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RISK-METRIYC STAFF HEALTH FACILITIES FOR THE DISPOSAL OF CHEMICAL WEAPONS

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Abstract. A comprehensive staff study at the chemical weapons destruction plants found that the staff involved in first-class hazard operations are exposed to adverse changes in the psychophysiological condition manifested in vascular control system stress, reduced reserve capacities of the cardiovascular system, exercise testing tolerance, reduced sensormotor response, and lower indicators of self- health assessments, Those changes result in high health risks and require a personalized action plan to the improvement of psychophysiological condition. Described below is a method of determination of the indications for an action plan to improve psychophysiological condition of employees after a work shift.
Keywords: occupational health, chemical weapon destruction workers, psychophysiological condition, risk-metric of health, personalized labor medicine.

Workers involved in chemical weapon destruction (CW destruction) are exposed to a hazardous and dangerous working environment. Labor safety here is ensured by mitigating measures - personal protection equipment, as well as the ‘time protection’ principle [4, 16].

Labor conditions at CW destruction plants such as mandatory use of personal protection equipment, high emotional load related to responsibility for the personal and group safety, high physical load, etc. - are considered health risk factors [5, 18]. This is documented by a 1.5-2.5 times higher primary disease incidence among the CW destruction staff (based on the number of hospital referrals as compared to the areas covered by protection measures) [2, 3, 8, 9]. For this reason, studies aimed at determining health risk factors among the CW destruction staff are essential for the activities aimed at health maintenance among the representatives of this profession [7, 9, 11 ,13].

The purpose of the research is to study health risk factors among the CW destruction staff related to changes in the psychophysiological condition during a work shift.

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Materials and methods. The studies were conducted in a group of 76 male workers of a CW destruction plant in Schuchie, Kurgan Region, Maradykovsky, Kirov Region, and Pochep, Bryansk Region. The respondents were placed into an experimental group (staff working in class 1 hazard environment) and reference group (other staff). The groups did not vary in terms of age, anthropometric measurements, and length of service:

Experimental group – 46 people, average age 31.5±10.6 years old, height 173±5 cm, weight 76.3±12.5 kg, length of service 3.2±1.7 years;

Reference group – 30 people, age 34.6±8.5 years, height 175±7 cm, weight 76.3±14.2 kg, length of service 3.8±2.1 years.

A comprehensive study among the respondents of the experimental group was conducted before and after a 4-hour shift, reference group – at the beginning and the end of a work day.

Via registration of K-sounds, we measured heart rate (HR), systolic blood pressure (SBP) and diastolic blood pressure (DBP).

On the basis of a 5-minute recording of RR intervals, we built a cardiointervalgram which helped us determine the difference (MxDMn))between the maximum and minimum RR interval (RRI); root mean square of successive differences (RMSSD); percentage of f successive normal sinus RR intervals >50 ms (pNN50); standard deviation (SDNN); dispersion (D); mode (Mo); mode amplitude (AMo); RR interval length; and RR interval spectrum power (TP). With the help of functional stress breath-holding test when inhaling (Shtange test) and exhaling (Gench test), we determined timed inspiratory (Tg) and expiratory (Ts) capacities, and calculated the response measurements during the Shtange's test (RMs) and Gench's test (RMg).

To describe the lability of the nervous system processes, we determined the time of simple (SSMR) and composite sensomotor reactions (CSMR). With the help of the WAM method (based on [6]), we determined wellbeing (W), activity (A) and mood (M) of the patient.

We measured the calculated hemodynamics parameters - average blood pressure (AvBP), stroke volume (SV), cardiac output (CO), pulse pressure (BPp), shock pressure (BPs), linear blood flow velocity (BFV), pulse wave velocity (PWV), cardiac function indicator (CFI).

We used the index of activity of the regulatory system (IARS) and stress index (SI) (based on [1]) as integral characteristics of the function state of the body.

Statictica 7.0 was used to process the results. In the process, we calculated the mean (M), standard deviation (SD) and mean-square error (m).

Testing of the hypotheses about the equality of mean values of the indicators in the analyzed groups before and after a work shift in each of the groups was conducted by sign criterion (the difference was considered statistically significant at the level of significance p<0.05). Testing of the hypotheses about the equality of mean differences (before and after a work shift) of the indicators between the analyzed groups was conducted by Mann-Whitney criterion (the difference is considered statistically at the level of significance p<0.05).

Results and discussion. Results of the comprehensive study of the patients from the experimental and reference groups are presented in Table 1 below.

The analysis of hemodynamic parameters showed no signs of hypertension, the entire spectrum of hemodynamic parameters in both groups was within the norm. The PWV of all the patients was close to the upper normal level (500-800 cm / s), which indicated a high degree of rigidity and density of the vascular wall and its reduced elastic properties. In addition, 25% of the experimental group and 40% of the control group at pre-shift inspection indicated increased specific peripheral vascular resistance which signifies a decrease in cross-precapillary bed. In the experimental group, the HR is higher and SV is lower than in the reference group indicating more pronounced stress regulatory mechanisms of central and peripheral hemodynamics before the start of a shift in the experimental group.

Analysis of the results of the study of heart rate variability showed that the cumulative effect of the regulation of cardiac activity in both groups corresponds to the normal cardia. The base activity indices of the sympathetic and parasympathetic regulation of heart rate in both groups were within the normal limits. SI and IARS values in both groups were higher than normal.

Analysis of the regulation of cardiac activity showed that in the experimental group, only 30% of the patients were in the area of optimal regulation, 45% - in the area of pronounced fatigue, and 25% - in the area of reduced reserve opportunities.

Table 1

Results of the study in the experimental and reference groups

Indicator	Experimental group (*n*=46)					Reference group (*n*=28)					*p*
	Before		After		*p*	Before		After		*p*	
	M	*m*	*M*	*m*		*M*	*m*	*M*	*m*		
HR, BPM	83,19	1,46	78,13	1,62	0,022	77,20	2,17	75,90	2,41	0,689	0,097
SBP, mm Hg	129,6	2,09	134,4	4,11	0,431	120,5	2,4	125,4	4,3	0,801	0,887
DBP, mm Hg	58,1	1,43	63,8	2,98	0,342	50,9	1,85	54,6	2,61	0,443	0,709
AvBP, mm Hg	84,0	1,45	89,7	3,65	0,231	77,6	1,99	80,1	2,76	0,342	0,197
APp, mm Hg	32,85	1,18	33,89	1,02	0,506	35,04	0,99	32,64	1,34	0,157	0,054
APs, mm Hg	38,59	1,42	33,00	1,39	0,006	34,54	2,06	32,64	1,68	0,480	0,111
CO, l/(min m^2)	4,94	0,10	5,04	0,08	0,463	5,15	0,08	4,93	0,11	0,124	0,036
SV, ml	62,80	1,99	70,11	2,52	0,025	72,14	2,97	69,04	2,96	0,462	0,002
BV, cm/s	36,7	0,74	36,0	0,98	0,543	37,7	0,66	34,4	2,32	0,239	0,087
PWV, cm/s	757,33	20,24	809,07	23,19	0,096	792,89	19,77	739,25	17,38	0,676	0,015
SSMR, ms	249,14	8,03	285,93	12,16	0,013	264,27	18,81	239,07	9,32	0,235	0,004
CSMR, ms	331,35	8,67	353,14	10,57	0,114	340,03	18,56	308,27	12,80	0,165	0,006
Ts, s	61,17	2,73	55,20	2,98	0,143	50,29	3,81	48,18	3,27	0,454	0,186
RMs, pts.	1,05	0,01	1,04	0,01	0,473	1,03	0,01	1,04	0,01	0,454	0,254

Tg, s	30,02	1,40	29,00	1,87	0,663	29,07	1,49	28,18	1,40	0,664	0,936
RM_G, units	0,97	0,01	0,98	0,01	0,418	0,97	0,02	0,96	0,02	0,705	0,238
CFI, units	9,00	0,12	8,4	0,92	0,651	8,96	0,15	8,02	0,77	0,432	0,241
MxDMn, ms	193,58	10,69	240,77	14,55	0,010	219,30	18,01	243,13	20,14	0,382	0,330
RMSSD, ms	24,62	2,37	29,15	2,38	0,180	29,76	3,27	33,29	2,85	0,419	0,770
pNN50, uts	6,96	1,61	10,71	1,96	0,143	11,60	2,62	13,46	2,18	0,587	0,473
SDNN, ms	38,46	2,21	45,05	2,89	0,073	41,77	3,46	46,61	3,66	0,341	0,677
D, ms^2	1699,02	188,31	2404,85	305,82	0,052	2067,25	317,82	2534,43	403,06	0,367	0,605
Mo, мs	733,83	14,26	781,26	16,81	0,034	789,36	21,28	807,04	23,74	0,582	0,157
TP, ms^2	1669,72	188,83	2262,06	284,56	0,086	1988,62	322,92	2205,83	312,05	0,631	0,330
W, units.	5,72	0,09	5,16	0,09	0,001	5,56	0,09	5,45	0,08	0,361	0,001
A, units.	5,46	0,12	5,05	0,12	0,018	5,41	0,12	5,35	0,12	0,744	0,014
M, units	5,65	0,12	5,62	0,10	0,826	5,55	0,15	5,76	0,10	0,263	0,089
SI, units	317,64	41,60	255,88	47,42	0,330	337,21	115,40	296,56	115,88	0,805	0,698
IARS, points	4,4	0,65	4,32	0,76	0,171	3,9	0,36	3,7	0,66	0,291	0,246

According to a pre-shift study, 67% of patients in the reference group were in the area of optimal regulation 30% - in the area of pronounced fatigue, and 13% - in the area of reduced reserve opportunities

According to the functional stress tests, the heart performance indicator showed a good level of functional reserves, and Shtange and Gench tests did not exceed the age-specific standards which indicates an adequate response of the cardiovascular system to oxygen deficiency. It is noteworthy, however, that the time of breath-holding in the Shtange test is longer in the experimental group as compared to the reference group which indicated a higher level of reserves of the cardio-respiratory system in this group of workers.

The values of wellness, activity and mood, SSMR and CSMR during the pre-shift monitoring in both groups were within the norm.

Consequently, the pre-shift study showed that the majority of the patients were in a good psychophysiological condition.

The change in the hemodynamic indicators in the control group before and after a work shift was less significant than in the experimental group; at the same time, in both groups, hemodynamic indicators after a work shift did not exceed the physiological standards. The changes in the hemodynamic indicators in the experimental group after a work shift indicated increased stress of the regulatory mechanisms in the patients of the group resulting in higher rigidity of the vessel wall. The changes in the blood pressure indicators in the experimental group indicated growing fatigue and stress of the hemodynamic regulatory mechanisms due to work in the environment of higher temperatures and humidity (when using personal protection equipment).

The registered increase in the heart rate variability indicators after a work shift in the experimental group indicated good tolerance of functional loads during a work shift; the heart rate in the experimental group decreased by the end of a work shift; in the reference group, the heart rate did not significantly change. The dynamics of the indicators of the heart rate variability showed in the experimental group, the sympathetic rate decreased, and the activity of the autonomous circuit of regulation increased. An increase in RMSSD и pNN50 in the experimental group after a work shift indicates increased activity of the parasympathetic nervous system in this group of workers.

A sharp increase in MxDMn after a work shift in the experimental group indicates a reduced sympathetic drive and a change in the regulatory mechanisms of the heart performance toward decentralization.

The initial values of SI exceeded the upper limit of normal rest (150 conv. units.) in 45% of patients in both groups. That fact points to a stress in the regulatory systems caused by chronic exposure to adverse factors of professional work environment. That is, in the pre-shift time, patients from the experimental and the control groups experienced pronounced psycho-emotional stress. After the shift, SI reduced in both groups, however, continued to remain at high values indicating a lack of the adaptive response of the cardiovascular system in a professional environment. A similar pattern is typical of IARS.

Self-assessment of wellbeing (W) and sensomotor reaction indicators (SSMR and CSMR) suggests severe fatigue in the experimental group. The identified changes in the psychophysiological indicators in the experimental group and their ratio are normal in terms of professional load which causes a decrease in the self-assessment of the state of health and (or) activity while a less pronounced fall in the mood (M).

The changes in the psychophysiological indicators registered in the experimental group are typical of professional stress and result in reduced state of health and (or) activity and decrease in mood (M).

The results of the SSMR and CSMR assessments in the experimental and control groups do not differ significantly, which can be a superposition of two reasons: reduced response time due to a workout and its increase because of the psycho-emotional and physical fatigue. The identified dynamics of sensorimotor responses indicate normal mobility of nervous processes.

The results of the study before and after a work shift determined that in 40% of the experimental group, the psychophysiological indicators showed a negative trend, for 15% the indicators remained unchanged at the pre-shift level or improved, and 45% showed competing psychophysiological indicators. The control group did not have any negative dynamics in the psychophysiological indicators after the shift, 80% showed competing changes in the psychophysiological indicators, and for 20% the indicators did not change or improved.

The registered negative trend in the psychophysiological indicators suggests high health risk to the experimental group [3, 4, 18].

The obtain results are consistent with the epidemiological data on the cause-and-effect relationship between health and work environment (Table 2) obtained in accordance with [8].

Table 2

Evaluation of the degree of cause-and effect relationship between health and work environment

Class of disease	Group	Relative risk, units	Etiological share, %	Relationship degree
Diseases of the nervous system	Experimental	1,55	34,2	Average
	Reference	1,2	28,4	Weak
Eye diseases	Experimental	1,15	21,3	Weak
	Reference	1,12	20,4	Weak
Ear diseases	Experimental	0,89	8,4	Zero
	Reference	0,78	4,6	Zero
Circulatory diseases	Experimental	3,18	58,9	Strong
	Reference	1,3	27,5	Weak
Diseases of the respiratory system	Experimental	2,1	54,1	Strong
	Reference	1,4	31,6	Weak
Diseases of the digestive system	Experimental	1,45	32,2	Weak
	Reference	1,24	27,5	Weak
Skin diseases	Experimental	1,39	30,1	Weak
	Reference	1,28	29,8	Weak

Strong (in the experimental group) and weak (in the reference group) cause-and-effect relationships between the work environment and circulatory / respiratory diseases can be explained by the negative changes in the psychophysiological indicators identified during the study (Table 1).

The above makes it necessary to implement measures aimed at improving (normalizing) the psychophysiological condition by reducing health risks in the experimental group [10, 12, 14, 17–19]. The lack of clear trends in the psychophysiological indicators suggests that the after-shift action plan developed to improve the psychophysiological condition should be personalized, taking into account the change in performance by the end of the work shift as compared to the indicators registered prior to the work shift [14, 17, 19].

In order to determine personalized indications for the after-shift action plan to improve the psychophysiological condition, we developed a program, based on the study results that includes the calculated function values ($G1$ and $G2$) based on the following values: $MxDMn$, SV, $RMSSD$ and SI, determined before and after a work shift (respectively, $MxDMn_{before}$, $MxDMn_{after}$, SV_{before}, SV_{after}, $RMSSD_{before}$, $RMSSD_{after}$, SI_{before}, SI_{after})

$$G1 = -0{,}004(MxDMn_{before} - MxDMn_{after}) + 0{,}001(SV_{before} - SV_{after}) -$$
$$- 0{,}033(RMSSD_{before} - RMSSD_{after}) + 0{,}002(SI_{before} - SI_{after}) - 0{,}799;$$

$$G2 = 0{,}035(MxDMn_{before} – MxDMn_{after}) + 0{,}141(SV_{before} – SV_{after}) –$$
$$– 0{,}123(RMSSD_{before} – RMSSD_{after}) + 0{,}005(SI_{before} – SI_{after}) – 4{,}708,$$

then the ones under study for which *G1* does not exceed *G2* are referred to the group of people in need of after-shift adjustment of the psychophysiological condition, and other patients are referred to the group of those who do not need after-shift adjustment of the psychophysiological condition.

G1 and *G2* functions were constructed based on the linear discriminant analysis that provides reliable (the quality satisfies the demands of the practice) division of the patients into two groups by the minimum number of reporting indicators based on the geometric (spatial) arrangement of the groups in high-dimensional space with axes that correspond to the psychophysiological indicators.

The structure of the personalized action plan for the adjustment of the psychophysiological condition does not depend on the difference between *G1* and *G2*, but is determined by a health worker based on the individual state of health of the employee.

Conclusion. Workers at chemical weapon destruction plants (involved in first-class hazard 7operations) are exposed to adverse changes in the psychophysiological condition manifested in vascular control system stress, reduced reserve capacities of the cardiovascular system, exercise testing tolerance, reduced sensormotor response, and lower indicators of self-health assessments. Those changes result in high health risks and require a personalized approach to the adjustment of psychophysiological condition after a work shift.

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