено, что по показателям токсикометрии (DL_{50}) при однократном внутрижелудочном введении мышам агидол-1 относится к умеренно опасным веществам (3-й класс опасности), а при введении крысам — к малоопасным веществам (4-й класс опасности). Вещество не оказывает раздражающего эффекта на слизистую оболочку глаза и кожу кролика, не обладает кожно-резорбтивным действием и кумулятивной активностью. Ингаляция агидола-1 в концентрациях 24,7 мг/м^3 и 67,8 мг/м^3 не оказывает токсического действия на нервную, сердечно-сосудистую и дыхательную системы, не изменяет состав периферической крови и биохимические параметры сыворотки крови и мочи. Отсутствие вредных эффектов агидола-1 в проведенном исследовании, наличие ПДК в атмосферном воздухе для веществ марки «Агидол», близких по химическому строению к агидолу-1, а также гигиенических нормативов агидола-1 в разных странах позволили обосновать ОБУВ для производственных помещений 10 мг/м3, аэрозоль, 4-й класс опасности.

Ключевые слова: агидол-1, токсичность, опасность, гигиеническое нормирование

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Synthetic non-enzymatic antioxidants are widely used in almost all areas of human life and activity, and the importance of those is constantly growing. Their effects aim to inhibit oxidative activity of free radicals and other substances, since oxidative processes can impair the properties of polymeric materials, oils used in industry, reduce the quality of food products, etc. [1–3]. Antioxidants play an important role in comprehensive approaches to disease treatment and prevention allowing one to adjust the diet and prevent a number of disease processes in the body [4].

Antioxidants are extensively used as food additives to improve stability of food products. These ensure extended shelf life of food products, preservation of nutritional value, natural color and flavor. Antioxidants are contained in pharmaceutical and cosmetic preparations, these are used in livestock production when producing animal feed and to increase productivity [5–9].

In addition to natural antioxidants, an example of which is vitamin E in foods, there are antioxidants obtained through organic synthesis, i. e. synthetic ones, such as propyl gallate (PG, E310), tert-butylhydroquinone (TBHQ, E319), butylated hydroxyanisole (BHA, E320), and butylated hydroxytoluene (BHT, E321). The latter, BHT or agidol-1 represents one of widely demanded synthetic antioxidants.

It is used to produce petroleum products, synthetic rubbers, plastics, elastomers, oils, waxes, soap, paints, and ink [1, 2]. Agidol-1 is a synthetic vitamin E analogue registered and licensed for cosmetics and packaging materials, food products and animal feed. Thus, in cosmetology, it is used as an additive when producting suppositories, creams, gels, and skin care products [10–12]. Manufacture of cosmetics, perfumes and pharmaceuticals, food products (food additive E321) require the use of agidol-1 having a Vulkanox BHT GMP Grade specification, which ensures microbiological purity of the product and the quality compliant with the HACCP (Hazard Analysis and Critical Control Points), GMP standards.

Agidol-1 as a food additive E321 is widely used to produce various confectionery, dairy products, soft drinks, alcoholic beverages, etc. The E321 food additive content standards have been established for food products, which are 100–200 mg/kg of the final product, and permissible daily intake of E321 with food products of 0.125–0.3 mg/kg/day [13–15].

Taking into account the widespread use of agidol-1 as a synthetic antioxidant and the increase in its production, it is necessary to develop a hygienic standard (tentative safe exposure level, OBUV) in workplace air, which is currently unavailable. In turn, OBUV substantiation is an essential requirement for creating optimal working conditions for workers in chemical, food and chemical-pharmaceutical industries.

The study aimed to perform experimental assessment of agidol-1 toxicity and hazard in order to estimate its workplace safety.

METHODS

Butylated hydroxytoluene (Butylhydroxytoluenum, BHT), the aromatic hydrocarbon, phenol derivative ($C_{15}H_{24}O$), was the study object. Its chemical names are as follows: 2,6-bis(1,1-dimethylethyl)-4-methylphenol; 2,6-Di-tert-butyl-4-methylphenol; 2,6- Di-tert-butyl-4-hydroxytoluene; 2,6- Di-tert-butyl-p-cresol. Synonims: Dibunol, Ionol. CAS: 128-37-0, molecular weight 220.35 g/mol. Tradenames: agidol-1 crystal mark A; food additive E321. This is a white crystalline substance, odorless or with a characteristic faint odor. T_m = 69–73 °C. It is almost insoluble in water, soluble in 96% alcohol, acetone, organic solvents, esters, fats [16–19].

Determination of the dispersion of agidol-1 dust particles has shown that the sample of the test substance is homogeneous, it consists mainly of large particles (1000 μm and more), the presence of a small number of medium size particles (about 20–100 μm) has been reported; the ratio of the first and the latter is 9 : 1. The mixture of substance particles after mechanical grinding was used for inhalation: particles sized 50–200 μm (70%), 10–50 μm (20%), and less than 10 μm (10%).

Experimental studies of toxicometry parameters and prediction of safe industrial exposure levels were conducted in accordance with the current legislation [20–23]. The experiments involved laboratory animals: outbred white mice and white rats, albino guinea pigs, chinchilla rabbits (Andreevka branch of the Scientific Center for Biomedical Technologies of FMBA of Russia). The animals quarantined for 10 days were kept under standard vivarium conditions with ad libitum access to water and food.

The agidol-1 toxicometry parameters (DL_{50}) were determined when performing intragastric administration of the substance to both male and female mice (24 males, 18 females) and male rats (18 animals), as well as when performing intraperitoneal administration to male mice (24 animals). The DL_{50} determination groups consisted of 6 animals each. The average lethal doses were calculated by probit analysis modified by V.B. Prozorovsky.

The irritant effect was assessed through a single injection of 50 mg of the substance into the conjunctival sac of the rabbit eye (3 animals), while the skin irritant effect was assessed through a single or repeated application of 500 mg of the substance in the form of suspension in starch gel (1 : 1) to the depilated skin of the rabbit back (3 animals) for 4 h. The skin-resorptive activity of the substance was assessed in male mice by dipping 2/3 of the tail length in the test substance suspension in starch gel, i.e. by the test-tube method. Tails of the control mice were dipped in the starch gel. The control and experimental groups consisted of 6 animals each. The 2-h applications were made daily throughout 4 weeks (5 days a week). The agidol-1 cumulative activity was assessed in male mice with intragastric administration of the increasing doses of the test substance in starch gel throughout 24 days by the method by Lim et al. [24]. Initial dose was 150 mg/kg (0.1 DL_{50}). The control animals were subjected to intragastric administration of starch gel. Experimental groups consisted of 10 animals each.

Taking into account low melting point (69–73 °C) of the studied agidol-1, we studied inhalation hazard of the substance under conditions of static inhalation. Single inhalations of outbred male rats were performed in the specialized sealed 200 L chambers for 4 h. Each group consisted of 8 animals. To record manifestations of poisoning in rats, integral parameters (body weight, body temperature), indicators of functional state of certain organs and systems (nervous, cardiovascular and respiratory systems), peripheral blood composition, liver and kidney function were estimated.

To assess the nervous system functional state, the summation threshold index (STI) estimation by the method by S.V. Speransky was used [22], along with the complex of behavioral responses in the open field test and the test in the dark chamber with holes [23]. Respiratory rate (RR), heart rate (HR) were recorded; blood pressure (BP) was measured, and rectal body temperature was determined. The BC-2800 Vet hematology analyzer (Mindray; China) was used to record red blood cell, white blood cell, and platelet counts, hematocrit and the white blood cell differential components: relative lymphocyte, neutrophil, eosinophil, monocyte, and basophil counts.

To assess functional state of the liver in experimental animals, serum glucose, total protein, albumin, and cholesterol levels were determined, as well as enzyme activity (alanine

Table 1. Agidol-1 acute toxicity parameter, intragastric and intraperitoneal administration

Вид, пол животных	Administration route	DL_{16}, mg/kg	DL_{50}, mg/kg	DL_{84}, mg/kg
Male mice	intragastric	715	1550	2400
Female mice	intragastric	1550	2290	3020
Male rats	intragastric	–	> 5000	–
Male mice	intraperitoneal	200	480	757

aminotransferase (ALT), aspartate aminotransferase (AST), alkaline phosphatase (AP)). Functional state of kidneys was assessed based on the 17 h urine output following the 4% water load, as well as based on the urinary protein and chloride levels; urinary pH and the levels of urea and electrolytes (Na, K, and Ca) in blood serum and urine were determined. Electrolyte concentration was determined using the PFM flame photometer (ZOMZ; USSR). Urinary pH was determined using the Kelilong automated pH meter (Kelilong; China) for small amounts of urine.

Statistical processing of the results was performed using the StatTech software package (StatTech; Russia) in order to determine significant differences in the reported responses of experimental and control animals under exposure to the drug using Student's *t*-test in accordance with the 95% ($p > 0.05$) confidence level taking into account the number of animals used in each experiment.

RESULTS

Determination of acute toxicity parameters after intragastric administration revealed species differences in susceptibility of rats and mice to agidol-1. DL_{50} for rats exceeded 5000 mg/kg (hazard class 4, slightly dangerous substances, GOST 12.1.007-76), in male mice it was 1550 mg/kg, and in female mice it was 2290 mg/kg (hazard class 3, moderately dangerous substances, GOST 12.1.007-76) (Table 1). Death of mice was reported on days 5–8 after intragastric administration of the substance. There were no clinical manifestations of poisoning, only weight loss (up to 10–15%) was reported. In case of intraperitoneal administration to male mice, DL_{50} is 480 mg/kg (according to classification by K.K. Sidorov, the substance belongs to class 4 of slightly toxic substances) [25] (Table 1).

Agidol-1 had no irritant effect on the eye mucosa and the skin (after the single and repeated application). No signs of the skin-resorptive or cumulative activity was reported, a single exposure to the agidol-1 saturated vapor caused no changes in the overall state, animals' behavior, and body's functional indicators (RR, STI, body temperature).

To determine the minimal effective concentrations (Lim_{ac}), two concentrations of the agidol-1 aerosol were tested: 24.7 ± 5.6 mg/m^3 and the maximum achievable concentration of 67.8 ± 12.5 mg/m^3. No deaths of laboratory animals were reported during the experiments. There were no differences in appearance and overall state between the experimental and control rats. No effects of the substance on the rectal body temperature and the studied physiological indicators (RR, STI, BP, HR) or behavioral responses were reported.

Biochemical testing of the animals' blood serum components revealed no increase in hepatic enzyme activity, as well as in the levels of protein, albumin, cholesterol, glucose, metabolism and synthesis of which involve the liver (Table 2). There was also no renal function impairment when inhaling agidol-1 in both concentrations: no significant differences in urine biochemistry parameters between experimental groups and the controls were reported (Table 3).

There were no differences in peripheral blood hemoglobin levels, red blood cell counts, hematocrit, platelet and white blood cell counts between experimental groups of rats and the controls (Table 4). The experimental rats' leucogram shows no differences from controls.

Thus, inhalation of agidol-1 concentrations of 24.7 mg/m^3 and 67.8 mg/m^3 (maximum achievable) had no harmful effect on the animals' overall state, functional state of the nervous, cardiovascular, and respiratory systems, as well as on peripheral blood composition and biochemistry parameters of blood serum and urea. No acute inhalation effect threshold was determined during the experiment, therefore the acute effect threshold Lim_{ac} of agidol-1 > 67.8 mg/m^3.

DISCUSSION

Agidol-1 being a representative of synthetic non-enzymatic antioxidants is widely used in various various industries, including chemical, pharmaceutical, food, medicine, and livestock production [15–17]. In this regard, a goal was set for the study to develop the agidol-1 safe exposure level in workplace air for industries involving synthesis and its use. Based on the mechanism

Table 2. Blood serum biochemistry parameters in male rats following a single agidol-1 inhalation, M ± *m* (*n* = 8)

Indicators	Units	Control	Concentration, mg/m^3	
			24.7 ± 5.6	67.8 ± 12.5
Glucose	mM/L	5.11 ± 0.12	5.08 ± 0.13	4.89 ± 0.11
Cholesterol	mM/h·L	2.23 ± 0.07	2.21 ± 0.06	2.18 ± 0.09
Urea	mM/L	8.48 ± 0.13	8.35 ± 0.16	8.21 ± 0.18
Total proteins	g/L	63.35 ± 1.13	63.03 ± 0.83	62.77 ± 1.03
Albumins	g/L	33.28 ± 0.73	33.09 ± 0.55	32.85 ± 0.93
ALT	mM/h·L	1.08 ± 0.03	1.11 ± 0.04	1.07 ± 0.02
ASP	mM/h·L	3.62 ± 0.05	3.68 ± 0.08	3.71 ± 0.09
AP	mM/h·L	7.14 ± 0.16	7.26 ± 0.12	7.37 ± 0.14
Sodium	mM/L	128.3 ± 0.75	128.2 ± 1.06	128.6 ± 0.93
Potassium	mM/L	6.59 ± 0.12	6.55 ± 0.09	6.43 ± 0.11
Calcium	mM/L	2.03 ± 0.02	2.04 ± 0.01	2.02 ± 0.03

Table 3. Urine biochemistry parameters in male rats following a single agidol-1 aerosol inhalation, M ± *m* (*n* = 8)

Indicators	Units	Control	Concentration, mg/m³	
			24.7 ± 5.6	67.8 ± 12.5
Urinary output	mL	5.42 ± 0.67	5.63 ± 0.46	6.01 ± 0.58
Urinary pH	U	7.02 ± 0.11	6.83 ± 0.13	6.92 ± 0.17
Protein	mg/L	31.23 ± 1.74	32.48 ± 1.53	32.85 ± 2.18
Chlorides	mM/L	45.12 ± 2.15	47.03 ± 1.68	50.05 ± 2.17
Urea	mM/L	473.5 ± 17.38	468.8 ± 14.21	482.9 ± 18.25
Urea clearance	mL/min	0.30 ± 0.03	0.32 ± 0.02	0.35 ± 0.03
Sodium	mM/L	45.08 ± 1.56	46.13 ± 1.72	48.52 ± 1.51
Potassium	mM/L	32.23 ± 1.67	32.82 ± 1.26	34.69 ± 1.53
Calcium	mM/L	0.38 ± 0.03	0.39 ± 0.02	0.41 ± 0.03

of action agidol-1 is like natural vitamin E, it is also a hydrogen atom donor and converts peroxide radicals into hydroperoxides, and the agidol-1 molecule deactivates two peroxide radical molecules. Being a synthetic analogue of vitamin E, it nevertheless effectively suppresses autocatalytic processes of radical oxidation of various materials and products.

Agidol-1 is easily absorbed through the gastrointestinal tract. After the long-term consumption of foods containing the antioxidant it accumulates in the adipose tissue and the liver with the half-life of 7–10 days. Agidol-1 is excreted mainly in urine and to a lesser extent in feces [13]. The study of the dispersion of the agidol-1 sample presented has shown that it is almost homogenous based on the particle size and is represented mainly by very large particles (about 1000 μm and more). The ratio of large and medium particles is 9 : 1, which can indicate the lack of the ability to penetrate into the lower respiratory tract and elimination of agidol-1 in the upper respiratory tract. The substance is almost insoluble in water, which also makes it difficult for it to enter the lung tissue. The findings on dispersion suggest the lack of negative agidol-1 aerosol effects when inhaled.

Experimental data on toxicometry and the substance hazard assessment confirm the above. It has been shown that based on the acute toxicity (DL_{50}) reported following intragastric administration to mice and rats agidol-1 belongs to moderately dangerous and slightly dangerous substances (hazard classes 3 and 4, GOST 12.1.007-76) respectively, which is fully in line with the literature data [18, 26–28]. Agidol-1 had no irritant effect on the rabbit skin and eye mucosa, the experiment revealed no skin-resorptive or cumulative activity.

According to the literature data, agidol-1 and agidol-0 (2,6-di-tert-butylphenol, the basic raw material for obtaining agidol-1 and other effective phenolic antioxidants) do not possess skin-resorptive or cumulative activity. The available literature data on the irritant effects of agidol-1 are slightly different. Most of authors note a weak irritant effect on the rabbit eye mucosa and skin [13, 16, 28, 29], however, a number of researchers report the lack of such effect [26, 30]. A single exposure to agidol-1 saturated vapor causes no changes in behavior or functional indicators of the animal's body (RR, STI, body temperature).

The literature data analysis shows that the prolonged or repeated use of high-dose BHT (agidol-1) can affect the function and structure of the lung, liver, kidney, result in hyperfunction of the thyroid gland, adrenal glands, cause alteration of peripheral blood composition (red blood cell counts), blood serum composition, as well as lead to weight. The authors believe that liver is the main target organ for agidol-1 due to its lipophilicity. In cases of chronic oral exposure to the BHT doses exceeding 25 mg/kg of body weight/days, liver enlargement and induction of a number of liver enzymes were observed [31]. In this regard, when performing inhalations we relied on biochemical indicators of the liver and kidney functional state, not avoiding assessment of other body's vital organs and systems.

The tests have shown that the dynamic inhalation exposure to the agidol-1 aerosol concentrations of 24.7 mg/m³ and 67.8 mg/m³ (maximum achievable concentration) for 4 h had no general toxic effect: no deviations in the state of the nervous, cardiovascular and respiratory systems, as well as changes in the function of the liver, kidneys and the composition of the rat peripheral blood were noted.

Multiple experimental and clinical data unequivocally confirm that agidol-1 has no sensitizing effect. The substance is not classified as a mutagen or carcinogen. Agidol-1 shows no selective effect on the reproductive system, since minimal embryotoxic activity (decreased fetal weight) was reported in chronic experiments involving exposure to the doses toxic for maternal body [13, 16, 18, 26, 28, 30, 31].

When substantiating the agidol-1 OBUV, if no acute inhalation effect threshold is established even for maximum achievable concentration, it is necessary to refer to the standardized analogues of the substance or to the approved standards for the substance in atmospheric air of urban and rural settlements. In domestic literature, there are data on toxicity

Table 4. Peripheral blood indicators of rats following a single agidol-1 aerosol inhalation, M ± *m* (*n* = 8)

Indicators	Units	Control	Concentration, mg/m³	
			24.7 ± 5.6	67.8 ± 12.5
Hemoglobin	g/L	144.8 ± 5.9	139.6 ± 4.5	138.1 ± 4.4
Red blood cells	10^{12}/L	7.9 ± 0.3	7.5 ± 0.9	7.4 ± 0.6
Hematocrit	U	44.5 ± 1.2	43.2 ± 1.3	42.4 ± 1.5
Platelets	10^{9}/L	765.2 ± 35.4	740.5 ± 25.9	738.9 ± 23.7
White blood cells	10^{9}/L	7.7 ± 0.4	7.5 ± 0.5	7.6 ± 0.8

and hazard of three alkylphenol antioxidants of the Agidol brand (agidol-0, agidol-1, agidol-10), comparative toxicological characteristics of these are also reported. These studies have yielded estimates of safety of these substances and recommended safe exposure levels in atmospheric air of populated areas [30]. The evidence-based MPC for three compounds of the Agidol brand (MPC, daily average — 0.6 mg/m^3, MPC, maximum single — 2.0 mg/m^3, hazard class 4) were approved by the Chief State Sanitary Physician of the Russian Federation [32]. At the same time in different countries (USA, Germany, UK, Denmark) the maximum permissible levels of occupational exposure (TLV, ACGIH, PEL — NIOSH, MAK — Europe) have been established for BHT (butylated hydroxytoluene). These are within the concentration range between 2 mg/m^3 and 10 mg/m^3, however, the hygienic standard of 10 mg/m^3 is valid in most countries [28].

CONCLUSIONS

The testing conducted has shown that agidol-1 belongs to slightly toxic and slightly dangerous substances and shows no irritant effect in cases of single injection in the eye or repeated application to the skin. Based on the lack of general toxic effects of the agidol-1 inhalation in the study conducted, considering the established MPC for three Agidol brand compounds in atmospheric air and hygienic standards of occupational exposure for agidol-1 in different countries, the tentative safe exposure level (OBUV) in workplace air of 10 mg/m^3, aerosol, hazard class 4 has been proposed. The recommended value has been considered and approved by the Chief State Sanitary Physician of the Russian Federation. Agidol-1 in workplace air is controlled by spectrophotometry within the concentration range of 5.0–40.0 mg/m^3 at the wavelength of 278 nm.

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