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PRELIMINARY ANALYSIS AND ASSESSMENT OF THE HEALTH STATUS OF THE DESCENDANTS OF PERSONS EXPOSED TO RADIATION, LIVING IN THE BESKARAGAI DISTRICT OF THE ABAY REGION

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Abstract

Introduction: The effects of chronic low-dose ionizing radiation on human health have been the subject of scientific research for several decades. However, the long-term effects of chronic low-dose irradiation on the human body, including those of the third and subsequent generations, remain unresolved.

Aim: To conduct a preliminary assessment of the health screening results of the Beskaragay District population, including second- and third-generation residents exposed to radiation from nuclear weapons testing.

Materials and Methods: A population screening was conducted in Beskaragai District, including questionnaires on health status, risks of developing non-communicable and socially significant diseases, and lifestyle. A preliminary analysis included 222 patients. All participants underwent a somatic assessment, as well as general clinical and biochemical analyses. Statistical analysis was performed using SPSS 20.0 (IBM Inc., New York, USA) and Jamovi (v2.5.5; https://www.jamovi.org).

Results: The mean age and age distribution differed statistically between men and women ($p = 0.0071$), with men being more likely to be aged 40–49 years (34.5%). 63.5% of participants had lived in the area since birth. The median systolic blood pressure in men was 130 (IQR 10) mmHg, which was significantly higher than in women ($p < 0.001$). 90.1% of patients had grade 1–2 thyroid enlargement. Cortisol levels were higher in men — 319.0 (122.0) nmol/L versus 249.3 (145.2) nmol/L in women ($p = 0.020$), while the opposite trend was observed for insulin. The median individual doses of external gamma radiation among participants were 1.8 cSv (IQR: 0.4–4.2) and did not differ statistically between men and women ($p = 0.433$).

Conclusion: The results of this phase of the study highlight the need for an expanded sample, in-depth clinical, laboratory, and instrumental examinations, and further registry development to study the relationship between radiation exposure and the development of somatic diseases in the offspring of exposed individuals.

Keywords: *Semipalatinsk Nuclear Test Site; health effects; screening; risk factors; radiation.*

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Резюме

ПРЕДВАРИТЕЛЬНЫЙ АНАЛИЗ И ОЦЕНКА СОСТОЯНИЯ ЗДОРОВЬЯ ПОТОМКОВ ЛИЦ, ПОДВЕРГШИХСЯ ВОЗДЕЙСТВИЮ РАДИАЦИИ, ПРОЖИВАЮЩИХ В БЕСКАРАГАЙСКОМ РАЙОНЕ АБАЙСКОГО РЕГИОНА

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Введение: Эффекты хронического низкодозового ионизирующего излучения на состояние здоровья человека являются предметом научных исследований в течение нескольких десятилетий. Однако остается нерешенным вопрос о долгосрочных эффектах хронического низкодозового облучения на организм человека, включая лиц третьего и последующих поколений.

Цель: Предварительно оценить результаты скрининга состояния здоровья населения Бескарагайского района, второго и третьего поколения лиц, подвергшихся воздействию радиации вследствие испытаний ядерного оружия.

Материалы и методы: Проведено скрининговое исследование населения Бескарагайского района, анкетирование участников о состоянии здоровья, рисков развития неинфекционных и социально-значимых заболеваний, образа жизни пациентов. В предварительный анализ включено 222 участника. Всем участникам проводили оценку соматического состояния, а также общеклинический и биохимический анализ. Статистический анализ проводился с применением программ SPSS 20.0 (IBM Inc., New York, USA) и Jamovi (версия 2.5.5; https://www.jamovi.org).

Результаты: Средний возраст и распределение по возрастным категориям статистически различались между мужчинами и женщинами (p = 0,0071), среди мужчин преобладали лица в возрасте 40–49 лет (34,5%). 63,5% участников проживали на данной территории с рождения. Медиана систолического артериального давления САД у мужчин составила 130 (IQR 10) мм рт. ст., что было достоверно выше, чем у женщин (p <0,001). 90,1% пациентов имели увеличение щитовидной железы до 1–2 степени. Уровень кортизола был выше у мужчин - 319,0 (122,0) нмоль/л против 249,3 (145,2) нмоль/л у женщин (p = 0,020), в то время как для инсулина установлена обратная тенденция. Медианные индивидуальные дозы внешнего гамма-облучения участников составляли 1.8 сЗв (IQR: 0.4–4.2) и статистически не различались между мужчинами и женщинами (p = 0.433).

Выводы: Результаты данного этапа работы подчёркивают необходимость расширения выборки, углублённого клинико-лабораторного и инструментального обследования, а также дальнейшее формирования регистра для изучения связи радиационного воздействия с развитием соматических заболеваний у потомков экспонированных лиц.

Ключевые слова: *Семипалатинский ядерный полигон; эффекты в отношении здоровья; скрининг; факторы риска; радиация.*

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Түйіндеме

АБАЙ ӨҢІРІНІҢ БЕСҚАРАҒАЙ АУДАНЫНДА ТҰРАТЫН, РАДИАЦИЯҒА ҰШЫРАҒАН АДАМДАРДЫҢ ҰРПАҚТАРЫНЫҢ ДЕНСАУЛЫҚ ЖАҒДАЙЫН АЛДЫН АЛА ТАЛДАУ ЖӘНЕ БАҒАЛАУ

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Кіріспе: Созылмалы төмен дозалы иондаушы сәулеленудің адам денсаулығына әсері бірнеше онжылдықтар бойы ғылыми зерттеулердің тақырыбы болып табылады. Алайда, созылмалы төмен дозалы сәулеленудің адам ағзасына, оның ішінде үшінші және кейінгі ұрпақтарға ұзақ мерзімді әсері туралы мәселе әлі де ашық.

Мақсат: Ядролық қару сынақтарының салдарынан радиацияға ұшыраған адамдардың екінші және үшінші буына кіретін Бесқарағай ауданы тұрғындары арасында денсаулық скринингінің нәтижелерін алдын ала бағалау.

Материалдар мен әдістер: Бесқарағай ауданы тұрғындары арасында скринингтік зерттеу жүргізілді, қатысушыларға денсаулық жағдайы, инфекциялық емес және әлеуметтік маңызы бар аурулардың даму қаупі, пациенттердің өмір салты туралы сауалнама жүргізілді. Алдын ала талдауға 222 қатысушы енгізілген. Барлық қатысушыларға соматикалық жағдайды бағалау, сондай-ақ жалпы клиникалық және биохимиялық талдаулар жүргізілді. Статистикалық талдау SPSS 20.0 (IBM Inc., New York, USA) және Jamovi (версия 2.5.5; https://www.jamovi.org) бағдарламаларын қолдану арқылы жүргізілді.

Нәтижелер: Орташа жас және жас санаттары бойынша бөліну ерлер мен әйелдер арасында статистикалық түрде ерекшеленді (p = 0,0071), ерлер арасында 40-49 жас аралығындағы адамдар басым болды (34,5%). Қатысушылардың 63,5% - ы осы аумақта туғаннан бері тұрады. Ерлерде БАҚ медианасы 130 (IQR 10) мм сын.бағ. болды, бұл әйелдерге қарағанда жоғары болды (p <0,001). Пациенттердің 90,1% - ында қалқанша безінің 1-2 дәрежеге дейін ұлғаюы байқалды. Ерлерде кортизол деңгейі жоғары болды-әйелдерде 319,0 (122,0) нмоль/л және 249,3 (145,2) нмоль/л (p = 0,020), ал инсулинге кері үрдіс бар. Қатысушылардың сыртқы гамма-сәулеленуінің орташа жеке дозалары 1.8 szv (IQR: 0.4–4.2) болды және ерлер мен әйелдер арасында статистикалық тұрғыдан ерекшеленбеді (p = 0.433).

Қорытынды: Жұмыстың осы кезеңінің нәтижелері үлгіні кеңейту, терең клиникалық-зертханалық және аспаптық тексеру, сондай-ақ экспонатталған адамдардың ұрпақтарында радиациялық әсердің соматикалық аурулардың дамуымен байланысын зерттеу үшін тіркелімді одан әрі жинақтау қажеттілігін көрсетеді.

Түйінді сөздер: *Семей ядролық полигоны; денсаулыққа қатысты әсерлер; скрининг; қауіп факторлары; радиация.*

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Introduction

The effects of chronic low-dose ionizing radiation on human health have been the subject of scientific research, with renewed interest in this area observed in recent years. One affected group is the population living in areas adjacent to the former Semipalatinsk Nuclear Test Site (SNTS). Since 1949, 468 tests have been conducted at the test site, including 117 above-ground tests [5]. Radiation contamination has affected significant areas, extending far beyond the test site's boundaries and into the eastern region of the Republic of Kazakhstan. Dosimetry studies indicate that the Beskaragay District of Abay Oblast is among the regions significantly affected by ionizing radiation [15].

Since the 1990s, studies have been conducted to examine the impact of nuclear tests on the health of people living in areas adjacent to the nuclear testing site, mainly based on dosimetric assessments [6, 8].

Notably, during the SNTS operation and after its closure, a large number of people continued to reside in the affected areas. Given this, it is of considerable interest to assess not only the direct effects of radiation exposure suffered by the population up until the cessation of testing in 1989, but also those in their descendants. This fact makes the epidemiological situation in the region unique.

Previous studies focused primarily on various aspects of assessing the health status of the population, but these studies generally included only individuals of the first generation, i.e., those directly exposed to ionizing radiation as a result of ground explosions. Thus, attempts were made to evaluate the oncologic effects [3, 4], cardiovascular [7, 14], and endocrine [9] effects of radiation exposure.

At the same time, the question of the long-term effects of chronic low-dose radiation on the human body, including third- and subsequent-generation individuals, remains unresolved. Available data on genetic alterations resulting from ionizing radiation, such as stable chromosomal aberrations, translocations, and other abnormalities, have also been reported for members of the first generation of the exposed population, including residents of the Beskaragay District.

Thus, a comprehensive analysis of the health status of the population, including the second and third generations of people exposed to ionizing radiation, is currently required.

The aim of this study was to conduct a preliminary assessment of the results of health screening in the population of the Beskaragay District, including the second and third generations of persons exposed to radiation as a result of nuclear weapons testing.

Materials and methods

Study Population

To comprehensively characterize the health status of the population representing the second and third generations of individuals exposed to ionizing radiation, a screening study was conducted among the population of the Beskaragay District. Exclusion criteria included the presence of central nervous system pathology that precluded screening and patient surveys, and individuals with no connection to the previously operating SNTS (residents who arrived after 1991).

The primary goal of screening was to identify individuals at higher risk of disease or pathological conditions in the population for subsequent monitoring and provision of medical care by primary care organizations. Screening allows for rapid provision of consultative medical care to a large population.

This preliminary analysis includes data on 222 patients living in the Beskaragay District, including residents of the villages of Dolon, Mostik, and Cheremushki. Sample size calculation was performed using the OpenEpi online program, ensuring 80% statistical power and 95% confidence. (https://www.openepi.com/SampleSize/SSCC.htm).

Stages and Main Research Methods

The first stage of the screening study included a survey on patients' health status, risks of developing non-communicable and socially significant diseases, diet, and lifestyle. The survey was conducted by completing specially developed questionnaires, which included socio-demographic questions and items on radiation exposure. Subsequently, patients were examined and their physical status was assessed. Blood pressure was measured

according to the recommendations of the European Society of Cardiology [17].

As part of the screening examination, blood samples were drawn for a complete clinical and biochemical blood test. Laboratory tests included thyroid peroxidase antibodies, TSH, free T4, glycated hemoglobin (as indicated), blood glucose, lipid profile (triglycerides, cholesterol, LDL), serum creatinine, ALT, AST, and blood electrolytes. Biochemical analysis of the parameters under study was performed using enzyme-linked immunosorbent assay (ELISA) using standard reagents.

Statistical Data Processing

Quantitative parameters were assessed for normal distribution using the Shapiro-Wilk test (for fewer than 50 subjects) or the Kolmogorov-Smirnov test (for more than 50 subjects). Normally distributed quantitative parameters were described using mean values (M) and standard deviations (SD), along with 95% confidence intervals (95% CI). In the absence of normal distribution, quantitative data were described using the median (Me) and interquartile range (IQR). Categorical data were described using absolute values and percentages. Comparisons between two groups for a non-normally distributed quantitative parameter were performed using the Mann-Whitney U test. Comparison of percentages in the analysis of four-field contingency tables was performed using the Pearson chi-square test (for expected values greater than 10) and Fisher's exact test (for expected values less than 10). Statistical analysis was performed using SPSS 20.0 (IBM Inc., New York, USA) and Jamovi (version 2.5.5; https://www.jamovi.org).

Results

The results of the preliminary analysis of the health status of the population of Beskaragay District, representing second- and third-generation descendants of victims of the STS activities, included 222 patients. Table 1 presents the socio-demographic characteristics of the patients. The mean age and distribution by age categories differed statistically significantly between men and women ($p = 0.0071$). Among men, the predominant age group was 40–49 years (34.5%), while among women, the majority were 30–39 years old (51.4%). There were no significant differences between men and women in terms of the duration of residence in the area ($p = 0.7281$); the majority of participants had lived here since birth (65.3%). Service in the armed forces, as expected, was characteristic predominantly of men — 35.7% versus 0.7% among women ($p < 0.001$). The level of education did not differ significantly between men and women ($p = 0.1311$); the most common education was secondary vocational education (36.0%), which is typical for the region. The proportion of individuals registered for dispensary care also did not differ by gender ($p = 0.2771$) and amounted to 25.7% of the total sample. Statistically significant differences were found in smoking status ($p = 0.021$), which was more common among men (21.4%) than women (10.1%). Similarly, alcohol consumption was more common among men (28.6%) than women (15.9%) ($p = 0.0241$).

Table 1.

Socio-demographic characteristics of people included in the study.

Parameter	Men (N=84)	Women (N=138)	Total (N=222)	p value
Age (years)				0.007[1]
<19	5 (6.0%)	1 (0.7%)	6 (2.7%)	
20-29	17 (20.2%)	33 (23.9%)	50 (22.5%)	
30-39	28 (33.3%)	71 (51.4%)	99 (44.6%)	
40-49	29 (34.5%)	28 (20.3%)	57 (25.7%)	
>50	5 (6.0%)	5 (3.6%)	10 (4.5%)	
Length of residence in the area (years)				0.728[1]
Since birth	58 (69.0%)	87 (63.0%)	145 (65.3%)	
> 1	1 (1.2%)	1 (0.7%)	2 (0.9%)	
3-5	0 (0.0%)	3 (2.2%)	3 (1.4%)	
Up to 10	5 (6.0%)	12 (8.7%)	17 (7.7%)	
10-30	14 (16.7%)	24 (17.4%)	38 (17.1%)	
>30	6 (7.1%)	11 (8.0%)	17 (7.7%)	
Service in the armed forces	30 (35.7%)	1 (0.7%)	31 (14.0%)	<0.001[1]
Education				0.131[1]
Incomplete secondary	19 (22.6%)	43 (31.2%)	62 (27.9%)	
Secondary vocational	28 (33.3%)	52 (37.7%)	80 (36.0%)	
Secondary	17 (20.2%)	14 (10.1%)	31 (14.0%)	
Higher	20 (23.8%)	29 (21.0%)	49 (22.1%)	
Dispensary registration	25 (29.8%)	32 (23.2%)	57 (25.7%)	0.277[1]
Currently smokes	18 (21.4%)	14 (10.1%)	32 (14.4%)	0.02[1]
Alcohol consumption	24 (28.6%)	22.0 (15.9%)	46 (20.7%)	0.024[1]

[1]Pearson's Chi-squared test

The physical status assessment was based on the classical approach (Table 2). Office systolic and diastolic BP (SBP and DBP, respectively) were studied. The median SBP in men was 130 (IQR 10) mmHg, which was significantly higher than in women ($p < 0.001$). DBP was also higher in men and amounted to 80 (IQR 10) mmHg, while in women it was 70 (IQR 20) mmHg ($p = 0.037$). It is worth noting the general tendency to maintain BP within the target range in accordance with currently valid international recommendations (McEvoy JW, 2024).

Heart rate (HR) did not differ significantly (p = 0.260). Signs of lymphadenopathy and thyroid enlargement did not show significant differences between men and women (p > 0.05). The majority of examined patients had an enlargement of the thyroid gland up to grade 1–2 (90.1%).

Of particular interest was the study of laboratory parameters in the study population. Men had higher levels of calcium (p = 0.003), sodium (p = 0.001), magnesium (p = 0.004), as well as liver enzymes - ALT (p < 0.001) and AST (p = 0.002). The average creatinine level was significantly higher in men - 77.7 (13.5) μmol/L versus 57.4 (10.4) μmol/L in women (p < 0.001). The median values of these parameters corresponded to the reference values, with a tendency to increase among men, which is due to gender differences.

HbA1c levels were within normal limits in both groups (~5.2%), indicating the absence of significant carbohydrate metabolism disorders in the majority of participants.

Table 2.

Clinical characteristics of study participants.

Parameter	Men (N=84)	Women (N=138)	p value
Systolic blood pressure (Me, IQR)	130 (10)	120 (10)	< 0.001[1]
Diastolic blood pressure (Me, IQR)	80 (10)	70 (20)	0.037[1]
Heart rate/min (Me, IQR)	70 (7.25)	68 (7.25)	0.260[1]
Lymphadenopathy	0 (0.0%)	2 (1.4%)	0.268[2]
Thyroid gland			0.881[2]
Increase to 1-2 degrees	76 (90.5%)	124 (89.9%)	
Increase to 3rd degree	8 (9.5%)	14 (10.1%)	
Laboratory data			
Ca, mmol/L (Me, IQR)	2.32 (0.1)	2.26 (0.12)	0.003
K mmol/L (Me, IQR)	4.6 (0.55)	4.5 (0.5)	0.749
Na mmol/L (Me, IQR)	141 (2.0)	140 (2.0)	0.001
Mg mmol/L (Me, IQR)	0.84 (0.05)	0.81 (0.06)	0.004
Glycated hemoglobin, % (Me, IQR)	5.19 (0.48)	5.16 (0.55)	0.263
Total protein (Me, IQR)	69.84 (4.25)	69.58 (6.07)	0.385
ALT U/L (Me, IQR)	21.91 (19.97)	13.89 (10.39)	<.001
AST U/L (Me, IQR)	19.13 (9.82)	16.52 (5.2)	0.002
Creatinine μmol/l (Me, IQR)	77.72 (13.51)	57.37 (10.38)	<.001
Thyroxine mIU/L (Me, IQR)	12.4 (1.85)	12.2 (1.65)	0.369
TSH mIU/L (Me, IQR)	1.65 (1.30)	1.91 (1.69)	0.627
ACTH pmol/L (Me, IQR)	17.9 (17.46)	16.7 (13.52)	0.993
Cortisol nmol/L (Me, IQR)	319.0 (122.0)	249.3 (145.2)	0.020
Insulin mIU/ml (Me, IQR)	5.2 (4.64)	6.79 (5.73)	0.048

[1]Mann–Whitney U test; [2]Pearson's Chi-squared test

Among the hormonal parameters, differences were found for cortisol, the level of which was higher in men - 319.0 (122.0) nmol/l versus 249.3 (145.2) nmol/l (p = 0.020), and insulin, the level of which, on the contrary, was higher in women - 6.79 (5.73) μU/ml versus 5.20 (4.64) μU/ml (p = 0.048). This finding reflects a moderately increased insulin resistance in women, which is physiologically explained by a higher content of adipose tissue and the effect of estrogens on glucose metabolism. Thyroid status indicators did not differ statistically and also corresponded to normal thyroid function despite the increase in its size detected during physical examination. For other parameters, including concentrations of potassium, total protein, thyroxine, TSH and ACTH, no statistically significant differences were found between men and women (p > 0.05).

The median individual external gamma radiation doses to the participants were 1.8 cSv (IQR: 0.4–4.2) and did not differ statistically between men and women (p = 0.433) (Table 3).

Table 3.

Characteristics of radiation doses of the subjects studied, as well as their previous generations (cSv, Median (IQR)).

Parameter	Male	Female	Total	p
Dose	2.2 (0.4 to 4.7)	1.7 (0.4 to 3.9)	1.8 (0.4 to 4.2)	0.433
Father's dose	4.7 (0.0 to 29.6)	4.6 (0.0 to 22.4)	4.7 (0.0 to 25.8)	0.898
Mother's dose	5.0 (0.0 to 19.3)	5.1 (0.0 to 16.8)	5.0 (0.0 to 17.8)	0.964

Figure 1 shows the distribution of individual external gamma radiation doses (cSv) among subjects in various age categories. The median radiation dose gradually increased with age, reaching a minimum value (less than 1 cSv) among participants under 19 years of age, increasing between 20 and 39 years of age, and reaching a maximum among patients over 40 years of age, reaching up to 20 cSv among some respondents over 50 years of age.

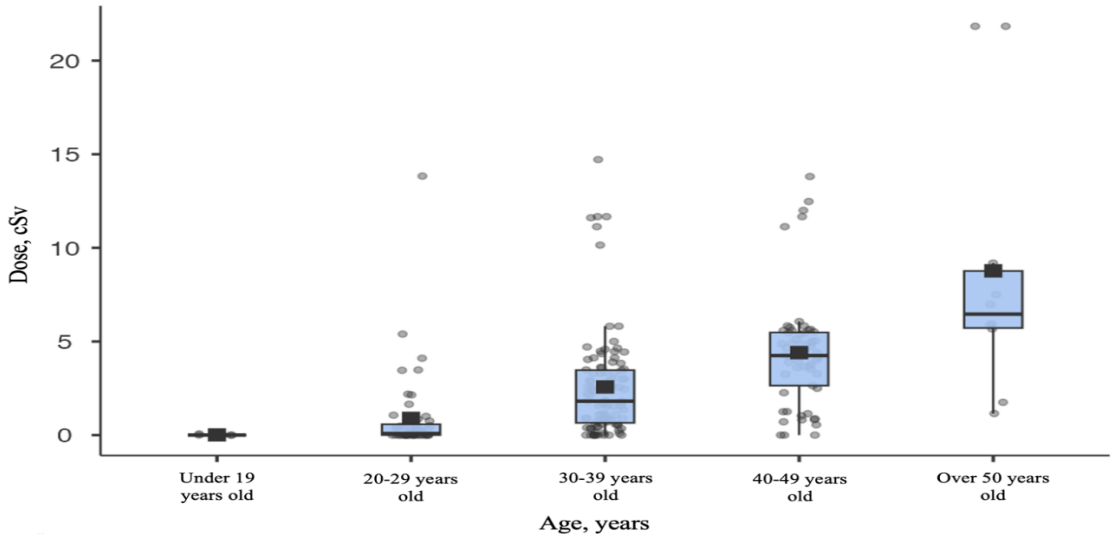

Figure 1. Doses of descendants of persons exposed to radiation, depending on age.

Discussion

Assessing the health status of the population affected by the activities of the STNS is a critical issue and remains relevant today. This is primarily due to the large population living in the adjacent areas, including those directly exposed to ionizing radiation, as well as their descendants. Studies at various levels (local and international) conducted over the past 30 years have demonstrated the need for further detailed analysis of radiation effects on the health of exposed populations. It is emphasized that all subsequent scientific research should focus specifically on the subsequent generations [14, 11].

The results we present demonstrate a preliminary assessment of the health status of individuals who are second - and third-degree descendants of individuals affected by the STS activities.

All study participants currently reside in the Beskaragay District, which is located in the zone of maximum radiation risk [2, 8]. The analysis revealed that the majority of participants in the registry are middle-aged patients (men were predominantly 40–49 years old (34.5%), and women were predominantly 30–39 years old (51.4%). It is important to note that the majority of participants (65.3%) had lived in the area since birth. This fact is of significant importance for the interpretation of further large-scale studies on the relationship between low-dose radiation and the development of stochastic and genetically mediated diseases. The degree of participation in medical checkups is an important indicator reflecting the preventive principle of healthcare organization. However, preliminary results demonstrate a relatively low rate of participation in medical checkups, amounting to 25.7%, with no significant differences between men and women. Traditional risk factors—smoking and alcohol consumption—were more common among men (21.4% smoking and 28.6% alcohol consumption, p=0.021 and p=0.0241, respectively), which is consistent with global and regional data.

The assessment of the physical status of patients is of great interest. It was found that the median value of office SBP was 130 (IQR 10) mmHg in men and 120 (IQR 10) mmHg in women ($p < 0.001$). DBP was also higher in men and was 80 (IQR 10) mmHg and 70 (IQR 20) mmHg in women ($p = 0.037$). This level corresponds to the target BP value for most patients [12]. However, this requires a more detailed definition. According to current recommendations, SBP in the range of 120-139 mmHg should be considered elevated BP, which was previously called prehypertension [12]. Thus, this category of patients requires more targeted dynamic monitoring. Heart rate (HR) did not differ significantly ($p = 0.260$) between men and women, amounting to 70 (IQR 7.25) and 68 (IQR 7.25) beats per minute, respectively. In recent decades, HR has received great attention, and experts recommend considering a resting HR of over 80 beats per minute as one of the risk factors for the development of cardiovascular events. This fact is especially important in patients with elevated blood pressure, representing a variant of chronic hyperactivation of the sympathetic nervous system [13]. Available research results emphasize the association between ionizing radiation and the development of hypertension, including in individuals living in areas adjacent to the STNS. Thus, it was found that age-adjusted odds ratios for arterial hypertension statistically significantly increase in groups with higher radiation levels [11]. In addition, it was found that cardiovascular diseases in general were diagnosed significantly more often than in the control group (RR=2.27) and among the population of the Republic of Kazakhstan (RR=2.25) [7].

The presented analysis showed that 90.1% of the patients examined had grade 1–2 thyroid enlargement. In this regard, it is important to note that a cross-sectional study examining the radiation risks of thyroid enlargement demonstrated a link between this pathology and the length of residence in radiation-contaminated areas and the patient's age at the time of exposure [9, 10].

The results demonstrate statistically significant gender differences in a number of laboratory parameters. Men had higher levels of calcium, sodium, magnesium, creatinine, transaminases (ALT, AST), and cortisol, which is likely related to physiological characteristics of male metabolism—greater muscle mass, increased anabolic activity, and enhanced functioning of the hypothalamic-pituitary-adrenal axis. Higher liver enzyme levels in men may also reflect greater physical activity and muscle catabolism, rather than liver pathology. Meanwhile, women had higher insulin levels, consistent with literature data on the tendency of women to have moderately

elevated insulin resistance due to a higher body fat percentage and the influence of estrogens on carbohydrate metabolism. The absence of differences in TSH, thyroxine, and ACTH levels indicates comparable endocrine regulation activity in both sexes.

The fact that all participants included in the analysis had a calculated radiation dose is also crucial, which is undoubtedly important for further research into the effects of radiation on public health. For example, the analysis shows a gradual increase in the median dose with age, reaching up to 20 cSv for some respondents over 50 years of age. This distribution reflects the cumulative effect of radiation exposure associated with age and duration of residence in contaminated areas [1]. Overall, there is a tendency for individual doses to increase with age, which is consistent with historical data on the heterogeneity of background radiation in different periods [15, 16].

Conclusion

Thus, the obtained data confirm the relevance of continuing research to assess the possible long-term effects of chronic low-dose irradiation and the intergenerational transmission of radiation-mediated changes among the population living in the territory of the former STS. The results of this phase of the study highlight the need for an expanded sample, in-depth clinical, laboratory, and instrumental examinations, and further registry development to study the relationship between radiation exposure and the development of somatic diseases in the descendants of exposed individuals.

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