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Research article

POSTERIOR ASSESSMENT OF OCCUPATIONAL RISKS ASSOCIATED WITH WORK HARDNESS BASED ON WORKERS' SUBJECTIVE PERCEPTION OF THEIR HEALTH

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Work hardness causes health impairments in workers of some occupations. Posterior assessment should be considered priority one in health risk analysis instead of relying solely on results obtained by prior assessment based on descriptions of working conditions,

This paper presents the results obtained by posterior occupational risk (OR) assessment associated with work hardness; the assessment is based on analyzing workers' subjective perception of their health (workers employed at a bearing production were used as an example).

A survey was accomplished within this study followed by analyzing subjective perception of one's health. It gave an opportunity to accomplish quantitative posterior OR assessment (that considered both likelihood of diseases and their severity) at the group and individual levels. Work hardness creates unacceptable group health risks associated with diseases of the musculoskeletal system and connective tissue ($1.93 \cdot 10^{-2}$–$2.56 \cdot 10^{-2}$), nervous system ($4.03 \cdot 10^{-2}$–$6.77 \cdot 10^{-2}$), genitourinary system ($2.04 \cdot 10^{-2}$–$2.7 \cdot 10^{-2}$) and cardio-vascular system ($1.47 \cdot 10^{-2}$–$1.69 \cdot 10^{-2}$). Such indicators as 'weight of constantly lifted cargo and cargo moved by hand' (35–58 %) and 'uncomfortable working posture / working upright' (29–54 %) make major contributions to the integral risk.

Risk categories were adjusted at the individual level (considering parameters of the relationship that describe how likelihood of disease is influenced by work hardness, age and working records). This allowed establishing that OR was predominantly caused by diseases of the musculoskeletal system and connective tissue ('medium risk' for 19–83 % of the workers and 'high risk' for 75–81 %), nervous system ('high risk' for 84–85 % and 'extremely high risk' for 15–16 % of the workers) and genitourinary system ('moderate risk' for 1 %, 'medium risk' for 8 %, and 'high risk' for 87 %).

Occupational health risk assessment allowed identifying priority indicators of work hardness ('weight of constantly lifted cargo and cargo moved by hand' and 'uncomfortable working posture / working upright') and establishing proper scope of relevant prevention activities at the group and individual level.

Keywords: *occupational risk, health risk, work hardness, posterior assessment, health disorder, subjective perception, methodical approaches, work-related diseases.*

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Over the last 10 years, work hardness has caused a growth in the share of diseases associated with physical overloads (the growth rate is 5.12 %)[1]. Assessment of occupational risk (OR) associated with work hardness is among relevant tasks of occupational hygiene. In practice, it mostly relies on prior health risk assessment based on SAWC (Special Assessment of Working Conditions) data [1–3]. Several publications report some results obtained by posterior assessment that involved establishing cause-effect relations between health impairments and work hardness as per results of epidemiological studies [4–8] as well as posterior assessments with the use of one-figure indexes [2]. However, this does not always allow quantifying OR levels and describing them in detail at the individual level.

To achieve optimal functioning of a system for preventive activities, it seems advisable to consider both working conditions for prior assessment and health for posterior assessment as comprehensively as only possible within OR assessment. Another important thing is a possibility to predict individual health risks over the whole period of working [9–11]. Given that a registered occupational incidence (OI) rate can fail to fully describe an actual situation [12, 13], it seems interesting to analyze aggregated health outcomes to describe workers' health. These outcomes should cover both occupational diseases (ODs) and prevalence of general somatic diseases that are likely to be associated with working conditions (work-related diseases or WRDs), which tend to grow as work records become longer[2]. International experience in assessing prevalence of work-related diseases of the musculoskeletal system [14–16] allows employing questioning with subsequent analysis of subjective health perception to solve these tasks. Such an approach, on one hand, can supplement available data obtained by medical check-ups; on the other hand, it ensures an independent information source about aggregated health responses in the body prior to disease development and putting a clinical diagnosis. This is especially vital for preventive medicine since this helps ensure substantial effects of implemented preventive activities.

The present study has been accomplished considering the priority given to posterior quantitative OR assessment in relevant guidelines and it supplements the previously published results of prior assessment of OR associated with work hardness [17].

The aim of this study was to perform posterior assessment of occupational risk associated with work hardness based on analyzing data about workers' subjective perception of their health (exemplified by workers employed at a bearing production facility).

Materials and methods. Hygienic health risk assessment was accomplished considering the basic provisions stated in the Guide R 2.2.3969-23 Assessment of Occupational Health Risk for Workers / Organization and Methodical Essentials, Principles and Assessment Criteria[3] (hereinafter R 2.2.3969-23). They stipulate relevant assessment stages, use of adequate methods for measuring exposure, quantitative characteristics and priority of posterior assessment, that is, use of data on actual workers' health.

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[1] O sostoyanii sanitarno-epidemiologicheskogo blagopoluchiya naseleniya v Rossiiskoi Federatsii v 2022 godu: Gosudarstvennyi doklad [On sanitary-epidemiological welfare of the population in the Russian Federation in 2022: the State Report]. *The Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing.* Available at: https://www.rospotrebnadzor.ru/documents/details.php?ELEMENT_ID=25076 (June 11, 2024) (in Russian).

[2] Professional'naya patologiya: natsional'noe rukovodstvo [Occupational pathology: national guide]. In: N.F. Izmerov ed. Moscow, GEOTAR-Media Publ., 2011, 784 p. (in Russian).

[3] Guide R 2.2.3969-23. Rukovodstvo po otsenke professional'nogo riska dlya zdorov'ya rabotnikov. Organizatsionno-metodicheskie osnovy, printsipy i kriterii otsenki; utv. Federal'noi sluzhboi po nadzoru v sfere zashchity prav potrebitelei i blagopoluchiya cheloveka 7 sentyabrya 2023 g. [Assessment of Occupational Health Risk for Workers. Organization and Methodical Essentials, Principles and Assessment Criteria; approved by the Federal Service for Surveillance over Consumer Rights Protection and Human Wellbeing on September 7, 2023]. *GARANT: information and legal support*. Available at: https://base.garant.ru/408890207/ (June 11, 2024) (in Russian).

Work hardness was assessed based on measures and criteria according to the Guide R 2.2.2006-05 Hygienic Assessment of Factors Related to Working Environment and Work Process / Criteria and Classification of Working Conditions[4]. This assessment involved analyzing workers' subjective perception of this factor including a survey with a specifically designed questionnaire and a template for automated risk calculation. The results obtained by implementing the foregoing approach were quite valid (sensitivity was 94 % and predictive value was 84 %) [17].

Data on workers' health were also obtained by questioning. A questionnaire as a survey tool was developed considering international experience in health assessment using the standardized Nordic questionnaire for the analysis of musculoskeletal symptoms[5]. The questionnaire consisted of 19 questions and was aimed at revealing symptoms of diseases associated with work hardness over the last 12 months; visits to a doctor to treat these symptoms; an established diagnosis (if any).

A list of relevant symptoms was created basing on data about likely negative changes associated with work hardness. They were established at the hazard identification stage. Symptoms typical for identified health outcomes were determined by expert estimates performed by occupational pathologists at the Federal Scientific Center for Medical and Preventive Health Risk Management Technologies under the guidance by O.Yu. Ustinova, Doctor of Medical Sciences, Professor. The symptoms were then used to create a matrix for identification of a likely disease.

Likelihood of health impairments (diseases) was calculated considering already existing symptoms associated with these diseases from a relevant disease class.

Health risk levels for workers were quantified according to R 2.2.3969-23 considering additional likelihood of negative outcomes (diseases) and their severity. Severity coefficients were determined as per assessments of disability-adjusted life years (DALY) recommended by the WHO[6]. When determining a risk category, quantitative values that corresponded to negligible and low OR were considered acceptable (permissible).

The study was accomplished on a sample made of workers employed at a bearing production facility (BPF) with various occupations (blacksmith, founder, driver, setter, furnace tender, roll-on handler, repairman, sorter, heat-treater, turner, polisher, electrician etc.) who worked in five divisions (workshops) (n = 97, average age was 45.1 ± 1.2 years) [17]. The test group was made of workers exposed to work hardness that was above its permissible level per some specific indicators. The reference group was made of workers from the same workshops provided they were not exposed to impermissible work hardness. A relationship between a factor and disease was considered significant ($p < 0.05$) at a relative risk

[4] Guide R 2.2.2006-05. Rukovodstvo po gigienicheskoi otsenke faktorov rabochei sredy i trudovogo protsessa. Kriterii i klassifikatsiya uslovii truda; utv. Glavnym gosudarstvennym sanitarnym vrachom Rossiiskoi Federatsii G.G. Onishchenko 29 iyulya 2005 g. [Hygienic Assessment of Factors Related to Working Environment and Work Process. Criteria and Classification of Working Conditions; approved by G.G. Onishchenko, the RF Chief Sanitary Inspector on July 29, 2005]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200040973 (June 11, 2024) (in Russian).

[5] Kuorinka I., Jonsson B., Kilbom A., Vinterberg H., Biering-Sørensen F., Andersson G., Jørgensen K. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl. Ergon.*, 1987, vol. 18, no. 3, pp. 233–237. DOI: 10.1016/0003-6870(87)90010-X

[6] Global Burden of Disease Study 2019 (GBD 2019) Disability Weights. Seattle, USA, Institute for Health Metrics and Evaluation (IHME), 2020. Available at: https://ghdx.healthdata.org/record/ihme-data/gbd-2019-disability-weights (June 17, 2024); WHO methods and data sources for global burden of disease estimates 2000–2019. *WHO*, 2020. Available at: https://cdn.who.int/media/docs/default-source/gho-documents/global-health-estimates/ghe2019_daly-methods.pdf?sfvrsn=31b25009_7 (June 17, 2024).

(*RR*) level and the lower limit of the confidence interval of 95 % (CI) being above 1. Additional likelihood of negative health outcomes was determined based on epidemiological analysis and an established relationship between a factor and disease as difference between likelihood of disease in the test and reference groups.

The integral group risk (R_{int}) associated with some specific indicators of work hardness was defined per the following formula 1:

$$R_{int} = 1 - \prod_{i=1}^{n} \cdot \left(1 - p_{ji} \cdot g_i\right), \qquad (1)$$

where

p_{ij} is likelihood of the *j*-th disease associated with the *i*-th indicator of work hardness;

g_j is the severity coefficient for the *j*-th disease (response).

Severity coefficients corresponded to average weighted measures per disease classes[6]: diseases of the musculoskeletal system and connective tissue, 0.079; diseases of the nervous system, 0.166; diseases of the circulatory system, 0.07; diseases of the genitourinary system, 0.078.

Individual OR was calculated based on created logistic regression models that described relationships between diseases and work hardness (exposure level), age and work records (Formula 2):

$$p_1 = \frac{1}{1 + e^{-(b_0 + b_1 x_1 \cdot x_2 + b_2 x_3)}}, \qquad (2)$$

where

p_1 is likelihood of the *j*-th response;

x_1 is a level of exposure to work hardness as an adverse occupational factor per some specific indicators (kg·m; kg; km; % of time; kg·sec; abs. units);

x_2 is work records, years;

x_3 is age, years;

b_0, b_1, b_2 are parameters of a mathematical model.

Significance of parameters and model adequacy was estimated by using dispersion analysis per the Fischer's test ($p < 0.05$).

Results and discussion. A list of most likely unfavorable health outcomes was created at the hazard identification stage. They included both ODs and WRDs[7]. The list was systematized for groups of indicators that described work hardness (physical dynamic load for a local and total load; weight of constantly lifted cargo and cargo moved by hand; stereotype work movements; static loads; uncomfortable working posture; body bending at an angle more than 30 degrees; moving horizontally or vertically) and included diseases of the musculoskeletal system and connective tissue, nervous system, circulatory system and genitourinary system.

Prevalence of the analyzed symptoms was established based on workers' subjective perception of their health as well as on frequency of visits to a doctor in case of health complaints and already diagnosed diseases. Over the last 12 months, more than 50 % of the workers felt discomfort, strain and / or pain in the small of the back; less than 50 % but more than 40 %, discomfort, strain and / or pain in arms and / or legs; less than 40 % but more than 20 % of the workers, discomfort, strain and / or pain in the neck, shoulder blades, shoulders, restriction of movements in joints of upper and / or lower extremities; less than 20 % of the workers complained about vascular asterisks on lower extremities, shin and foot edemas, impaired sensitivity, and changes in skin color of upper and / or lower extremities (Table 1). In terms of occupations, malaise signs were the most frequently identified in turners (pains in different part of the spine, upper and / or lower extremities 6.3–9.1 %), setters (pain in the small of the back 9.5 %, pain in the legs 7.8 %), founders and polishers (pain in the small of the back 6.8 %).

[7] Ob utverzhdenii perechnya professional'nykh zabolevanii: Prikaz Ministerstva zdravookhraneniya i sotsial'nogo razvitiya RF ot 27 aprelya 2012 g № 417n [On Approval of the List of Occupational Diseases: the Order by the Ministry for Healthcare and Social Development of the Russian Federation issued on April 27, 2012 No. 417n]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/902346847/titles/64U0IK (June 11, 2024) (in Russian).

Table 1

Subjective perception of ones' health by workers employed at a bearing production facility

№	List of symptoms	Total	Symptoms occurred over the last 12 months		Black-smith	Foun-der	Setter	Repair-man	Sorter	Heat-treaterт	Turner	Polisher
			abs.	%	%	%	%	%	%	%	%	%
1	Restricted motion, discomfort, strain and pain in the neck	79	22	27.8	2.5	2.5	3.8	0.0	3.8	1.3	7.6	2.5
2	Neck noises at head turns	77	19	24.7	2.6	2.6	3.9	0.0	1.3	1.3	5.2	5.2
3	Headache (back to temple), which is not stopped by analge-sics	76	20	26.3	1.3	2.6	5.3	1.3	3.9	1.3	3.9	3.9
4	Discomfort, strain and pain in the shoulder blades	77	18	23.4	0.0	1.3	3.9	0.0	3.9	3.9	3.9	1.3
5	Discomfort, strain and pain in the shoulders	77	22	28.6	1.3	3.9	5.2	2.6	2.6	2.6	3.9	3.9
6	Discomfort, strain, weakness and pain in the arms and hands	70	28	40.0	2.9	4.3	4.3	1.4	4.3	2.9	8.6	4.3
7	Impaired sensitivity, changes in skin color of the shoulder girdle	74	5	6.8	0.0	1.4	2.7	0.0	0.0	1.4	0.0	1.4
8	Muscle weakness, reduced mus-cle force of the arms	76	17	22.4	1.3	1.3	1.3	1.3	2.6	0.0	3.9	2.6
9	Discomfort, strain and pain in the small of the back	74	38	51.4	4.1	6.8	9.5	1.4	4.1	5.4	6.8	6.8
10	Stiffness, restricted motion of the spinal column	79	20	25.3	1.3	1.3	5.1	0.0	0.0	2.5	6.3	5.1
11	Discomfort, strain and pain in the legs	77	33	42.9	2.6	3.9	7.8	0.0	3.9	5.2	9.1	5.2
12	Changes in the gait, swaying, fatigue	74	23	31.1	2.7	2.7	5.4	1.4	4.1	1.4	5.4	4.1
13	Discomfort, strain and pain of lower extremities	74	4	5.4	1.4	1.4	1.4	0.0	0.0	0.0	1.4	0.0
14	Impaired sensitivity and func-tions of the pelvis organs (con-stipation, enuresis; in females, bloody discharge, bulging of genital organs)	74	4	5.4	0.0	0.0	0.0	0.0	2.7	1.4	1.4	0.0
15	Restricted motion, pain in joints of upper extremities upon movement and physical loads	74	18	24.3	1.4	4.1	5.4	1.4	2.7	1.4	4.1	2.7
16	Restricted motion, pain in joints of lower extremities upon movement and physical loads	73	17	23.3	1.4	2.7	5.5	0.0	2.7	2.7	4.1	4.1
17	Spontaneous bone fractures	74	3	4.1	0.0	0.0	0.0	1.4	0.0	0.0	1.4	0.0
18	Vascular asterisks, varicose saphenous veins of lower ex-tremities	75	14	18.7	4.0	1.3	4.0	1.3	2.7	0.0	1.3	2.7
19	Shin and foot edemas by the end of a work day	74	13	17.6	1.4	0.0	1.4	1.4	2.7	1.4	4.1	4.1

Not more than 30 % of the workers who had health complaints visited a doctor. Thus, 29 % of the workers went to a clinic to treat discomfort, strain and / or pain in the small of the back and a diagnosis was put in 45 % of the cases (osteochondrosis, a herniated disk); 12 %, to treat discomfort, strain and / or pain in the legs; of them, a diagnosis was put in 25 % of the cases (osteoarthrosis); 7 %, to treat discomfort, strain and / or pain in the arms without any diagnosis at the moment the present study was being accomplished.

Within this study, presence of likely adverse health outcomes was established using symptoms mentioned by a respondent and according to the above mentioned matrix for identification of health responses. These health outcomes were determined per relevant classes of diseases (ICD-10): diseases of the musculoskeletal system and connective tissue (M00–M99), diseases of the nervous system (G00–G99), diseases of the circulatory system (I00–I99), and diseases of the genitourinary system (N00–N99).

To perform posterior OR quantification, the Exposure – Response relationship was estimated and cause-effect relations were established between adverse health outcomes in workers employed at BPF and levels of exposure to the analyzed factor per specific indicators that described work hardness (Table 2). Out of 17 indicators that described work hardness, significant cause-effect relations were identified for three (no relation was established for one indicator, and there were not enough observations to estimate 9 indicators for the test group).

Epidemiological analysis established that diseases of the musculoskeletal system and connective tissue were probably caused by too heavy weight of cargo that was constantly lifted and moved around by hand (1.67 (1.2; 2.4), EF = 40 %, $p < 0.05$) as well as too long time spent working in an uncomfortable posture (1.71 (1.2; 2.4), EF = 41 %, $p < 0.05$) or working upright (1.65 (1.0; 2.7), EF = 40 %, $p < 0.05$). Diseases of the nervous system were associated with the same indicators of work hardness with the etiological fraction of the factor being 44–52 %. A major contribution was made to diseases of the circulatory system by long periods spent working upright (2.29 (1.1; 5.0), EF = 56 %, $p < 0.05$) and too heavy weight of cargo that was constantly lifted and moved around by hand (1.77 (1.0; 3.0), EF = 43 %, $p < 0.05$). Diseases of the genitourinary system in the analyzed sample had the strongest association with weight of cargo that was constantly lifted and moved around by hand (2.19 (1.4; 3.5), EF = 54 %, $p < 0.05$) and uncomfortable working posture (1.75 (1.1; 2.8), EF = 43 %, $p < 0.05$).

Table 2

Relative risk of negative health outcomes (per classes of diseases) associated with some specific indicators of work hardness for BPF workers as per epidemiological analysis results

Indicators	Diseases of the musculoskeletal system and connective tissue (M00–M99)	Diseases of the nervous system (G00–G99)	Diseases of the circulatory system (I00–I99)	Diseases of genitourinary system (N00–N99)
Weight of a cargo lifted and moved by hand: interchanging with other work tasks, kg	0.6 (0.3; 1.0)	0.43 (0.2; 0.9)	0.39 (0.2; 1.0)	0.72 (0.4; 1.4)
Weight of a cargo lifted and moved by hand: constantly, kg	**1.67 (1.2; 2.4)**	**1.96 (1.3; 2.9)**	**1.77 (1.0; 3.0)**	**2.19 (1.4; 3.5)**
Uncomfortable working posture, % of time	**1.71 (1.2; 2.4)**	**2.09 (1.4; 3.0)**	1.57 (0.9; 2.7)	**1.75 (1.1; 2.8)**
Working upright, % of time	**1.65 (1.0; 2.7)**	**1.78 (1.0; 3.1)**	**2.29 (1.1; 5.0)**	1.69 (0.9; 3.1)

Note: significant cause-effect relations are given in bold, $p < 0.05$.

The risk characterization stage involved identifying levels of group OR associated with some specific indicators of work hardness considering additional likelihood and severity of negative health outcomes per various classes of diseases (Table 3).

The highest group OR values per specific indicators of work hardness were established for diseases of the nervous system and corresponded to the 'high risk' category. OR levels corresponded to the 'medium risk' category for all other classes of diseases. Still, the integral group risk associated with various characteristics of work hardness and caused by diseases of the musculoskeletal system and connective tissue ($6.64 \cdot 10^{-2}$), circulatory system ($4.31 \cdot 10^{-2}$) and genitourinary system ($6.13 \cdot 10^{-2}$) was estimated as 'high'; the integral group risk caused by diseases of the nervous system ($1.56 \cdot 10^{-1}$) was estimated as 'very high'.

Major contributions were made to the integral risk by such indicators as 'Weight of constantly lifted cargo and cargo moved by hand' (from 35 to 58 %) as well as 'uncomfortable working posture' (from 37 to 44 %) and 'working upright' (from 29 to 54 %). Estimated structure of contributions per various classes of diseases showed that 'uncomfortable working posture' made the greatest contribution to the risk of diseases of the nervous system (43 %).

Individual ORs were established using the results of mathematical modeling. Its parameters are provided in Table 4.

The individual risk was established to be caused by diseases of the musculoskeletal system and connective tissue, nervous system and genitourinary system. Lifting and moving heavy cargos (their weight being above safe standards) as a constant activity during a work shift created an individual OR caused by diseases of the musculoskeletal system and connective tissue with its value varying between $1.69 \cdot 10^{-2}$ and $7.9 \cdot 10^{-2}$ and with workers being distributed into groups of medium (25 %) and high risk (75 %). The same indicator created

Table 3

Levels of group occupational risks of negative health outcomes (per classes of diseases) caused by specific indicators of work hardness among workers employed at BPF

Indicators	Likelihood of disease		Additional likelihood	Risk level
	Test group	Reference group		
Diseases of the musculoskeletal system and connective tissue (M00–M99) (g = 0.079)				
Weight of constantly lifted cargo and cargo moved by hand, kg	0.727	0.435	0.292	$2.31 \cdot 10^{-2}$
Uncomfortable working posture, % of time	0.783	0.458	0.324	$2.56 \cdot 10^{-2}$
Working upright, % of time	0.619	0.375	0.244	$1.93 \cdot 10^{-2}$
Diseases of the nervous system (G00–G99) (g = 0.166)				
Weight of constantly lifted cargo and cargo moved by hand, kg	0.697	0.355	0.342	$5.68 \cdot 10^{-2}$
Uncomfortable working posture, % of time	0.783	0.375	0.408	$6.77 \cdot 10^{-2}$
Working upright, % of time	0.556	0.313	0.243	$4.03 \cdot 10^{-2}$
Diseases of the circulatory system (I00–I99) (g = 0.07)				
Weight of constantly lifted cargo and cargo moved by hand, kg	0.485	0.274	0.211	$1.47 \cdot 10^{-2}$
Working upright, % of time	0.429	0.188	0.241	$1.69 \cdot 10^{-2}$
Diseases of the genitourinary system (N00–N99) (g = 0.078)				
Weight of constantly lifted cargo and cargo moved by hand, kg	0.636	0.290	0.346	$2.7 \cdot 10^{-2}$
Uncomfortable working posture, % of time	0.609	0.347	0.261	$2.04 \cdot 10^{-2}$

Table 4

Parameters of models that describe relationships between likelihood of diseases and effects produced by various indicators of work hardness, age and work records

Work hardness indicator	Class of disease	Model parameters			
		b_0	b_1	b_2	p
Weight of constantly lifted cargo and cargo moved by hand, kg	Diseases of the musculoskeletal system and connective tissue (M00–M99)	-2.26	0.00095	0.048	0.0009
	Diseases of the nervous system (G00–G99)	-2.03	0.0011	0.036	0.0013
	Diseases of the genitourinary system (N00–N99)	0.54	-0.0013	0.002	0.002
Uncomfortable working posture, % of time	Diseases of the musculoskeletal system and connective tissue (M00–M99)	-2.08	0.0007	0.045	0.003
	Diseases of the nervous system (G00–G99)	-1.8	0.0008	0.032	0.005
Working upright, % of time	Diseases of the musculoskeletal system and connective tissue (M00–M99)	-1.96	0.0002	0.042	0.015

Table 5

Distribution of workers employed at BPF per levels of individual health risks, abs. (%)

Likely health outcome	Risk level and category						
	0–0.001 Negligible	0.0001–0.001 Low	0.001–0.01 Moderate	0.01–0.03 Medium	0.03–0.1 High	0.1–0.3 Very high	0.3–1 Extremely high
Weight of constantly lifted cargo and cargo moved by hand, kg							
Diseases of the musculoskeletal system and connective tissue (M00–M99)	0	0	0	22 (24.7)	67 (75.3)	0	0
Diseases of the nervous system (G00–G99)	0	0	0	0	76 (85.4)	13 (14.6)	0
Diseases of the genitourinary system (N00–N99)	2 (2.2)	2 (2.2)	1 (1.1)	7 (7.9)	77 (86.5)	0	0
Uncomfortable working posture, % of time							
Diseases of the musculoskeletal system and connective tissue (M00–M99)	0	0	0	17 (19.1)	72 (80.9)	0	0
Diseases of the nervous system (G00–G99)	0	0	0	0	75 (84.3)	14 (15.7)	0
Working upright, % of time							
Diseases of the musculoskeletal system and connective tissue (M00–M99)	0	0	15 (16.9)	74 (83.1)	0	0	0

an individual OR caused by diseases of the nervous system with its value varying between $3.54 \cdot 10^{-2}$ and $16.6 \cdot 10^{-2}$ and with workers being distributed into groups of high (85 %) and very high risk (15 %). And finally, it created an individual OR caused by diseases of the genitourinary system with its value varying between $3.52 \cdot 10^{-9}$ and $5.2 \cdot 10^{-2}$ and with workers being distributed into groups of negligible (2 %), low (2 %), moderate (1 %), medium (8 %) and high (87 %) risk (Table 5).

Long periods of time spent working in an uncomfortable posture and / or upright created an OR associated with diseases of the musculoskeletal system and connective tissue with its value varying between $1.99 \cdot 10^{-2}$ and $7.81 \cdot 10^{-2}$

and with workers being distributed into groups of moderate (17 %), medium (20–83 %) and high (81 %) risk. They also created an OR caused by diseases of the nervous system with its value varying between $4.15 \cdot 10^{-2}$ and $1.64 \cdot 10^{-1}$ and with workers being distributed into groups of high (84 %) and very high (16 %) risk.

Therefore, the accomplished quantitative posterior OR assessment established a relationship between negative health outcomes per classes of diseases and specific indicators of work hardness and determined contributions made by these indicators to the integral risk level. In addition, it allowed identifying relevant groups of workers for subsequent implementation of targeted medical and preventive activities relying on such a criterion as an unacceptable risk level.

Questioning as a method for establishing prevalence of diseases, on one hand, brings about some limitations to a study since it is based on subjective perception of one's health, which can cause both overestimation and underestimation of an actual health state. On the other hand, the questionnaire used in this study is an adapted version of the Nordic Musculoskeletal Questionnaire, which is used worldwide as an optimal instrument not for clinical diagnostics but rather for measuring prevalence of diseases of the musculoskeletal system under various working conditions within epidemiological research [18, 19]. It can supplement available results obtained by periodical medical check-ups.

Effects produced by work hardness on development of diseases (both ODs and WRDs) have been described in literature in detail [20–22]. Leading indicators of work hardness are described in some cases for some occupations [23, 24]. Our results obtained for workers employed at a bearing production facility do not contradict any previously described regularities. Thus, epidemiological analysis established occupational causation of diseases of the musculoskeletal system and connective tissue ('medium correlation', *EF* = 33–50 %), nervous system, circulatory system and genitourinary system ('medium' and 'high' correlation, *EF* = 33–66 % per specific indicators), which is similar to findings reported in other studies [1, 4]. Similar relationships between diseases of the musculoskeletal system and such indicators as 'lifting and moving heavy cargoes' (weighing above safe standards) and 'uncomfortable working posture / working upright' have also been confirmed in foreign studies with presented results of epidemiological research (*RR* = from 1.4 (1.3–1.5) to 4.1 (2.2–7.6) in various occupational groups) [14–16].

The published recommendations on how to use mathematical models make it possible to predict ODs of the peripheral nervous system and musculoskeletal system depending on a class of working conditions (CWC) and work hardness per such indicators as 'stereotype movements under local loads' and 'stereotype movements under regional loads'[8]. However, results of such assessment are limited by using only two indicators and this does not allow considering variable characteristics of work in some specific occupational groups. Moreover, the model includes CWC categories and not actual levels of exposure to an affecting factor, which can vary within one class and to a great extent reflect results obtained by individual assessments. Some other studies have focused on creating models for predicting likelihood of diseases of the circulatory system and musculoskeletal system. They allow assessing individual health risks but do not make it possible to establish a relationship between these diseases and some

[8] MR 2.2.9.2311-07. Sostoyanie zdorov'ya rabotayushchikh v svyazi s sostoyaniem proizvodstvennoi sredy. Profilaktika stressovogo sostoyaniya rabotnikov pri razlichnykh vidakh professional'noi deyatel'nosti; utv. Glavnym gosudarstvennym sanitarnym vrachom Rossiiskoi Federatsii G.G. Onishchenko 18 dekabrya 2007 g., vved. v deistvie 18.03.2008 [Methodical guidelines 2.2.9.2311-07. Workers' health associated with an occupational environment. Prevention of stress in workers for various occupational activities; approved by G.G. Onishchenko, the RF Chief Sanitary Inspector on December 18, 2007, came into force on March 18, 2008]. *KODEKS: electronic fund for legal and reference documentation*. Available at: https://docs.cntd.ru/document/1200072234 (June 16, 2024) (in Russian).

specific indicators of work hardness [25]. The parameters of the Exposure – Work Records – Age – Response relationship that are presented in this study supplement the available mathematical models for individual health risk assessment with such indicators as 'weight of constantly lifted cargo and cargo moved by hand' and 'uncomfortable working posture / working upright'.

The results obtained by quantitative posterior OR assessment established that the group risk level for workers employed at BPF varied from 'medium' to 'high' whereas preliminary prior assessment [17] had earlier established workers' distribution into groups with risks varying from 'low' to 'high'. Additionally estimated individual risk levels vary from 'negligible' to 'very high'. These adjusted data allow creating risk groups of workers which should be considered priority ones as regards provision of targeted medical and preventive activities.

Conclusion. Questioning employed in this study together with subsequent analysis of subjective perception of one's health makes it possible to perform preliminary quantitative posterior OR assessment (considering both likelihood of disease and its severity) at the group and individual level.

In this study, workers employed at a bearing production facility were used as an example in occupational risk assessment. As a result, unacceptable group health risks were established for them that were caused by diseases of the musculoskeletal system and connective tissue, nervous system, genitourinary system and circulatory system and were likely to be associated with work hardness (the risk category varied from 'medium' to 'high'). Such indicators as 'weight of constantly lifted cargo and cargo moved by hand' (35–58 %) and 'uncomfortable working posture / working upright' (29–54 %) made the greatest contributions to the integral risk level. Adjustment of a risk category at the individual level established OR to be caused predominantly by diseases of the musculoskeletal system and connective tissue, nervous system and genitourinary system (its levels varied from 'medium' to 'very high' risk categories).

OR assessment results should be considered when planning group sanitary-technical, organizational, as well as targeted medical and prevention activities.

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