UDC 613.6.027
DOI: 10.21668/health.risk/2021.1.08.eng

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Research article

METHODICAL APPROACHES TO ASSESSING INDIVIDUAL OCCUPAITONL HEALTH RISK CAUSED BY WORK-RELATED DISEASES DURING THE WHOLE EMPLOYMENT PERIOD

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An increase in retirement age means that employment period is prolonged; it calls for preserving people's working capacities for a longer period of time including those with long-term working experience. It is especially vital when it comes to adverse working conditions that might cause high health risks for workers due to work-related diseases.

We suggested methodical approaches to determining individual occupational health risks; these approaches took into account occupationally induced negative responses to impacts exerted by work-related factors; pathogenetic mechanisms of health disorders occurrence; gravity of health disorders; workers' age and working experience. To implement these approaches, we applied a set of procedures that included hygienic and epidemiologic analysis, clinical and laboratory examination of workers, mathematic modeling and prediction.

We tested these approaches via assessing occupational health risks for workers employed at oil-extracting enterprises and it allowed us to determine parameters of dependence between changes in arterial hypertension predictors under exposure to occupational noise and changes in age and working experience ($b_0 = 0.1427$; $b_1 = 0.007$; $b_2 = –0.372$). The obtained parameters can be used in assessing risks of arterial hypertension occurrence due to exposure to occupational noise for workers employed in oil extraction.

Individual occupational risk caused by arterial hypertension in people exposed to occupational noise was higher than its permissible level ($1 \cdot 10^{-3}$) for 13% workers (33 people) aged from 41 to 52 and working experience from 19.8 to 33 years; the risk detected in our research amounted up to $2.4 \cdot 10^{-2}$.

Maximum individual risks of work-related arterial hypertension that are predicted to occur at an age close to 59 years amount up to $4.3 \cdot 10^{-2}$ and they will be higher than permissible levels for 56.6% работников; at an age close to 65 years, up to $4.7 \cdot 10^{-2}$, and they will be higher than permissible levels for 64.8% workers.

Key words: *individual occupational risk, risk assessment, work-related diseases, cardiovascular diseases, arterial hypertension, occupational factors, noise, labor hardness.*

In 2019 in Russia average life expectancy reached its historical maximum and amounted to 73.6 years [1]. An increase in life expectancy, together with birth rate going down, gave grounds for a legislative decision[1] to increase retirement age. Retirement at older age makes it necessary to provide conditions for workers' health preservation and improvement, decrease in morbidity with non-communicable diseases, and reducing disability at pre-retirement age [2].

Retirement at older age extends a period during which people remain employable and it can result in such a negative outcome as longer

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[1] On making alterations into specific legislative acts of the Russian Federation on granting and paying retirement pensions: The Federal Law issued on October 03, 2018 No. 350-FZ. *KonsultantPlus.* Available at: http://www.consultant.ru/document/cons_doc_LAW_308156/ (06.06.2020) (in Russian).

exposure to adverse occupational factors and, consequently, greater occupational health risks. And occupational risks here are determined not only by occupational diseases but also work-related ones [3]. Diseases of the circulatory organs are the most widely spread work-related diseases that lead to the greatest losses of working activities due to temporary disability [4].

Occurrence of work-related diseases to a great extent depends on individual features a worker has such as his or her initial health, age, working experience under exposure to adverse occupational factors etc. [5–7]. Individual features should be taken into account when assessing occupational risks together with exposure to adverse occupational factors as it allows establishing personified health risks levels practically for each individual worker. It is vital for developing activities aimed at risks reduction, especially medical and preventive ones.

Certain functional disorders associated with pathogenetic mechanisms of their development usually occur prior to most diseases [8]. To assess such disorders, experts use predictors, or disease occurrence indicators [9]. Analysis of predictors frequency in an examined group can be used for assessing probability of a disease prior to its clinical manifestation; it makes for obtaining more precise health risk assessment, including occupational risks.

Contemporary methodical approaches to occupational risk assessment allow assigning it into specific categories using labor conditions ranks or classes and occupational diseases index. They give grounds for assessing cause-and-effect relations between health disorders and work. But at the same time, issues related to quantitative assessment of occupational risks caused, among other things, by work-related diseases have not been resolved completely. Also, there is still a lot to be studied when it comes to assessing individual health risks for each worker taking into account his or her individual health, age, and working experience.

Given that, it seems vital to further develop methodical approaches to assessing and predicting occupational health risks taking into account workers' individual features. Results obtained via assessing individual occupational health risks will provide more solid grounds for organizational and technical, administrative and legal, and, above all, medical and preventive activities aimed at their management during the whole employment period and will make such activities more efficient. It is advisable to test the suggested approaches to individual occupational health risk assessment involving workers who have to perform their work tasks under exposure to a set of adverse occupational factors with some of them exceeding hygienic standards. Such a situation exists in oil extraction industry since workers employed in the brunch suffer from both occupational diseases (sensorineural hearing loss) and work-related ones (arterial hypertension) and these diseases prevent them from continuing their working activities [10].

Our research goal was to develop and test methodical approaches to assessing individual occupational health risks caused by work-related diseases taking into account workers' age, working experience, and exposure to adverse occupational factors.

Data and methods. Individual occupational health risks were assessed as per the following algorithm:

– analyzing data on working conditions;

– performing epidemiologic analysis of workers' health parameters in order to assess cause-and-effect relations between health disorders and work;

– accomplishing clinical and laboratory tests aimed at examining workers' health;

– assessing cause-and-effect relations between health disorders and work;

– building up mathematical models showing dependence between negative responses probability and working conditions, age, and working experience;

– applying the obtained models to calculate individual health risks caused by work-related diseases.

We suggest methodical approaches to assessing individual occupational health risks that involve using several procedures including:

1. Analysis of data on working conditions (data obtained via specific assessment of

working conditions, industrial laboratory supervision), workers' age and working experience, assessment of working conditions category in accordance with R 2.2.2006-05 «Guide on hygienic assessment of occupational factors and factors related to labor process»[2], assigning risks into specific categories according to R 2.2.1766-03 «Guide on assessing occupational health risks for workers. Organizational and methodical grounds, principles, and assessment criteria»[3].

2. Epidemiologic analysis of workers' health in order to assess cause-and-effect relations between health disorders and work (occupational causation) as per such criteria as risk ratio (RR) and etiological fraction (EF) of negative responses.

3. Clinical and laboratory tests aimed at detecting any predictors (determined via literature sources analysis) of work-related diseases; these tests were performed by experts from the Common and Occupational Pathology Department (headed by O.Yu. Ustinova, Doctor of Medical Sciences, Deputy Director responsible for clinical research), the Department for Biochemical and Cytogenetic Diagnostics (headed by M.A. Zemlyanova, Doctor of Medical Sciences), the Department for Immune and Biological Diagnostics (headed by O.V. Dolgikh, Doctor of Medical Sciences).

Our next task was to establish dependence between development of work-related diseases and exposure to occupational noise; to do that, we built logistic regression models that showed dependence between a probability of negative responses and working conditions, age, and working experience (Formula 1). These models quantitatively determine dependence between a probability that there will be a deviation from physiological standards in predictors characterizing mechanisms of work-related diseases and an exposure factor, age, and working experience.

$$p_1 = \frac{1}{1 + e^{-(b_0 + b_1 x_1 \cdot x_2 + b_2 x_3)}} \quad (1)$$

where p_1 is a probability that predictors will deviate from physiological standards;

x_1 is a level of exposure to a certain factor;

x_2 is working experience;

x_3 is age;

b_0, b_1, b_2 are parameters included into a mathematical model.

Parameters included into a mathematical model were determined via least-square procedure and with specific software for statistical data analysis (Statistica-6.0). Parameters authenticity and model adequacy were assessed basing on one-factor dispersion analysis as per Fischer's test. When building models, we tested both statistical hypotheses and obtained dependences in order to estimate their biological adequacy.

To establish correlations between changes in predictors of diseases and morbidity levels (to assess actual realization of pathogenetic mechanisms), we determined a probability that work-related diseases might occur in workers who had certain signs of negative effects (predictors) developing in their bodies. This probability was determined as frequency of diseases in groups of workers with negative effects developing in them and without such effects.

Individual health risk caused by certain work-related diseases ($R^i_{w\text{-}r}$) was determined as per Formula 2.

$$R^i_{w\text{-}r} = p_1 \cdot p_2^i \cdot G^i \quad (2)$$

where p_1 is a probability that predictors will deviate from physiological standards taking into account worker's age;

p_2 is a probability that *i*-th work-related disease might occur in workers who have signs of negative effects (predictors) developing in their bodies;

G is gravity of *i*-th work-related disease.

[2] R 2.2.2006-05. Guide on hygienic assessment of occupational factors and factors related to labor process. Criteria and working conditions classification. Approved by the RF Chief Sanitary Inspector on July 29, 2005, 142 p. (in Russian).

[3] R 2.2.1766-03. Guide on assessing occupational health risks for workers. Organizational and methodical grounds, principles, and assessment criteria. *KODEKS: an electronic fund for legal and reference documentation*. Available at: http://docs.cntd.ru/document/901902053 (06.06.2020) (in Russian).

Acceptable (permissible) occupational health risk was taken as being equal to $1 \cdot 10^{-3}$.

Results and discussion. Suggested approaches were tested via examining impacts exerted by working conditions on health of workers employed in oil extracting industry.

When testing the suggested algorithm, we assessed working conditions as per results obtained via industrial supervision and specific assessment of working conditions performed at 60 workplaces (256 operators dealing with oil and gas extraction in the test group and 37 engineers in the reference group).

Data on workers' health, diseases they suffered from, and clinical-laboratory predictors of work-related diseases were obtained via specific medical examination; we also obtained relevant data via analyzing medical aid appeal ability. According to data taken from literature sources, pro-hypertensive effects produced by occupational noise directly depend on its intensity, frequency, and duration of exposure to it[4]. Changes in the circulatory system caused by exposure to intense occupational noise usually involve neural-circulatory syndrome occurrence and oxidative stress developing together with hypertensive reactions and a trend for transforming into arterial hypertension [11]. Several observation indicate that there are mechanisms underlying functional disorders in the cardiovascular system; these mechanisms, among other things, include endothelial dysfunction and arterial stiffness and are considered to be early signs of damage to vessels occurring due to arterial hypertension [12–15]. It is endothelial dysfunction that is seen as the basic predictor of cardiovascular diseases [16–19].

We examined malonic dialdehyde in blood plasma (293 samples), hydrocortisone (106 samples), lipid hydroperoxide (68 samples), and adrenalin (61 samples) as predictors for work-related arterial hypertension; these predictors changed during actual realization of such pathogenetic mechanisms as oxidative stress, vegetative dysfunction, astheno-vegetative syndrome, and peripheral angiodystonic syndrome [11].

Operators dealing with oil and gas extraction were chosen as our basic research objects since their occupation involved exposure to adverse occupational factors existing at their workplaces. All the workers accomplished similar work tasks under the same working regime.

We established that the examined workers were exposed to the following hazardous and adverse occupational factors: physical, chemical, and psycho-physiological ones[5]. Workers who directly dealt with oil extraction and preliminary oil processing had to perform their work tasks under combined exposure to occupational noise, hazardous chemicals, and adverse parameters of labor hardness. Adverse chemical factors at workplaces predominantly included substances belonging to 2–4 hazard category (oil and its components, and hydrogen sulphide as well). As per results obtained via assessment of working conditions performed at the examined enterprise, working conditions at 100.0 % workplaces of operators dealing with oil and gas extraction were estimated as harmful according to the Guide R 2.2.2006-05 «The Guide on hygienic assessment of factors related to working environment and labor processes. Criteria and classification of working conditions». As per results obtained via specific assessment of working conditions, noise achieved 80–85 dBA at workplaces (its hygienic standard is 80 dBA); labor hardness was ranked as harmful working conditions, I–II degree; dihydrosulphide concentrations estimated as per laboratory control reached simple maximum peaks equal to 6.9 mg/m^3 (the hygienic standard is 3 mg/m^3). But still, monitoring observations over aromatic hydrocarbons (benzene, toluene, ethyl-benzene, and xylol) contents in working area air didn't reveal any concentrations exceeding maximum single and average shift maximum permissible ones (MPC) during the whole observation period.

[4] O.Yu. Kuz'mina. Clinical and epidemiological peculiarities of metabolic syndrome in patients suffering from work-related diseases: abstract of the thesis … for Candidate of Medical Sciences degree. Samara, 2009, 24 p. (in Russian).

[5] GOST 12.0.003-74. The system for labor safety standards. Hazardous and adverse occupational factors. Classification. *KODEKS: an electronic fund for legal and reference documentation*. Available at: http://docs.cntd.ru/document/gost-12-0-003-74-ssbt (06.06.2020) (in Russian).

Table 1

Classification of working conditions as per results obtained via assessing workplaces of operators dealing with oil and gas extraction according to P 2.2.2006-05

Working area	Occupation	Working conditions category as per intensity of exposure to factors						Overall assessment
		Chemical	Noise (Lequiv.)	Microclimate	Lighting environment	Labor hardness	Labor intensity	
1	Operator, 4th grade	3.1	2–3.1	2	2	3.1–3.2	2	3.2
2	Operator, 5th grade	3.1	2–3.1	2	2	3.1–3.2	2	3.2
3	Operator, 6th grade	3.1	2–3.1	2	2	3.1–3.2	2	3.2

Noise, labor hardness, and chemical factor (dihydrosulphide mixed with hydrocarbons) are basic occupational factors that exert their influence on workers and determine occupational health risks.

Working conditions at workplaces of engineers were estimated as harmful at 100.0 % of such workplaces (working conditions category is 3.1). Labor intensity was the basic occupational factor that allowed ranking working conditions at engineer' workplaces as harmful.

According to the Guide R 2.2.1766-03 operators dealing with oil and gas extraction had average (significant) occupational health risks at their workplaces; engineers, small (moderate) risks.

Labor hardness together with elevated noise levels make for developing sensorineural hearing loss due to disorders in cerebral hemodynamics [20]. Apart from this, labor hardness accelerates degenerative-dystrophic processes in the spinal column and makes for more frequent polysegmental osteochondrosis occurrence [21].

We established structure of morbidity in both occupational groups basing on the medical examination as well as data on morbidity among workers provided by the administrative staff at the examined enterprise. A significant number of workers, namely 11.8 %, had disorders of the musculoskeletal system (various dorsopathy and osteoarthritis). Cardiovascular diseases accounted for another significant 15.5 % share (hypertensive disease with predominant damage to the heart without heart failure, vascular headache, varicose veins on lower extremities); gastric diseases accounted for 5.3 % (gastroduodenitis, cholecystitis, pancreatic diseases); a big share of 20.9 % belonged to respiratory diseases (pharyngitis, rhinitis, bronchitis, and tonsillitis). Apart from the above mentioned diseases, some workers from the test group also had disorders of the vegetative (autonomous) nervous system (1.99 %). There were no occupational diseases detected among the examined workers.

Occupational causation of diseases among operators dealing with oil and gas extraction was confirmed only for essential (primary) hypertension (RR – 2.02; EF % – 50.57, average occupational causation, χ^2 – 3.92). We didn't detect any relations between other diseases and occupation.

Deviations in predictors that changed due to oxidative stress and vegetative dysfunction thus resulting in arterial hypertension occurrence were revealed in 51 % operators and 37 % engineers.

Mathematical modeling allowed obtaining parameters for dependence between changes in arterial hypertension predictor (hydrocortisone concentration) under exposure to occupational noise and changes in age and working experience (b_0=0.1427; b_1=0.007; b_2=–0.372). These parameters were used in assessing risks of arterial hypertension occurrence due to exposure to occupational noise.

Probability of arterial hypertension occurrence with changes in the selected predictor (10 people out of 121) amounted to 0.083. Arterial hypertension gravity (G) was equal to 0.578 [22, 23].

The suggested methodical approaches to determining individual occupational health risk take into account occupational causation of negative responses to impacts exerted by occupational factors, pathogenetic mechanisms of health disorders occurrence, their gravity, as

well as workers' age and working experience. They allowed us to establish individual risks of work-related arterial hypertension for workers from the test group.

Individual risk of work-related arterial hypertension (among workers exposed to occupational noise) exceeded permissible level ($1 \cdot 10^{-3}$) for workers aged from 41 to 52 with working experience ranging from 19.8 to 33 years (33 people, 13 % of the test group) and varied from $1 \cdot 10^{-3}$ to $2.4 \cdot 10^{-2}$ and it was significantly (up to 24 items) higher than the permissible level for workers with the longest working experience equal to 33 years.

Table 2 contains data on individual risks of work-related arterial hypertension occurrence for workers from the test group.

Individual risk of work-related arterial hypertension that is predicted to occur by the age of 59 is higher than permissible level for 56.6 % workers (145 people) with their working experience being from 29.8 to 41.2 years and varies from $1 \cdot 10^{-3}$ to $43 \cdot 10^{-3}$ and it is significantly (up to 43 times) higher than permissible level.

Individual risk of work-related arterial hypertension that is predicted to occur by the age of 65 is higher than permissible level for 64.8 % workers (166) people with their working experience being from 34.4 to 47.2 and varies from $1 \cdot 10^{-3}$ to $4.7 \cdot 10^{-2}$ and it is significantly (up to 47 times) higher than permissible level.

Therefore, having tested methodical approaches to assessing individual occupational health risks caused by exposure to adverse occupational factors, we were able to prove that these approaches allowed both quantitatively assessing risks for individual workers and predicting their levels for the whole employment period.

Conclusion. In this work we suggest methodical approaches to establishing individual occupational health risks caused by work-related diseases; these approaches take into account occupational causation of negative responses to impacts exerted by occupational factors, pathogenetic mechanisms of health disorders occurrence, their gravity, as well as workers' age and working experience.

We tested these approaches in assessing occupational risks for workers employed in oil extraction and established parameters for dependence between changes in predictors of work-related arterial hypertension (hydrocortisone contents) under exposure to occupational noise and changes in age and working experience (b_0=0.1427; b_1=0.007; b_2=–0.372). These parameters can be used in assessing risks of arterial hypertension occurrence due to exposure to occupational noise for workers employed in oil extracting industry.

The suggested approaches allow quantitatively assessing risk levels for individual workers and predicting them for the whole employment period. Thus, individual risks of work-related arterial hypertension (for workers exposed to occupational noise) exceeded permissible level ($1 \cdot 10^{-3}$) for 13 % workers (aged from 41 to 52 and with working experience varying from 19.8 to 33 years) at the moment the research was accomplished and amounted up to $2.4 \cdot 10^{-2}$. Maximum individual risks of work-related arterial hypertension predicted by the age of 59 will amount up to $4.3 \cdot 10^{-2}$ and will be higher than permissible levels for 56.6 % workers; by the age of 65 they will rise up to $4.7 \cdot 10^{-2}$ and they will be higher than permissible levels for 64.8 % workers.

Table 2

Individual risks of work-related arterial hypertension for workers from the test group

Age	Working experience range for workers facing risks higher than permissible level	Risk values higher than permissible one	A share of people with risks higher than permissible one (%)
From 41 to 52 years (at the moment the research was accomplished)	19.8–33	0.001–0.024	13
By the age of 59	29.8–41.2	0.001–0.043	56.6
By the age of 65	34.42–47.17	0.001–0.047	64.8

Medical and preventive activities were suggested for workers with unacceptable individual health risks of work-related arterial hypertension at the moment the research was accomplished. These activities included an extended medical examination aimed at determining values of arterial hypertension predictors (hydrocortisone, lipid hydroperoxide, and malonic dialdehyde in blood plasma), more efficient personal protection equipment (that is able to reduce noise exposure by 10 and more dBA), and revised work and leisure regimes.

Funding. The research was not granted any sponsor support.

Conflict of interests. The authors declare there is no any conflict of interests.

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Shur P.Z., Zaitseva N.V., Fokin V.A., Kiryanov D.A., Khasanova A.A. Methodical approaches to assessing individual occupaitonl health risk caused by work-related diseases during the whole employment period. Health Risk Analysis, 2021, no. 1, pp. 82–89. DOI: 10.21668/health.risk/2021.1.08.eng

Received: 30.09.2020
Accepted: 17.11.2020
Published: 30.03.2021