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Research Article

Comprehensive Assessment of Health Impacts from Exposure to Nonionizing Radiation for Healthcare Practitioners Working with MRI and Ultrasound

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Background. It is necessary to monitor the health disorders of healthcare practitioners exposed to a complex of occupational hazards to optimize their activities and substantiation of preventive health measures. The purpose of the study was the hygienic assessment of occupational hazards, analysis of data on self-assessment of the state of health (SASH questionnaire) among healthcare practitioners (MRI diagnostics specialists, ultrasound diagnostics specialists, and ophthalmologists, as a control group) exposed to nonionizing radiation, ultrasound, and noise. *Materials and Methods*. An analysis of hygienic parameters of the working environment (workplace) and questionnaire data of healthcare practitioners were carried out. The number of illnesses and absences from work, the level of quality of life, the level of depression, and the self-assessment of the state of health were evaluated according to the questionnaire. *Results*. An analysis of workloads made it possible to rank the severity and intensity of labor. Health disorders (according to the self-assessment of the state of health), the number of absences from work due to illness, an increase in complaints and level of depression, and a decrease in the level of quality of life were corresponded to the severity of labor. It was revealed that healthcare practitioners were exposed to a number of hazards during their work (above the threshold limit value (TLV)), which caused an increase in health disorders. *Conclusions*. During the organization of workplace ergonomics and implementation of preventive measures directed to maintaining health and early diagnosis of diseases, one should take into account the hygienic indicators of the working environment that exceed TLV, the results of self-assessment of the state of health (complaints) and morbidity of healthcare practitioners, the level of quality of life and the level of depression.

1. Introduction

Healthcare practitioners do their best to provide proper care for patients, but they often do not pay attention to maintaining their health. Healthcare Systems have to promote the health and well-being of healthcare practitioners. A number of studies have shown that more than 50% of healthcare practitioners experienced emotional burnout; more than 50% of nurses reported suboptimal physical and mental health; in 25% of surveyed physicians with depression, medical errors were registered [1, 2].

During the pandemic period, healthcare practitioners noted hard working conditions caused by prolonged time of working days and time "on call," psycho-emotional stress, and associated with increased physical and mental fatigue and depression [3]. The results of a number of studies revealed significant physiological "cost" of labor and violations of the physical and mental health of medical personnel in various structural units of medical centers [4].

It was revealed that the level of morbidity of healthcare practitioners is largely determined by age, work experience, and type of work. The duration of contact with occupational

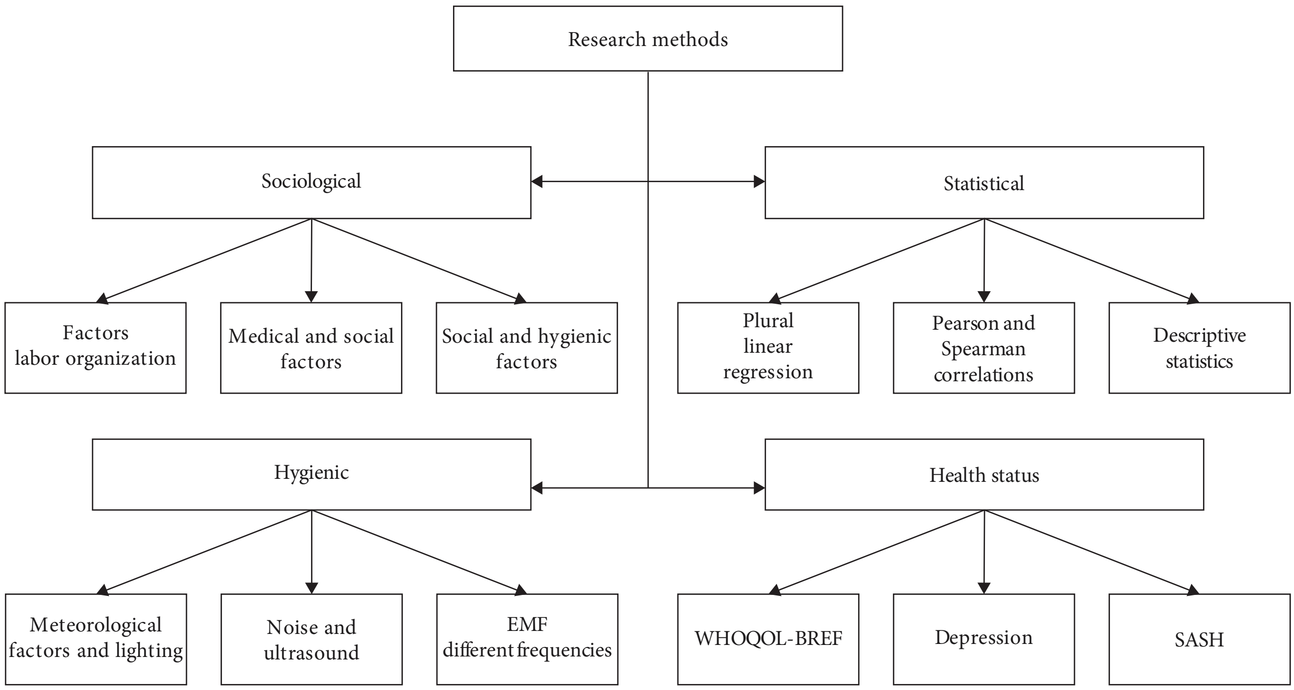

Figure 1: Brief flowchart of the research.

hazards (11–20, 21–30, 31–40 years) caused occupational morbidity of workers in multidisciplinary health centers [5].

It was shown that in the process of labor activity, healthcare practitioners are exposed to many chemical, biological, and microclimatic factors of the working environment and the intensity of the labor process. The activity of a small part of healthcare practitioners of diagnostic departments (6.5% and 3.3%) proceeded under the influence of electromagnetic fields (EMFs) of industrial and radio frequencies (RFs) above the threshold limit value (TLV) [6].

Occupational hazards may cause professional burnout, as well as lead to an increase in the prevalence of behavioral disorders. It was revealed that 36.7% of physicians had chronic disease. So, the frequency of hypercholesterolemia was 49.7%, and high glucose levels were registered at 5.9%. About 30% of physicians did not know their cholesterol level, and 25% did not know their glucose level. A high frequency of such risk factors as irrational nutrition, physical inactivity, and high blood pressure was revealed. Irrational nutrition could be associated with short breaks for meals and a high workload. Physical inactivity was more typical for diagnostic specialists [7].

Based on the listed above, the purpose of this study was a hygienic assessment of occupational hazards among healthcare practitioners exposed to nonionizing radiation (EMFs, ultrasound, noise), analysis of data from self-assessment (questionnaires) of the state of health and level of quality of life. It was hypothesized that a hard work schedule (for example, during a pandemic) may lead to an increase in complaints and depression among healthcare practitioners of MRI and ultrasound units exposed to a complex set of hygienic factors (EMFs, noise, suboptimal microclimate).

2. Materials and Methods

A sanitary and hygienic examination of the workplaces of 60 diagnostics specialists (MRI diagnostics specialists (1st group, $n_1 = 20$); ultrasound diagnostics specialists (2nd group, $n_2 = 20$); ophthalmologists (3rd group, $n_3 = 20$—control group with minimal exposure to electric, magnetic, EMFs and ultrasound)), working in the cities of Karaganda region of the RK (Karaganda, Zhezkazgan, Shakhtinsk, Temirtau) was carried out.

Workplaces for measuring noise, EMFs, and other factors were selected according to the duration of the presence of healthcare practitioners at a particular place. MRI diagnostics specialists spent more time at the control panel of the MRI machine in a shielded room. In the unit with the MRI machine, they spent time to pose the patient on the MRI table, to perform additional manipulations, to release and remove the patient from the MRI chamber. Ultrasound diagnostics specialists examined patients at the unit with an installed ultrasound machine and computer. The workplace of ophthalmologists was equipped with optical and ultrasound devices, and some of them were located in a "dark" room.

According to the regulations for the hygienic assessment of working conditions [8], microclimate indicators (air temperature, relative humidity, and air velocity), characteristics of the environment lighting (total, artificial, combined illumination of the working surface, daylight factor), total and equivalent noise levels (LEQ; dBA), the level of ultrasound (dBA) on the geometric mean frequencies of third-octave bands were registered (Figure 1). The strength (A/m) and magnetic induction (mT) of constant magnetic field (CMF), electric field strength (kV/m), and magnetic flux density (μT) were also determined. EMF of industrial frequency—IF (50 Hz), RF range—RF (30 kHz −300 GHz), and at frequencies of personal computer (5–2,000 Hz) were determined. EMFs in ultrasound units were measured at the level of the head, at a distance of 10–15 cm. The ultrasound sensor cord was fixed on the device stand. The intensity of radiofrequency fields in ultrasound units was caused by the hospital's Wi-Fi network. Level of magnetic field in MRI units was measured at the edge of the diagnostic table next to the coil, at a distance of every 100 cm from the coil to the screen. The MRI specialists were not equipped with individual sensors to register the influence of magnetic fields. Radiofrequency fields in MRI units were generated by a radiofrequency coil that was used to improve image clarity during MRI scans.

In addition, the strength of the electrostatic field (V/m) was measured. The assessment of working conditions was carried out according to the requirements and standards of the Health Ministry of the RK [9, 10]. The following equipment was used in the research: multifunctional environmental parameter meter—Multinorm MI 6201(METREL d.d., Horjul, Slovenia); Sound and Vibration Analyzer—SVAN 949,(SVANTEK Sp.zo.o, Warszawa, Poland); Constant magnetic field meter—MTM-02 (Moscow, Russia) (LLC "IMC" NTM-Zashchita); Climate measuring instrument—Testo 445, Testo SE & Co. KGaA (Titisee-Neustadt, Germany); EMF parameter meter-П3-34 (Moscow, Russia) (LLC "IMC" NTM-Zashchita).

To conduct a sociological survey the questionnaire was developed by us [11]. The reliability and validity of the questionnaire were determined. Its modification was implemented through peer review, peer validation, and pilot testing. The questionnaire showed good construct validity and internal reliability, which suggests the possibility of its use in the future. The certificate on entering information into the State Register of Rights to Objects Protected by Copyright was received for the questionnaire. The 38 questions of the questionnaire were grouped into 4 blocks: 1st block—passport data (gender, nationality, education, place of work, job title, specialization of respondents); 2nd block—social and economic factors (family, living conditions); 3rd block—social and hygienic factors (labor organization, work and rest schedule, risk factors); 4th block—medical and social factors (bad habits, diet, number and duration of illnesses over the last 3 years, caused by work complaints).

The questionnaire data were evaluated with considering of the possible influence of occupational hazards according to the available models with similar impact [11]. An analysis of data on self-assessment of the state of health (SASH questionnaire) of specialists of the described above groups was carried out according to the questionnaire developed by us [12] to identify the most adversely affected risk groups. The number of cases, their duration, and structure over the past 3 years had been analyzed in accordance with the questionnaire data. The level of depression (Patient Health Questionnaire scale (PHQ-9)) and the level of quality of life (WHOQOL-BREF questionnaire) were also assessed [13, 14].

2.1. Characteristics of the Study Participants. To participate in the study, healthcare practitioners of clinical and diagnostic medical organizations (both municipal and private) performing diagnostic testing in MRI diagnostics, ultrasound diagnostics, and ophthalmology (control group), were included. All participants were full-time specialists in the cities of Karaganda region of the RK. Criteria for inclusion in the study: higher or secondary medical education with specialization in the specified profile, at least 3 years experience in direct patient care in specified specialties. Exclusion criteria: pregnancy, retirement age, and older (60 years for women, 63 for men).

The average age of MRI and ultrasound diagnostics specialists and ophthalmologists was 33.5 ± 2.9, 44.4 ± 2.1, and 44.0 ± 2.6 years, respectively. The average professional experience was 4.8 ± 0.9, 14.2 ± 2.1, and 16.1 ± 2.7 years, respectively.

2.2. Research Procedure. The medical personnel included in the study were interviewed once. The survey was conducted in an auditory individual format after performing instrumental hygienic studies of working environment factors.

2.3. Statistical Analysis. Descriptive statistics of variables, including testing the hypothesis of normal distribution, calculation of the arithmetic mean with an error of the mean and 95% confidence intervals (M ± m and 95% CI) for values with normal distribution, the median value (Me), 25%–75% quartiles for quantitative variables, fractions (%) of the trait count for qualitative data. Comparison between groups was performed by using Student's *t*-test for independent groups for indicators corresponding to a normal distribution with equal standard deviations (according to the Walf–Wolfowitz method) and the Mann–Whitney index for qualitative variables and variables with no normal distribution. Correlation analysis of Pearson and Spearman and multiple linear analysis with their assessment and calculation of the shared contribution of individual predictors to the change of dependent variables were performed [15].

3. Results

According to the results of hygienic examination of the workplaces of MRI and ultrasound diagnostics specialists, as well as ophthalmological units, a number of hazards in the working environment were registered.

It was noted that despite the modern equipment and sufficient squares of units, suboptimal microclimate at the workplace could impede thermoregulation in healthcare practitioners [16]. This can also lead to a decrease in the contrast sensitivity of vision [17]. Taking into account the season of the study (from May until September), the nonoptimal microclimatic working condition was noticed by the doctors of the diagnostic pool, as well as by the main part of healthcare practitioners. In 47.1% of MRI diagnostics units, they exceeded the TLV by 4.6°C levels of temperature, decreased by 6.9% air humidity values, and decreased by 0.04 m/s air speed were registered. Uncomfortable microclimate was registered more often (in 77.8% of workplaces) at ultrasound diagnostics units due to increased air temperature (by 6.5°C), reduced humidity (by 10.0%), and low air

Table 1: The levels of occupational hazards at the workplaces of MRI specialists.

Indicators		Dimension	n	Mean ± m	Min–Max	Standard deviation	TLV	Percentage of exceeding	Mean/TLV
				The 1st group—MRI diagnostics specialists					
Noise		dBA	17	48.6 ± 1.5	37.0–64.3	6.3	50	35.3	1.0
Ultrasound (kHz)	12.5	(a) dB	17	24.3 ± 1.3	14.9–30.2	5.5	80	0	0.3
	16		17	19.4 ± 1.6	7.3–29.1	6.7	90	0	0.2
	20		17	13.7 ± 2.4	0.0–36.6	10.0	100	0	0.1
	25		17	10.8 ± 1.9	0.0–29.6	7.7	105	0	0.1
	31.5		17	10.2 ± 1.4	0.0–19.5	5.8	110	0	0.1
EMF (50 Hz)		Electric (kV/m)	17	0.55 ± 0.1	0.08–1.3	0.4	0.5	47.1	1.1
		Magnetic (A/m)	17	0.65 ± 0.07	0.06–1.2	0.3	4	0	0.6
CMF		Strength (kA/m)	17	2.59 ± 1.29	0.04–21.30	5.31	8	5.8	0.3
		Magnetic induction (mT)	17	3.38 ± 1.69	0.05–27.90	6.98	10	5.9	0.3
EMF of RF		Electric field (V/m)	17	4.34 ± 1.05	1.12–16.87	4.32	80	0	0.05
		Magnetic field (A/m)	17	4.02 ± 1.34	0.13–16.23	5.52	3	41.2	1.3
EMF (5–2,000 Hz)		Electric field (V/m)	17	16.45 ± 5.01	5.17–94.10	20.66	25	5.9	0.7
		Magnetic field (nT)	17	107.7 ± 10.1	0.5–155.9	41.7	250	0	0.4
EMF (2–400 kHz)		Electric field (V/m)	17	0.98 ± 0.12	0.50–1.92	0.48	2.5	0	0.4
		Magnetic field (nT)	17	6.3 ± 0.7	1.9–11.5	2.8	25	0	0.2
Electrostatic field		kV/m	17	0.20 ± 0.03	0.02–0.45	0.14	20	0	0.01

velocity (up to 0.04 m/s), as well as insufficient illumination (less than 153 lx) of the main part of workplaces (83.3%). At 92.6% of workplaces of ophthalmologists an increased by 6.5°C temperature, decreased by 17.2% air humidity, and decreased by 0.04 m/s air speed was revealed. Insufficient illumination (less than 252 lx) was registered in 74.1% of cases. Reduced illumination levels were registered in "dark units" of ophthalmological departments due to the specifics of the diagnostic ophthalmological examination.

The influence of a complex set of EMFs of different frequencies on the state of health and working ability of healthcare practitioners is not fully explored. The highest values of EMF of industrial frequency (up to 1.3 kV/m) were observed at 47.1% of MRI specialist workplaces (1.5 T) (Table 1, Figure 2). Their negative influences were increased at 18.2% of workplaces due to high (up to 6.97–16.23 A/m) levels of EMF of RF and continuous work for up to 12 hr (Figure 3).

In the assessment of the intensity of electromagnetic factors in the industrial environment at workplaces of MRI specialists, the highest values of EMFs of various ranges were revealed (Figures 4 and 5). Thus, the average intensity of the electric component of industrial frequency EMFs at the workplaces of MRI specialists achieved 0.55 kV/m and exceeded the TLV. For EMFs of the RF, a high level of magnetic component intensity was also noted (exceeding the TLV by 1.3–5.4 times). At 41.2% of workplaces, it achieved 4.6–16.2 A/m. The average level of intensity of the electrical component of EMFs from PC (5-2,000 Hz (16.45 V/m)) at the workplaces of MRI specialists did not exceed the TLV, but at 5.9% of workplaces, its level was 94.1 V/m (exceeding the TLV by 69.1 V/m).

The average level of CMF tension at the workplaces of MRI specialists was 2.58 kA/m and did not exceed the TLV. However, at 5.9% of workplaces, its level exceeded the TLV and achieved 21.3 kA/m. The average level of magnetic induction of CMFs at the workplaces of MRI specialists was 3.37 mT, which corresponded to TLV, whereas, at 5.9% of workplaces, its level amounted 27.9 mT, which exceeded the TLV.

At 50% of workplaces, the level of noise exceeded the permissible levels: at 36.4% of workplaces (Figure 6). The hazards were assessed as class 3.1, and at 22.7%—as class 3.2 [8, 9]. High levels of noise can disrupt the functioning of the cardiovascular system or manifest as nervous disorders [18]. The level of noise at 36.4% of workplaces exceeded the TLV and ranged from 51.6 to 64.3 dBA. However, its average values at the workplaces of MRI specialists were 48.6 dBA and approached the upper limit of the TLV.

At the workplaces of ultrasonic diagnostics specialists, it was revealed that the average level of intensity of the electric component of EMF of industrial frequency (IF) (0.54 ± 0.1 kV/m) exceeded the TLV by 1.1 times due to its fluctuation from 0.55 to 1.13 kV/m at 50% of workplaces (Table 2, Figure 2).

The level of airborne ultrasound at any of the five analyzed frequencies (from 12.5 to 31.5 Hz) at the workplaces of ultrasound diagnostics specialists did not exceed the TLV (Figure 7). A more detailed study of the parameters revealed that the average level of noise was 50.1 ± 2.1 dBA, but in 61.1% of ultrasound units, its level ranged from 51.6 to 63.1 dBA, exceeding the TLV (Figure 6).

The results of measurements of factors and fields of physical nature in medical ophthalmological units revealed that the levels of EMFs in various ranges did not exceed the TLV at any workplace (Table 3, Figure 2). The level of noise in 33.3% of workplaces exceeded the TLV up to 50.4–57.9 dBA. However, its average in the units was 44.1 ± 2.0 dBA, which was lower than TLV (50 dBA) (Figure 6).

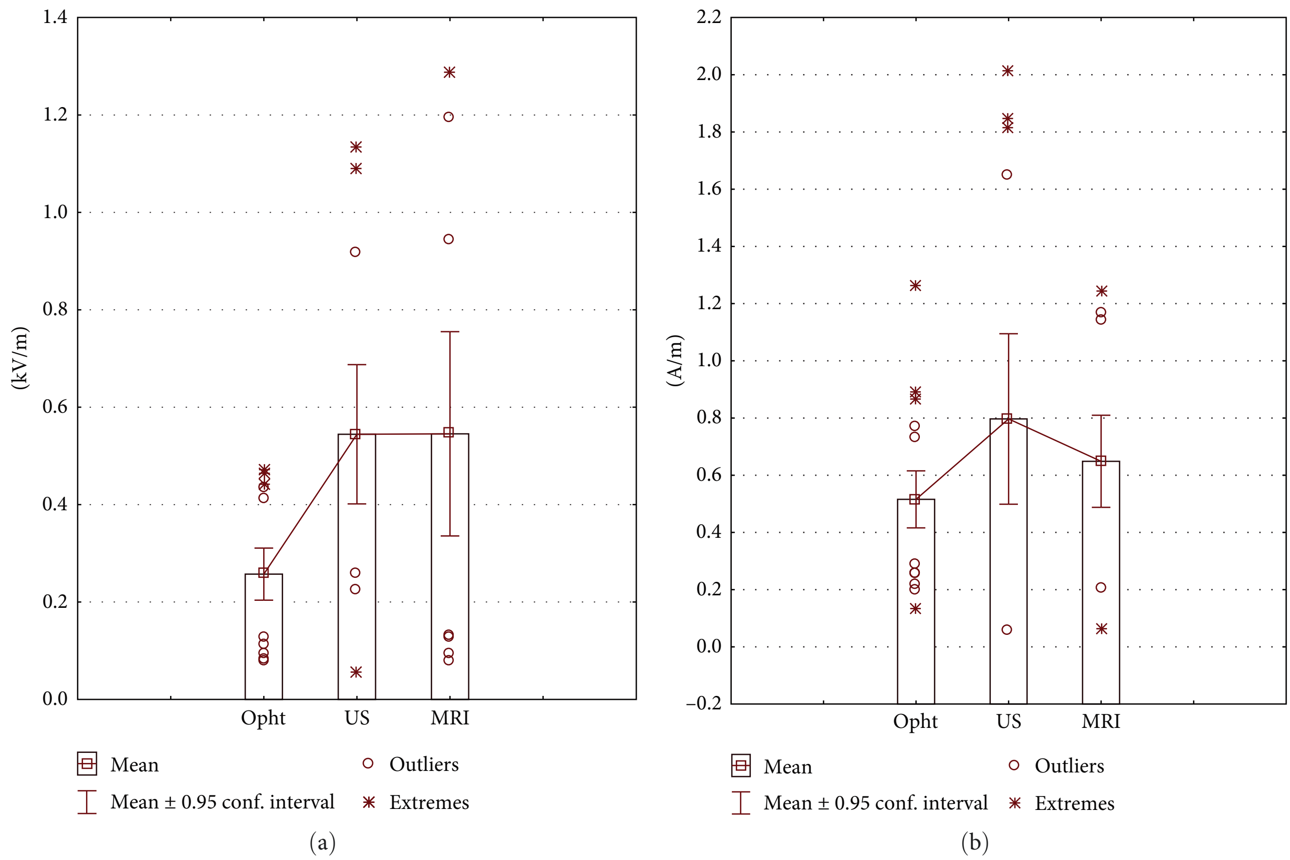

Figure 2: Level of electromagnetic radiation of industrial frequency (50 Hz) at workplaces of MRI diagnostics specialists (MRI), ultrasound diagnostics specialists (US), and ophthalmologists (Opht): (a) electric component; (b) magnetic component.

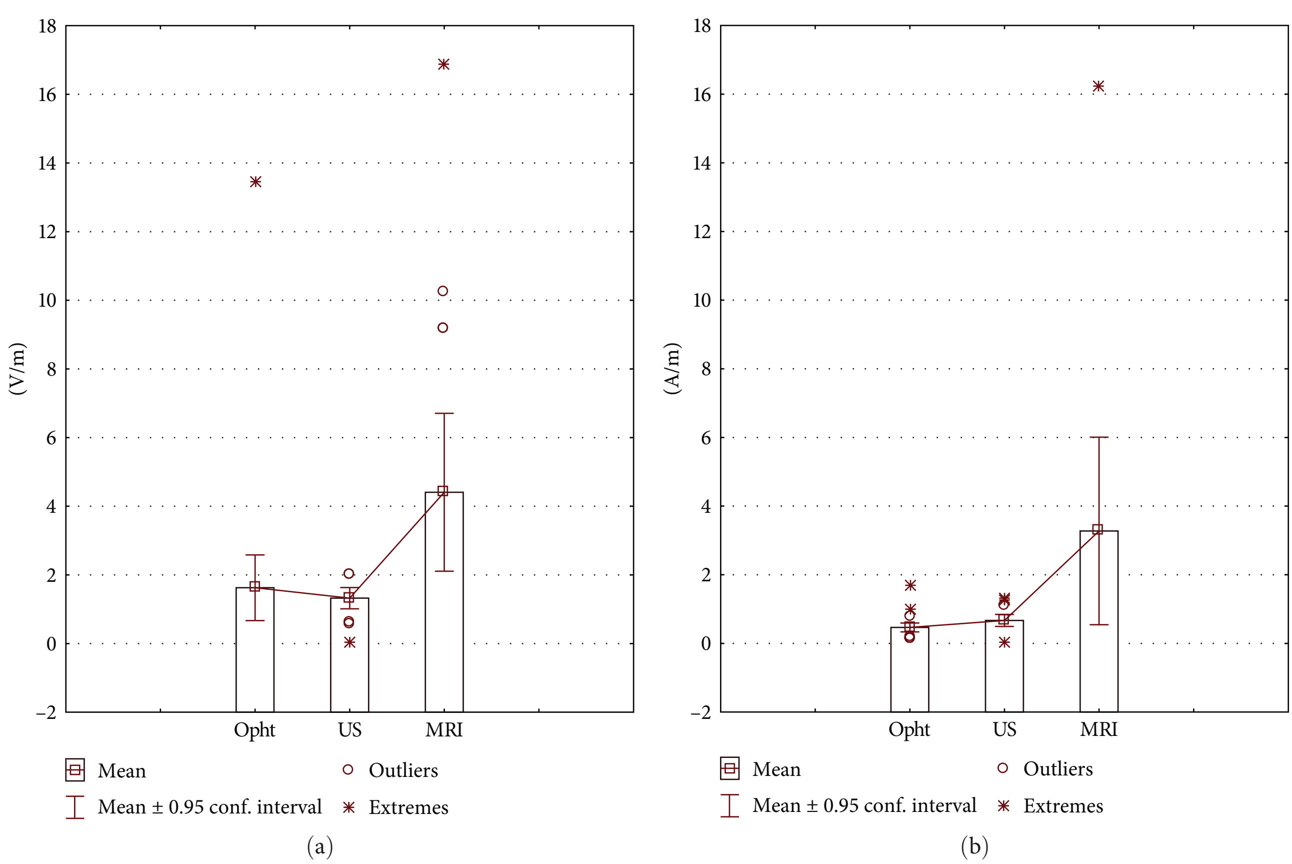

Figure 3: Level of electromagnetic radiation of radio frequency at workplaces of MRI diagnostics specialists (MRI), ultrasound diagnostics specialists (US), and ophthalmologists (Opht): (a) electric component; (b) magnetic component.

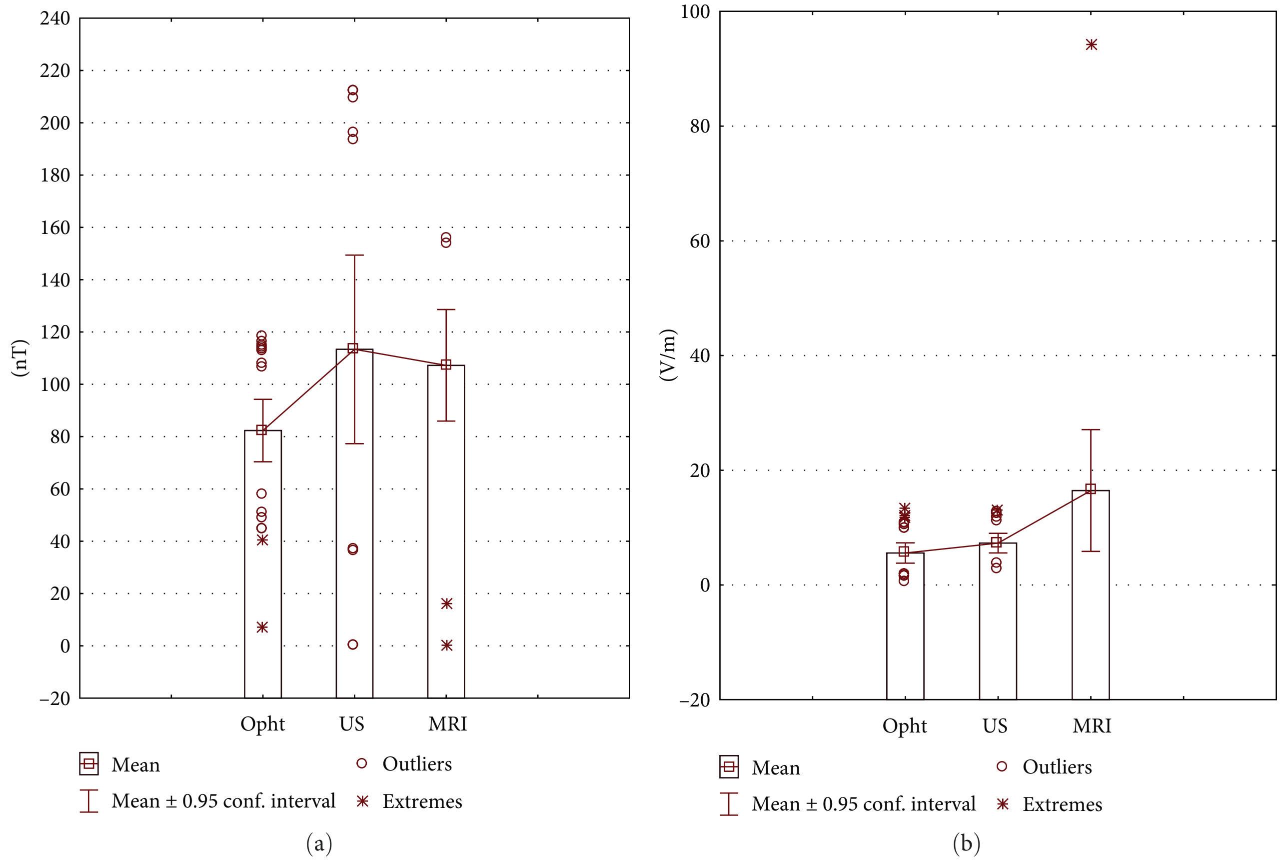

Figure 4: Level of electromagnetic radiation (5–2,000 Hz) at workplaces of MRI diagnostics specialists (MRI), ultrasound diagnostics specialists (US), and ophthalmologists (Opht): (a) electric component; (b) magnetic component.

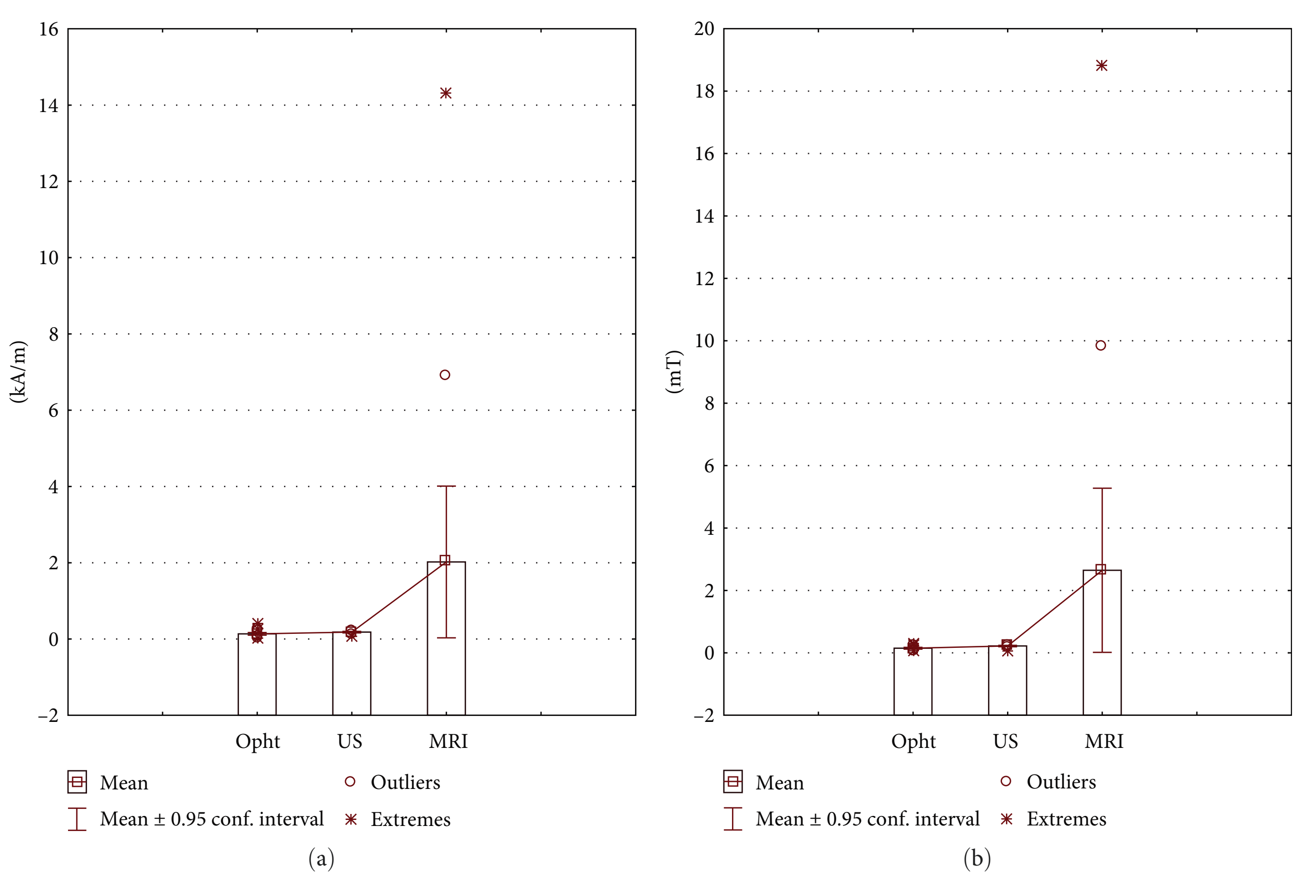

Figure 5: Level of constant magnetic field at workplaces of MRI diagnostics specialists (MRI), ultrasound diagnostics specialists (US), and ophthalmologists (Opht): (a) strength of magnetic field; (b) magnetic induction.

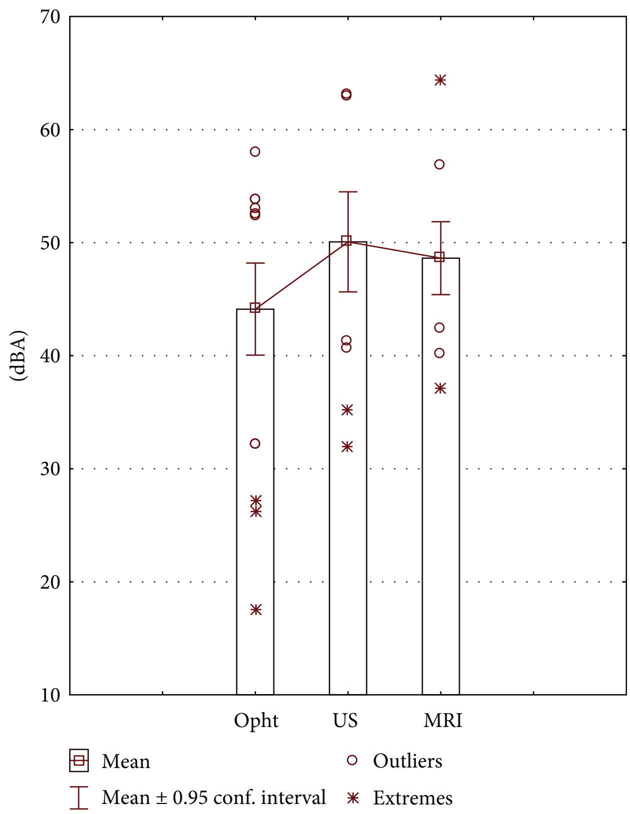

Figure 6: Equivalent level of noise per work shift at workplaces of MRI diagnostics specialists (MRI), ultrasound diagnostics specialists (US), and ophthalmologists (Opht).

It should be noted that the time of contact with hazards during the day was 6.3 ± 0.9 hr per day in respondents of the 2nd group (95% CI 4.49–8.22) and was noticeably longer than in respondents of the 1st (3.8 ± 0.7 hr per day (2.35–5.32)) and in the 3rd groups (4.1 ± 0.7 hr per day (2.66–5.58)).

An integral assessment of hygienic parameters [7] in the studied units revealed the most unfavorable working conditions at 63.4% of the workplaces of MRI specialists. At the same time, at 36.4% of workplaces, they were determined by an increased level of one factor (EMF of IF), at 9.1%—due to an increased level of two factors (EMF of IF and RF), and at 18.2%—due to an increased level of three and more factors (EMF of IF and RF, PMF, noise). Unfavorable working conditions were noted at 80.0% of the workplaces of ultrasound diagnostics specialists. Combinations of high levels of the two factors were noted in 35.0% of cases (noise and EMF of IF). In 45.0%, only noise impact was noted (with 3.2 or 3.1 hazard class). In 50.0% of the units of ophthalmologists, acceptable working conditions were noted. In 11.1% and 38.9% of units, the high noise level could form an unfavorable class of occupational hazards (3.2 and 3.1, respectively).

It was revealed that the integral assessment of occupational hazards at the workplaces of specialists of the three groups differed markedly: by the level of intensity of EMF of industrial frequency (Kruskal–Wallis rank indicator $H = 9.26/p = 0.0097$) and by the magnetic flux density of EMF of the RF ($H = 17.71/p = 0.0001$). However, a comprehensive assessment of all hygienic parameters in point [8] smoothed out these features ($H = 4.075/\ p = 0.130$).

It should be noted that a combination of occupational hazards (microclimate at workplaces, exposure to ionizing and non-ionizing radiation, and electromagnetic radiation) may more likely contribute to occupational diseases among healthcare practitioners. Their impact is often combined with negative factors of a different nature [19].

Factors of the labor process that characterize the severity of physical labor in healthcare practitioners (performing of numerous therapeutic and diagnostic operations in a forced or uncomfortable position of the body and limbs, repeating stereotypical work movements, holding and moving the sensor with deep body inclinations) contributed to the occurrence of various complaints about the musculoskeletal system in 50% of employees. $9.0\% \pm 6.1\%$ of the respondents of the 1st group complained of whole body and head fatigue, fatigue of neck, and hands during the working day. From 20% to 40% of respondents of the 2nd group complained of fatigue of hands, upper limbs, body, and head, and several departments at once ($30.0\% \pm 10.2\%$). Only $20.0\% \pm 8.9\%$ of respondents in the 2nd group did not complain of muscle dysfunction. Respondents of the 3rd group also complained of headache ($33.3\% \pm 11.1\%$), pain in the hands ($22.2\% \pm 9.8\%$), or upper limbs in general ($16.7\% \pm 8.8\%$).

The intensity of the work of healthcare practitioners is determined by intellectual load (analysis and perception of visual signals during the working day with a high work density; small size of the survey object, which determines the accuracy of visual work at level Ia for ophthalmologists and IIa for specialists in radiation diagnostics, as well as work with screens of monitors and video terminals; high responsibility for results of work; monotony of loads due to repetitive operations; unfavorable operating mode). The greatest stress due to high work density (number of patients per working day and spent on examining of one patient time (in minutes)) was recorded in the 1st group (20.6 ± 1.4 patients). Lower rates were observed in the 2nd group (18.9 ± 2.4 patients) and the 3rd (control) group (17.9 ± 1.8 patients).

Time of examination of one patient took 32.2 ± 3.2, 25.5 ± 3.0, and 26.6 ± 3.1 min, respectively. The duration of the working days was 8 hr for ultrasound diagnostics specialists and ophthalmologists and 12 hr for MRI specialists (no more than 40 hr per week). Actual working hours exceeded the normative values for 20% of ultrasound diagnostics specialists, for 16.7% of ophthalmologists, and 9.1% of MRI specialists. It was connected with counseling of difficult patients and additional work at other workplaces. So, the high duration of contact with risk factors in healthcare practitioners was observed.

The longest contact with risk factors during the day was observed in persons of the 2nd group (6.3 ± 0.9 hr (4.49–8.22)) and significantly shorter in persons of the 1st and 3rd groups (3.8 ± 0.7 hr (2.35–5.32)) and 4.1 ± 0.7 hr (2.66–5.58), respectively.

83.3% of MRI diagnostics specialists, 75.0% of ultrasound diagnostics specialists, and 88.9% of ophthalmologists noted the normal duration of the working days. The lunch break

Table 2: The levels of occupational hazards at the workplaces of ultrasound diagnostics specialists.

Indicators		Dimension	n	Mean ± m	Min–Max	Standard deviation	TLV	Percentage of exceeding	Mean/TLV
The 2nd group—ultrasound diagnostics specialists									
Noise		dBA	18	50.1 ± 2.1	32.0–63.1	8.9	50	61.1	1.0
Ultrasound (kHz)	12.5	dB	18	26.8 ± 2.0	10.1–41.3	8.4	80	0	0.3
	16		18	23.7 ± 1.7	11.3–40.3	7.4	90	0	0.3
	20		18	28.6 ± 2.1	13.5–50.3	8.9	100	0	0.3
	25		18	20.1 ± 1.7	12.1–32.4	7.0	105	0	0.2
	31.5		18	17.4 ± 1.2	12.9–28.1	4.9	110	0	0.1
EMF (50 Hz)		Electric (kV/m)	18	0.5 ± 0.1	0.06–1.1	0.3	0.5	50	1.1
		Magnetic (A/m)	18	0.8 ± 0.1	0.1–2.0	0.6	4	0	0.2
CMF		Strength (kA/m)	18	0.18 ± 0.01	0.05–0.23	0.04	8	0	0.02
		Magnetic induction (mT)	18	0.22 ± 0.01	0.06–0.26	0.04	10	0	0.02
EMF of RF		Electric field (V/m)	18	1.32 ± 0.15	0.05–1.99	0.6	80	0	0.02
		Magnetic field (A/m)	18	0.67 ± 0.08	0.03–1.32	0.35	3	0	0.2
EMF (5–2,000 Hz)		Electric field (V/m)	18	7.30 ± 0.81	2.69–13.01	3.42	25	0	0.3
		Magnetic field (nT)	18	113.4 ± 17.1	0.07–12.3	72.5	250	0	0.5
EMF (2–400 kHz)		Electric field (V/m)	18	0.92 ± 0.12	0.19–1.66	0.51	2.5	0	0.4
		Magnetic field (nT)	18	4.8 ± 1.0	0.50–13.8	4.2	25	0	0.2
Electrostatic field		kV/m	18	0.27 ± 0.04	0.03–0.62	0.19	20	0	0.01

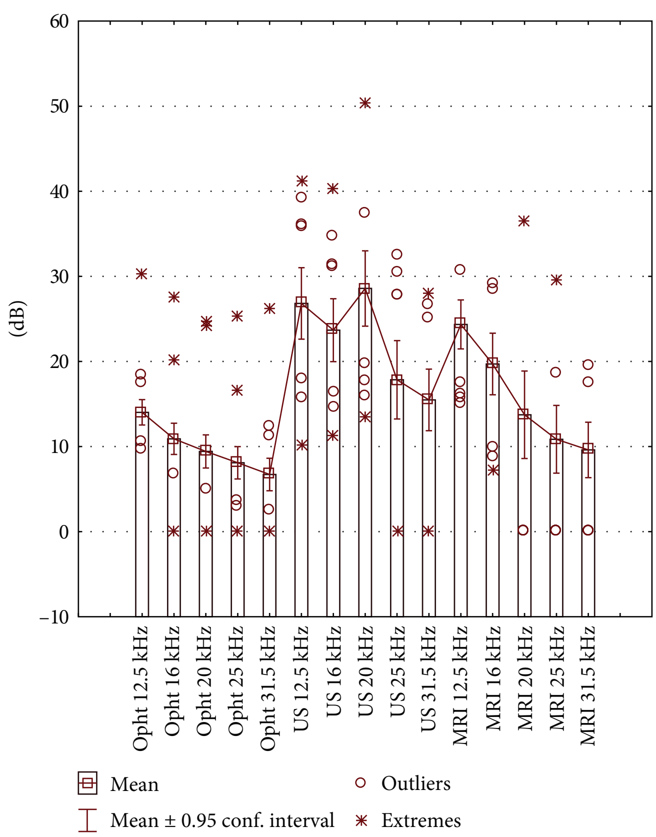

Figure 7: Ultrasound level at workplaces of MRI diagnostics specialists (MRI), ultrasound diagnostics specialists (US), and ophthalmologists (Opht).

was used in full by 42.8% of MRI specialists, 55.0% of ultrasound specialists, and 33.3% of ophthalmologists. Places for eating were equipped in separate units for 71.4% of MRI specialists and for 50.0% of ultrasound specialists and ophthalmologists. Night shift work had 50% of MRI and 5.6% of ultrasound specialists. All listed above made it possible to consider the work of MRI specialists as more intense.

Some authors refer to indicators of labor process intensity among doctors as the leading occupational hazard, which can determine the class of working conditions as harmful (I–III degree) [20].

Overall, 66.7% of MRI and ultrasound diagnostics specialists indicated EMF of various frequencies as a factor influencing the state of health, 56.7%—noted the influence of noise or ultrasound, and 43.3%—noted the influence of constant magnetic field (CMF). Overall, 43.3% of the respondents considered night shift work as an occupational hazard, 23.3%—noted nonoptimal air temperature, and 20%—insufficient illumination. Overall, 73.3% of the respondents noted the use of various disinfectants (chlorine or alcohol) at the workplace.

Separate sections of the questionnaire included questions on identifying occupational hazards and subjective assessment of adverse reactions of the organism during the working process and after it. It turned out that subjectively perceived factors often exceed the number of objective physical parameters that do not correspond to acceptable levels. Thus, 72.7% ± 9.5% of respondents of the 1st group complained about exposure to EMFs, 72.7% ± 9.5%—to CMFs, 40.9% ± 10.5%—to noise. Specialists of the 2nd group more

Table 3: The levels of occupational hazards at the workplaces of the ophthalmologist.

Indicators		Dimension	n	Mean ± m	Min–Max	Standard deviation	TLV	Percentage of exceeding	Mean/TLV
The 3rd group—ophthalmologists									
Noise		dBA	27	44.1 ± 2.0	17.5–57.9	10.2	50	33.3	0.9
Ultrasound (kHz)	12.5	dB	27	14.0 ± 0.7	9.7–30.4	3.8	80	0	0.2
	16		27	10.9 ± 0.8	0–27.5	4.6	90	0	0.1
	20		27	9.4 ± 0.9	0–24.6	4.9	100	0	0.1
	25		27	8.1 ± 0.9	0–25.3	4.8	105	0	0.1
	31.5		27	6.7 ± 0.9	0–26.3	4.8	110	0	0.1
EMF (50 Hz)		Electric (kV/m)	27	0.3 ± 0.03	0.08–0.47	0.13	0.5	0	0.5
		Magnetic (A/m)	27	0.5 ± 0.05	0.1–1.3	0.2	4	0	0.1
CMF		Strength (kA/m)	27	0.14 ± 0.02	0.01–0.42	0.09	8	0	0.02
		Magnetic induction (mT)	27	0.15 ± 0.01	0.047–0.28	0.07	10	0	0.01
EMF of RF		Electric field (V/m)	27	1.63 ± 0.46	0.46–13.47	2.42	80	0	0.02
		Magnetic field (A/m)	27	0.46 ± 0.06	0.13–1.67	0.32	3	0	0.15
EMF (5–2,000 Hz)		Electric field (V/m)	27	5.57 ± 0.87	0.67–13.38	4.5	25	0	0.2
		Magnetic field (nT)	27	82.3 ± 5.8	7.4–118.7	30.1	250	0	0.3
EMF (2–400 kHz)		Electric field (V/m)	27	0.8 ± 0.06	0.43–1.49	0.33	2.5	0	0.3
		Magnetic field (nT)	27	3.0 ± 0.7	0.7–18.2	3.8	25	0	0.1
Electrostatic field		kV/m	27	0.1 ± 0.01	0.01–0.26	0.06	20	0	0.005

often suffered from vibration (15.0% ± 8.0%) and noise (9.5% ± 4.9%), EMFs exposure (45.0% ± 11.1%), insufficient illumination (30.0% ± 10.2%) and higher temperature (35.0% ± 10.7%). Healthcare practitioners of the 3rd group indicated EMFs exposure in 61.1% ± 11.5%, noise—in 44.4% ± 11.7%. They also reported about insufficient air exchange, disrupted working ability, and worsened state of health. Thus, the perception of occupational hazards by healthcare practitioners affects their attitude to work and its results [21].

Analyzing the impact of working conditions of healthcare practitioners (MRI and ultrasound diagnostics specialists, ophthalmologists) on their status of health (number of cases of diseases, duration of diseases), self-assessment (complaints, questionnaire), and level of quality of life, the following features were identified. The main complaints caused by exposure to physical fields (electromagnetic field (EMF), constant magnetic field (CMF)) in the 1st group were flickering black spots or blurred vision (in 36.4% ± 10.3%), dry eyes (4.5% ± 4.4%), feeling of physical weakness (in 27.3% ± 9.5%), anxiety (in 27.3%), tingling (in 13.6% ± 7.3%) and increased heart rate (in 18.2% ± 8.2%). In the 2nd group, complaints of blurred vision (in 65.0% ± 10.7%), dry eyes (5.0% ± 4.9%), feeling of sand in the eyes (in 65.0% ± 10.7%), increased heart rate (in 65.0% ± 10.7%), anxiety (in 45.0% ± 11.1%), tingling (in 40.0% ± 10.9%) were revealed. In 38.9% ± 11.5% of the respondents in the 3rd group, complaints of blurred vision, feeling of sand in the eyes, feeling of weakness, and increased heart rate were revealed. Only 2.2% ± 9.8% of the respondents of the 3rd group suffered from tingling. Metallic taste in the mouth was reported by 11.1% ± 7.5% of respondents in the 3rd group and by 15.0% ± 8.0% in the 2nd. About 11.1% ± 7.5% of respondents in the 3rd group and 10.0% ± 6.7% in the 2nd group reported unusual taste sensations. The sensation of strong and unexpected smell was noted in 11.1% ± 7.5% of the respondents in the 3rd group and 5.0% ± 4.9% in the 2nd. Lack of air and headache were noted in 4.5% ± 4.4% of the respondents of the 1st group.

About 36.3% ± 9.3% of MRI specialists, 10.0% ± 6.7% of ultrasound diagnostics specialists, and 16.7% ± 8.8% of ophthalmologists rated their health level as high, according to SASH. The majority of specialists rated their health as average: 59.2% ± 9.5% of MRI specialists, 40.0% ± 10.0% of ultrasound diagnostics specialists, and 66.6% ± 10.1% of ophthalmologists. 50.0% ± 10.2% of ultrasound diagnostics specialists, 16.7% ± 8.8% of ophthalmologists, and 4.5% ± 4.4% of MRI specialists rated their health as low. That is, the low, most favorable values were found more often in MRI specialists, and the most unfavorable high values were found in ultrasound diagnostics specialists (Table 4). This determined significant differences in (SASH) the Health Self-Assessment Questionnaire between groups 1 (8.23 ± 0.15, 95% CI 6.65–9.80) and 2 (15.0 ± 1.31, 95% CI 12.25 −17.74, $p = 0.000044$), groups 2 and 3 (9.89 ± 1.11, CI 7.58 −12.19, $p = 0.0054$) according to Student's coefficient.

During the questioning, 50.0% ± 6.4% of respondents noted that they had never been ill for the last 3 years, 33.3% ± 6.1% of the respondents got ill in the past 3 years, 15.0% ± 4.6%—two times, and 1.7% ± 1.6% of the respondents got ill three or more times. The largest number of people who had not been ill in the past 3 years (59.1% ± 10.5%) was in the group of MRI specialists, and the smallest

Table 4: The indicators of the level of quality of life of healthcare practitioners of the diagnostic pool (M ± m, CI 95%).

Indicators	Parameters					
	N	M ± m	CI 95%	ME	Q1–Q3	P_{1-2-3}
MRI diagnostics specialists						
Physical and mental well-being	22	81.98 ± 2.04*	77.73 : 86.23	82.14	78.6 : 85.7	0.0004
Self-perception	22	80.68 ± 2.30	75.89 : 85.47	81.25	75 : 87.5	
Social support	22	81.82 ± 3.23	75.11 : 88.53	83.33	75 : 91.7	
Social well-being	22	79.40 ± 2.05*	75.13 : 83.67	81.25	71.9 : 87.5	0.039
Level of quality of life	22	80.78 ± 1.56*	77.52 : 84.03	79.12	76.0 : 84.4	0.003
Ultrasound diagnostics specialists						
Physical and mental well-being	20	68.75 ± 2.76	62.96 : 74.54	67.86	60.7 : 76.8	0.008
Self-perception	20	76.04 ± 3.76	68.17 : 83.9	75	70.8 : 87.5	
Social support	20	72.08 ± 4.33	63.02 : 81.14	75	66.7 : 83.3	
Social well-being	20	70.31 ± 3.88	62.2 : 78.4	71.87	67.1 : 79.7	
Level of quality of life	20	71.51 ± 3.34	64.5 : 78.5	72.92	69.3 : 77.6	
Ophthalmologists						
Physical and mental well-being	18	79.17 ± 3.09#	72.65 : 85.68	78.57	75 : 89.28	
Self-perception	18	79.17 ± 2.74	73.39 : 84.94	81.25	70.83 : 87.5	
Social support	18	78.24 ± 4.21	69.35 : 87.13	83.33	58.3 : 91.7	
Social well-being	18	73.96 ± 3.08	67.45 : 80.46	75	68.75 : 84.4	
Level of quality of life	18	71.51 ± 3.34#	71.76 : 82.87	78.12	75 : 84.37	

Note: 1—* significant difference in Student's t-test (t) between 1st and 2nd groups; 2—# significant difference between 2nd and 3rd groups.

(40.0% ± 10.9%) among ultrasound diagnostics specialists. The number of ophthalmologists who had not been ill in the past 3 years was 50.0% ± 11.8%.

Respondents who were sick for once or twice were more often observed among ultrasound diagnostics specialists (35.0% ± 10.7% and 20.0% ± 8.9%, respectively) and ophthalmologists (33.3% ± 11.1% and 16.7% ± 8.8%, respectively). Among MRI specialists, the number of those who fell ill one or two times was 27.3% ± 9.5% and 13.6% ± 7.3%, respectively. Only 5.0% ± 4.9% of ultrasound diagnostics specialists got ill three or more times.

Acute respiratory disease dominated in the structure of pointed disease and amounted 40.0% ± 8.9%. These diseases were observed in 66.7% ± 15.7% of ophthalmologists and in 22.2% ± 8.8% and 25.0% ± 12.5% of MRI and ultrasound diagnostics specialists, respectively. Diseases of the musculoskeletal system (osteochondrosis, arthrosis) were observed in 16.7% ± 6.9% of respondents (in MRI and ultrasound diagnostics specialists and ophthalmologists (22.2% ± 8.8%; 16.7% ± 10.7% and 11.1% ± 10.5%, respectively)). Respiratory diseases (pneumonia) more often occurred in ultrasound diagnostics specialists (16.7% ± 10.7%), and diseases of the cardiovascular system (arterial hypertension)—in MRI specialists (50.0% ± 10.7%). The incidence of COVID-19 in ophthalmologists was 11.1% ± 10.5%. The incidence of COVID-19 in MRI and ultrasound diagnostics specialists was 33.3% ± 15.7% and 16.7% ± 10.7%, respectively (due to the high frequency of visits by patients).

The relative indicator of the number of cases of diseases per 100 examined was higher in ultrasound diagnostics specialists than in MRI specialists (90.0 ± 6.1 cases, 95% CI 76.6–103.0, and 50.0 ± 10.7 cases, 95% CI 28.7–71.3, $p < 0.05$). The average duration of absenteeism due to illness was 9.15 ± 6.3 days per 1 disease (366 days in general (40 cases in 30 patients)). The longest duration of the disease was in MRI specialists (12.1 ± 3.3 days), and the shortest—in ophthalmologists (7.3 ± 3.3 days). Acute diseases lasting up to 3 days were more often observed in ophthalmologists (11.1% ± 10.5%) and more than 10 days—in MRI specialists (55.5% ± 16.5%).

The use of correlation analysis made it possible to determine the strength and directionality of the link between environmental factors and indicators of the health quality level self-assessment of the state of health (SASH), number of diseases, and their duration (for the last 3 years). A moderate negative link was found between SASH and weekly workloads ($r = -0.311$, $p < 0.05$), between SASH and illumination ($r = -0.266$, $p < 0.05$), between SASH and an increase of high-frequency ultrasound ($r = -0.412$–0.451, $p < 0.05$), between SASH and electric component of EMF of IF ($r = -0.314$, $p < 0.05$), between SASH and concentration of alcohol in the air ($r = -0.312$, $p < 0.05$). A positive link was found between SASH and air speed ($r = 0.333$, $p < 0.05$). When conducting a regression analysis, it was revealed that the dependence of the unfavorable increase in SASH in healthcare practitioners was mainly caused by the effect of ultrasound, electrostatic potential, and a decrease in illumination (Formula (1)).

$$Y = 109.03 - 0.520 \times X_1 - 0.567 \times X_2 + 0.452 \times X_3. \quad (1)$$

Y—self-assessment of the state of health, point; X_1—illumination, lux; X_2—US_{25}, dB; X_3—EMF of RF, V/m; $F = 15.97$;

$p = 0.00000709$; $R = 0.747$; $R^2 = 55.8\%$; share of significance: $X_1 = 34.0\%$; $X_2 = 40.3\%$; $X_3 = 25.7\%$.

A positive correlation of an average degree ($r = 0.396$ and $r = 0.402$, $p < 0.05$) was found between the increase in the duration of disease and weekly and daily workloads in healthcare practitioners. The increase in the duration of disease in healthcare practitioners depended on hygienic factors (linear model, Formula (2)), where the daily workload and the intensity of EMF of RF dominated, and the influence of increased level of EMF of IF and noise turned out to be weaker.

$$Y = -19.36 + 0.529 \times X_1 - 0.354 \times X_2 + 0.166 \times X_3 + 0.238 \times X_4 + 0.184 \times X_5 + 0.184 \times X_6. \quad (2)$$

Y—duration of the disease, day; X_1—daily load, hr; X_2—EMF of RF, A/м; X_3—EMF of CF, V/м; X_4—family composition, person; X_5—noise, dBA; X_6—professional experience, year; $F = 2.83$; $p = 0.023221$; $R = 0.566$; $R^2 = 32.0\%$; share of significance: $X_1 = 32.0\%$; $X_2 = 21.4\%$; $X_3 = 10.0\%$; $X_4 = 14.4\%$; $X_5 = 11.1\%$; $X_6 = 11.1\%$.

Share of the impact of EMF of RF, of 20 Hz US, daily workload, and dust content on the duration of the disease in healthcare practitioners was described by a linear model (Formula (3)).

$$Y = -6.75 + 0.435 \times X_1 - 0.436 \times X_2 + 0.27 \times X_3 + 0.161 \times X_4. \quad (3)$$

Y—duration of the disease, day; X_1—daily load, hr; X_2—EMF of RF, A/м; X_3—US_{20}, dB; X_4—dust concentration in the air, mg/m^3; $F = 3.85$; $p = 0.0101$; $R = 0.537$; $R^2 = 28.8\%$; share of significance: $X_1 = 39.5\%$; $X_2 = 39.7\%$; $X_3 = 15.3\%$; $X_4 = 5.4\%$.

Health-related quality of life is currently considered an integral characteristic of the physical, mental, and social functioning of a healthy and sick person, based on his subjective perception [22]. The following criteria of the WHOQOL-BREF questionnaire were used to assess the level of quality of life: assessment of quality of life and health status, physical and psychological well-being, social well-being, perception of quality of microsocial support, self-perception, subjective well-being, life orientations, strategies of human behavior to overcome life stresses [23]. The indicator “Physical and mental well-being” is often considered a direct reflection of the health status of an individual due to the inclusion of questions about the presence of physical pain, energy for daily life, satisfaction with sleep, ability to work, and ability to perform daily duties, as well as the need for medical care for normal functioning. The results of the WHOQOL-BREF questionnaire were analyzed for each indicator (Table 4, Figure 8).

The quantitative analysis revealed the greatest differences in the level of quality of life (median test $p = 0.0197$ with $\chi^2 = 7.85$), in “physical and mental well-being” and “social welfare” indicators (median test $p = 0.0059$ and $p = 0.0435$ with $\chi^2 = 10.28$ and 6.27, respectively). Pairwise significant differences were found in the field of “Physical and mental well-being” between MRI and ultrasound diagnostics specialists ($p = 0.00036$) and between ultrasound diagnostics specialists and ophthalmologists ($p = 0.00816$).

All indicators were qualitatively assessed according to the gradations [24, 25]. The indicators of “Physical and mental well-being” and “Social support” by MRI specialists were assessed as “high.” The “Level of quality of life” indicator was assessed as “high” for all healthcare practitioners. Different inverse data were obtained only for 7.3% of the respondents. Reduced quality of life, the presence of negative emotional conditions (anxiety, stress), feelings of emptiness, and abandonment were characteristic of these individuals.

It is known that anxiety (depression) develops as a result of a complex interaction of social, psychological, and biological factors. People who have experienced any adverse events are more likely to depression development. Depression, in turn, can exacerbate stress, disrupt normal functioning, worsen life situations, and lead to more severe degrees of depression. The assessment of the level of anxiety (depression) on the PHQ-9 scale in respondents of the three groups was carried out with the mean and median values.

Thus, the average values of the level of anxiety in the group of MRI specialists were 4.68 ± 0.52 points (95% CI 3.59–5.77), in the group of ultrasound diagnostics specialists -7.20 ± 0.88 points (95% CI 5, 36–9.04), and in the group of ophthalmologists—5.39 ± 0.83 points (95% CI 3.63–7.15). These values indicated mild depression in all three groups. However, the level of depression in ultrasound diagnostics specialists was higher than in MRI specialists ($p = 0.016$). Median values were in the range of 4.5 points (25%–75%, Q3.0–6.0) in MRI specialists, ranging from 6.0 points (25%–75% Q5.0–9.5) in ultrasound diagnostics specialists, and 4.0 points (25%–75% Q4.0–7.0) in ophthalmologists. This indicates a high prevalence of mild and moderate depression in individuals of the analyzed groups.

Based on the results of the frequency domain analysis, the reason of the high level of depression in ultrasound diagnostics specialists became clear. So, the absence of depression was observed in $50.0\% \pm 10.7\%$ of MRI specialists, in $55.5\% \pm 11.7\%$ of ophthalmologists, and only in $20\% \pm 8.9\%$ of ultrasound diagnostics specialists. Mild depression was observed in $50\% \pm 10.7\%$, $55\% \pm 11.1\%$, and $27.8\% \pm 10.5\%$ of MRI and ultrasound diagnostics specialists and ophthalmologists, respectively. Moderate depression was observed in $20\% \pm 8.9\%$ of ultrasound diagnostics specialists and in $16.7\% \pm 8.8\%$ of ophthalmologists.

A mild degree of depression may be formed due to the high workload associated with night shifts. It was typical for MRI specialists. High workload due to the lengthening of the working day, an increased number of patients, and a high level of responsibility for the correct diagnosis could lead to moderate depression in some ultrasound diagnostics specialists and ophthalmologists. Severe form of depression was registered only in a small part of ultrasound diagnostics specialists ($5\% \pm 4.9\%$).

The level of depression in healthcare practitioners was more correlated with the prolongation of the working week ($r = 0.581$, $p = < 0.05$). The dependence of the depression in healthcare practitioners on the frequency of ultrasound, daily workload, the number of examined patients, and electrostatic potential was not less and was reflected in a significant informative and qualitative linear model (Formula (4)):

$$Y = 6.21 + 0.49 \times X_1 - 0.32 \times X_2 + 0.19 \times X_3 - 0.17 \times X_4. \quad (4)$$

Y—PHQ, point; X_1—daily load, hr; X_2—number of examined patients, case; X_3—electrostatic potential, kV/m; X_4—ultrasound magnitude, dB; $F = 4.15$; $p = 0.00710$; $R = 0.556$; $R^2 = 30.95\%$; share of significance: $X_1 = 59.0\%$; $X_2 = 24.5\%$; $X_3 = 9.25\%$; $X_4 = 7.12\%$.

In addition to workload and working conditions, the level of depression was also influenced by SASH in healthcare practitioners ($r = 0.345$). The value of SASH, as well as the life quality level, was correlated with the number and duration of the diseases ($r = -0.336$ and $r = 0.282$) and ($r = -0.309$ and $r = -0.354$).

Thus, according to the opinion of respondents based on the results of the questioning, the using of complex and unsafe equipment for diagnostic manipulations may cause adverse reactions of the organism, an increase in morbidity, formation of certain adverse syndromes, a decrease of the level of quality of life and lead to depression.

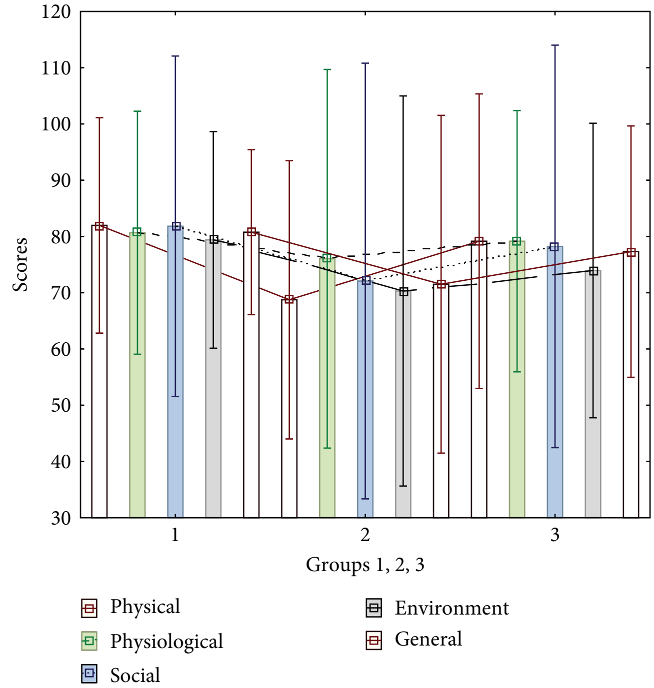

Figure 8: The indicators of the life quality level in healthcare practitioners of the diagnostic pool: 1st group—MRI diagnostics specialists, 2nd group—ultrasound diagnostics specialists, 3rd group—ophthalmologists (M ± m).

4. Discussion

All respondents noted uncomfortable microclimatic conditions. According to the results of instrumental measurements, they were registered in 50% of workplaces of MRI specialists, in 80% of workplaces of ultrasound diagnostics specialists, and in almost all premises of ophthalmologists. Low air mobility and high temperatures at workplaces may worsen the normal functioning of the central nervous system and thermoregulation. It reduces work efficiency and attention, provoking errors and prolonging the time of diagnostic study in patients. In addition, working in a “dark room” with a switched-on display may reduce melatonin levels and negatively impact the immune system. This is of great interest to study, since the International Agency for Research on Cancer (IARC) has declared that work with artificial light sources at nighttime is carcinogenic for humans due to disruption of circadian rhythms and reduction of melatonin levels [26].

4.1. Impact of Occupational Hazards on the State of Health. It was revealed that the integral assessment of occupational hazards at the workplaces of specialists of the 3rd group differed markedly by the level of intensity of EMF of IF and the magnetic flux density of EMF of RF.

The high variability of the EMF of RF flux density was determined by the area and type of the research, as noted by other authors. Thus, the design of the RF impulse, the adjustment of the rotation angle, and the scanning sequence influenced the measured EMF of RF in the scanning of the brain, cervical spine, and limbs [27]. In addition, it has been shown that the magnitude of the induced electric field strongly depends on the operator’s walking speed [28]. To assess the impact of CMF, a few models were proposed, and an analysis of the spatial distribution of the magnetic fields during the movement of operators was performed [29].

High-level EMFs of industrial and RFs were revealed in more than 40% of the workplaces of MRI specialists. Higher levels of EMFs of industrial frequency were revealed in 50% of workplaces of ultrasound specialists. So, constant monitoring of contact time with EMF was required. It was found that low-frequency EMF exposure causes mild oxidative stress and affects the progression of neurodegenerative diseases, leading to depression, anxiety, and poor sleep quality [30, 31]. A review of epidemiological studies showed that nonionizing radiation may be carcinogenic and affect human reproductive function and neurobehavioral reactions. It was revealed that the risk of breast cancer development with an estimated 1-year exposure to magnetic fields ≥ 0.2 μT for women aged 50 years or younger was 1.8 OR (95% CI, 0.7–4.3); for older women—0.9 (95% CI 0.5–1.4), for men—2.1 (95% CI 0.3–14) [32]. A trend toward a dose–response relationship was found in leukemia with SIRs of 1.8 (95% CI, 1.1–2.8), 1.4 (95% CI, 0.81–2.2), 1.1 (95% CI, 0.81–2.2) and 1.1 (95% CI, 0.70–1.6) for the exposure categories of high magnetic, electrical, medium magnetic and low magnetic, respectively [33]. It was revealed that ELF-EMFs may reduce the number and motility of spermatocytes, as well as cause structural changes in testicular tissue [34]. It was found that radiologists who used intrauterine contraceptives while they were occupationally exposed to CMF from MRI scanners reported about abnormal uterine bleeding more often than not exposed to CMF radiologists [35]. The influence of electromagnetic waves on the development of fetal disorders in parents exposed to EMFs was studied: there were more fetal abnormalities than in parents not exposed to EMFs (OR 1.34; CI 1.17–1.52), as well as oncological diseases—1.14 (CI 1.05–1.23), DNA damage—1.01 (CI 0.17–1.86) [36]. Zanotti et al. [37] found that the main symptoms associated with exposure to induced electrical fields in the organism due to movement in the SMF were problems with concentrating, headaches, drowsiness/fatigue, sleep disturbances, nausea, illusion of movement, and dizziness/vertigo.

This suggested an increase in the risk of neurological, degenerative, and cardiovascular diseases under the influence of magnetic fields.

The biological mechanisms of the damaging effects of CMF and EMF have not yet been sufficiently studied. There are data that they may provoke leukemia in children, brain tumors, and breast cancer; may cause genotoxic effects, allergic and inflammatory reactions; may cause dysregulation of the immune system, neurodegenerative diseases, miscarriage; may affect the cardiovascular system [38]. The WHO Expert Agency for Cancer Research (IARC) has classified both low-frequency magnetic fields and radiofrequency fields as potentially hazardous to humans [32]. A number of studies have shown that the nervous system is an important target system that is sensitive to EMR and EMR affects the metabolism and transport of neurotransmitters responsible for brain function [39]. It has been established that exposure to high levels of SMF associated with MRI may lead to the development of hypertension. Moreover, the intensity of exposure to SMF is more important for the risk of hypertension development than the duration of exposure [40].

EMF with exposure intensity above TLV accounted 5.9% of occupational hazards for amyotrophic lateral sclerosis (ALS) [41]. The intensity and magnetic induction of CMF in MRI machines exceeded TLV only in a small part of workplaces and achieved high values (21.3 kA/m and 27.9 mT). It was established that CMF (0.025 mT and above) activates cellular systems, releasing free radicals in moderate quantities. This can lead to the consumption of intracellular antioxidants and the increase of anti-inflammatory cytokines [42].

The noise level exceeded the TLV at 35.3%–61.1% in the workplaces of MRI and ultrasound diagnostic specialists and ophthalmologists. Currently, the synergy of the impact of noise and labor intensity on cardiovascular pathology development (including arterial hypertension) was studied. Hypertension, hearing loss, decreased work ability, and overstrain of the cardiovascular system were the most important occupational hazards in combination with simultaneous exposure to noise and other hazards: chemical, physical (lighting, heat), personal and occupational (workload and shift work) [43, 44]. Complaints of MRI, ultrasound diagnostics, and ophthalmological unit specialists were caused by insufficient illumination (less than 500 Lx), small size of survey objects (less than 0.15 cm), long work with screens of monitors and video terminals, as well as repeated diagnostic manipulations. Visual impairment, such as "computer vision syndrome," is becoming increasingly relevant to the radiology community [45]. It was revealed that CMF may cause blurred vision, eye inflammation, and lacrimation [46]. Kues and Monahan [47] presented experimental data on the damage of the corneal endothelium, an increase of vascular permeability of the iris, and degenerative changes in the cells of the iris and retina after exposure to low doses of pulsed microwaves at a frequency of 2.45 GHz.

It was revealed that due to the increase in time of work on PC, 57% of students complained about eye strain, 61% had symptoms of insufficient convergence, and in 17% eye diseases were diagnosed [48]. Dry eyes and headaches were common side effects of long-term use of various digital devices due to rarely blinking caused reduce of eye hydration. This leads to dry eyes, pain, and a feeling of fatigue. A dry microclimate exacerbates the listed above symptoms. Headaches due to eye strain tend to be felt around the eyes and most commonly occur toward the end of the day [49].

Flickering black spots (in $36.4\% \pm 10.3\%$), feelings of physical weakness (in $27.3\% \pm 9.5\%$) and anxiety (in 27.3%), tingling (in $13.6\% \pm 7.3\%$) and palpitations (in $18.2\% \pm 8.2\%$) were observed in participants of the 1st group under the influence of EMFs of various frequencies and constant magnetic field. Rathebe P.C. more often observed headache, nausea, and tinnitus in MRI specialists. The author found that increasing work experience was a significant predictor of headaches ($p < 0.05$), and the position of MRI specialist was a predictor of nausea ($p < 0.05$) [50].

CMF and pulsed electromagnetic fields rendered a negative impact on medical staff in MRI and ultrasound units. They may violate nervous and hemodynamic system functioning and lead to the development of musculoskeletal system diseases. Poor ergonomics and musculoskeletal pain development during scanning were positively correlated [51]. Ophthalmologists in the USA complained about musculoskeletal pain (4–10 points according to the visual analog scale (VAS)) associated with the time of work and surgical operation continuity [52].

Acute respiratory disease dominated in the structure of pointed disease and amounted $40.0\% \pm 8.9\%$. These diseases were observed in $66.7\% \pm 15.7\%$ of ophthalmologists and in $22.2\% \pm 8.8\%$ and $25.0\% \pm 12.5\%$ of MRI and ultrasound diagnostics specialists, respectively. It is known that disease transmission from infected patients to healthcare practitioners often occurs in hospitals and medical centers [53]. Healthcare practitioners are less willing to comply with infection control regulations when working overtime [54].

4.2. The Level of Depression as a Reflection of the State of Health. The use of PHQ-9 is acceptable for the most part of the social and demographic groups in the USA. This allows to carry out meaningful comparisons on general, cognitive/affective, and somatic depressive symptoms in these groups [55]. The reliability and validity of the PHQ-9 (assessment of both somatic and cognitive-emotional spheres) was proved by Rahman et al. [56]. PHQ-9 was also recommended for depression screening in primary care units. The PHQ-9-MZ, with thresholds ranging from ≥8 to ≥11, was recommended for use in primary healthcare units in Mozambique [57].

A significant prevalence of people with increased and high levels of depression among healthcare practitioners was associated with the impact of a complex set of labor factors. Therefore, the use of questionnaires for self-assessment of the quality of the state of health was justified. It was found that higher PHQ-9 scores were associated with female gender, young age, high body mass index, chronic diseases, higher incidence of comorbidities, and acute diseases (leg cramps, mood changes, lack of energy ($p < 0.0001$) [58].

Similar findings were also registered in men (≥30 years) and women working more than 46 hr per week; in men and women (≥30 years) working at night shifts, with an assessment of the state of health as "poor" [59].

According to the guidelines for the use of PHQ-9 [60], for people with mild depression, it is necessary to monitor and repeat PHQ-9 tests in dynamics. According to the literature data, a high level of depression in healthcare practitioners was associated with professional "burnout" [61, 62]. So, screening for burnout is essential and may help to supply an adequate support and treatment for healthcare practitioners with a high risk of depression [63]. The present of gender differences due to the PHQ-9 was revealed in Germany: women were more likely to report the symptoms of depression, important for mental health characterization and subsequent prevention of depression [64]. The necessity to report about unfavorable prognosis to the patient may cause the development of depression in ultrasound specialists [65].

SASH is a subjective indicator of the quality of health in healthcare practitioners. To determine biological age, the proposed questionnaire, consisting of 29 simple questions, was used [66]. However, it has not been used independently to assess the state of health in professional groups. In our research, the SASH indicator was quite informative. It differed markedly among respondents, $p < 0.05$. The SASH indicator had a negative close relationship with factors of labor organization and occupational hazards, and that was reflected in the coefficients of correlation.

4.3. Life Quality Level as an Indicator of the State of Health. All of the respondents noted that the level of quality of life satisfies their basic needs and wishes. The respondents also noted sufficient physical and psychological well-being. They considered themselves successful in social interaction. However, the indicators of "Social support" and "Physical and mental well-being" were higher in MRI specialists.

The "Physical and mental well-being" indicator in respondents unidirectionally, to a large extent, depended on the increase in illumination and vice versa on the magnitude of the ESP and the time of examination of one patient. It was reflected in a significant informative and qualitative linear model (Formula (5)).

$$Y = 15.6 + 0.123 \times X_1 + 0.632 \times X_2 + 0.676 \times X_3 + 0.685 \times X_4 + 0.341 \times X_5 - 0.274 \times X_6 - 0.566 \times X_7 + 0.402 \times X_8 + 0.228 \times X_9 + 0.21 \times X_{10}. \tag{5}$$

Y—life quality: physical and psychological well-being, points; X_1—EMF of RF, V/m; X_2—nitrogen dioxide concentration, mg/m^3; X_3—EMF of PC, nT; X_4—EMF of RF, A/m; X_5—illumination, lux; X_6—time of 1 diagnostic examination, min; X_7—ESF, кV/m; X_8—EMF of CF, A/m; X_9—temperature, °C; X_{10}—duration of contact with the factor, hr; $F = 5.27$; $p = 0.000145$; $R = 0.789$; $R^2 = 62.2\%$; share of significance: $X_1 = 0.7\%$, $X_2 = 18.9\%$, $X_3 = 21.6\%$, $X_4 = 22.2\%$, $X_5 = 5.5\%$, $X_6 = 3.6\%$, $X_7 = 15.2\%$, $X_8 = 7.7\%$, $X_9 = 2.5\%$, $X_{10} = 2.1\%$.

However, the WHOQOL-BREF shows that the associations of socio-demographic factors and level of quality of life in relation to gender, age, marital status, education, and income can significantly influence the results of the assessment of all areas of quality of life (from 5% to 17%) [67]. The methodology of the level of quality of life assessment is designed for a qualitative and realistic analysis of social, health, environmental, and economic aspects of life [68]. Such studies would be very useful in efforts to develop safety guidelines for occupational exposure to EMF of various frequencies. The scientific literature is particularly lacking in research on the health effects of static magnetic fields up to 8 T, such as those produced by MRI devices, including long-term effects [69]. MRI with field strengths above 3 T has only recently begun to be used in some research centers. Most MRI apparatus produces a magnetic field of 1.5 or 3 T. However, unless there is no need to be near the magnetic coil of the MRI apparatus, technicians are not exposed to the maximum field strength of the MRI magnet. Magnetic fields that MRI technicians would normally be exposed to are between 10 and 200 mT [70].

Modern economists understand that good health and occupational safety of their employees is an important component of financial success [71]. The results of a systematic meta-analysis showed that high requirements for the quality of the performed work, the discrepancy between salary and efforts of employees, and the low level of social and professional protection in the workplace were associated with a greater risk of psychological problem development [72].

The general principles for health disorders prevention in healthcare practitioners should be based on primary prevention measures aimed to reduce the impact of occupational hazards [73]. The efficacy of preventive programs should also be reflected in the improvement of the level of quality of life of employees [74, 75]. In case of a decrease in occupational safety control, there was an increase in trauma and an incidence that may lead to a decrease in the level of quality of life of healthcare practitioners [76–81]. A number of authors have found that exposure of medical personnel to EMR may be associated with adverse effects on their cardiovascular system [82].

It has been established that such factors as working conditions, job content, rewards, and career development do not get due attention from managers [83].

5. Conclusions

(1) The main occupational hazards for MRI and ultrasound diagnostic specialists were occupational exposure to higher level EMFs of various frequencies and CMF, in combination with insufficient illumination, increased noise levels, and unfavorable microclimate.

(2) The high workloads among servicing modern high-energy equipment healthcare practitioners causing complaints about adverse symptoms of cardiovascular, vegetative, and musculoskeletal systems functioning were revealed.

(3) Peculiarities of the morbidity of healthcare practitioners of different specialties are determined by the highest prevalence of persons that had never been ill among MRI specialists (group 1) and the lower prevalence among ultrasound diagnostics specialists. The average duration of one case of the disease in ultrasound diagnostics specialists and ophthalmologists was determined by the dominance of acute diseases and by the dominance of chronic disease in MRI specialists. Acute respiratory disease dominated in the structure of diseases in 66.7% of ophthalmologists. Diseases of the musculoskeletal system dominated in MRI and ultrasound diagnostics specialists. Diseases of the cardiovascular system dominated in MRI diagnostics specialists.

(4) Among the subjective indicators of the quality of health of healthcare practitioners, the SASH indicator was informative. Its favorable values were registered in MRI specialists and ophthalmologists, and unfavorable (high) — in ultrasound diagnostics specialists ($p < 0.05$). The level of SASH indicator was well correlated with occupational hazards (EMF of IF and US, air speed and illumination workload; $p < 0.05$) and depended on US parameters, electrostatic potential and reduced level of illumination ($p = 0.000031$).

(5) The complex impact of labor factors and its intensity determined the prevalence of healthcare practitioners with moderate (20%) levels of depression. A high level of depression was observed in 5% of ultrasound diagnostics specialists, in contrast to MRI specialists ($p = 0.016$).

(6) It has been established that the "Physical and mental well-being" indicator of the quality of life allows to characterize objectively the problem key points of formation and preservation of health of the studied healthcare practitioners. The level of "Physical and mental well-being" indicator among healthcare practitioners of the diagnostic pool unidirectionally depended to a large extent on the increase in illumination and vice versa on the magnitude of the ESP and the time of examination of one patient.

(7) Both the identified features of the incidence of healthcare practitioners and occupational hazards must be taken into account in labor ergonomics and the organization of preventive and screening measures for diagnosing diseases.

Data Availability

The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Additional Points

Limitations of the Study. The workplace conditions of healthcare practitioners of private medical offices and organizations were analyzed in the study. The workplaces of healthcare practitioners of municipal clinics were not studied. Individuals with more than 3 years of professional experience were included in the study, which may have an influence on the results of the study.

Ethical Approval

The study was approved by the Decision of the Committee on Bioethics of the non-commercial joint-stock company "Medical University of Karaganda" (No. 11 of 08.09.2020, Protocol No. 4).

Consent

Written consents were signed for voluntary participation and the use of information obtained during the study.

Disclosure

All respondents were made aware of the purpose, procedure, and timing of the study. All statistical data was depersonalized before analysis.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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