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Research Article

Psychophysiological Model of Stress-Induced Cardiovascular Disorders Development Risk

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Abstract

Aim and Introduction: According to the Russian Center of Emergency and Radiation Medicine, cardiovascular disorders remain one of the most important for firefighters and rescuers: during a 20-year monitoring period the rate for IX class diseases has changed from 19.5% to 29% with a constant increase in days away from work among firefighters. Arterial hypertension is in the leading place among cardiovascular disorders. Therefore, the issue of the early diagnosis of these disorders remains relevant. The article deals with describing a psychophysiological model of stress-induced cardiovascular disorders risk development in various categories of professional expertise for fire-fighters.

Materials and Methods: A comparative analysis of heart rate variability index, pulse wave velocity, rheoencephalography is conducted. 146 respondents were examined: 81 cadets of the 1st, 3rd and 5th years of study in 3 categories of professional expertise (average age 20 ± 1.64 years) and 65 males, aged from 20 to 50 years (average age 24.7 ± 5 years). The recording of HRV and PWV data was carried out using VNS-Micro and Poly-Spectrum-8 (Neurosoft LLC) digital systems. The results were processed with the standard methods of non-parametric statistics. Categories of professional expertise were determined by standard methods, according to the order of the Russian Emergencies Ministry.

Results: Personnel of the 1st and 3rd categories of professional expertise are characterized by the optimal heart rate regulation; they are better adapted to the effects of professional extreme factors and have a good level of adaptive reserves of the body. Cadets of the 2nd category of professional expertise are more at risk of maladaptive cardiovascular disorders. A critical period for the formation of stress-related disorders is the work experience of 5 to 10 years.

Conclusion: The described model of cardiovascular disorders development risk allows us to make suggestions for improving the system of medical and psychological support, as well as the professional selection system, for firefighters depending on the category of professional expertise.

Keywords: *Firefighters and Rescuers; Psychophysiological Model; Professional Expertise Category; Heart Rate Variability; Pulse Wave Velocity*

Introduction

Professional selection, the requirements for the state of health and its preservation on the entire professional route of firefighters and rescuers are extremely high (order of the Ministry of Internal Affairs of Russia dated 07.14.2010 No. 523, order of the Ministry of Health and Social Development of Russia dated 12.04.2011 No. 302n). A significant factor of professional longevity and the preservation of high working capacity of firefighters and rescuers is a "wide" corridor of psychophysiological adaptation, which allows stress-induced disorders not to pass into the outlined stress-induced nosological forms. Currently, the main way to determine the category of professional suitability is 9 test methods, which are divided into several blocks:

1. Intellectual-mnestic block (assessment of intelligence. Tests designed to identify the mental potential of an individual, his abilities and inclinations).

2. Emotional-personal block (questionnaires, allowing to obtain information characterizing the personality of the subject in a wide range - from his physical and mental state to his moral, ethical, social views.

3. Motivational-volitional block (diagnostics of motivations based on the direct identification of behavioral strategies, as well as an assessment of the volitional component).

It should be emphasized that early forms of maladaptive stressful disorders are difficult to diagnose - traditional, routine examinations in the system of medical and psychological support are not very informative. But only early, at the prenosological level, rehabilitation is able to fully preserve the health of persons in hazardous professions, and not compensate for the violations that have already arisen.

In this regard, it is promising to study autonomic disorders, which are ultimately observed in the onset of almost all diseases, the most socially significant of which are cardiovascular. In the above analysis of data on morbidity, injury, disability and mortality of employees of the State Fire Service (FFS) of Russia for 20 years from 1996 to 2015 [4], cardiovascular diseases continue to be in the group of the most significant: »Over the years ranges from 19.5 to 29%, with a steady increase in the proportion of cases of labor losses among firefighters. Among cardiovascular diseases, the first place is occupied by arterial hypertension. It is known that the level of blood pressure in the arterial system is determined not only by the minute blood volume and total peripheral resistance, but also by the stiffness of the great vessels, especially the aorta. Determination of the stiffness of the vascular wall by measuring the velocity of propagation of the pulse wave (PWV) is currently included in the list of recommended examinations of patients with arterial hypertension. PWV analysis is widely recognized by the European Society for the Treatment of Hypertension as an integral part of the diagnosis and treatment of hypertension, and the relationship between PWV and cardiovascular disease, impairment and death has been proven. In Russia, this technique is not yet generally available, especially for examining healthy individuals.

The width of the adaptation corridor (psychophysiological cost of activity) can be assessed by performing a functional test of low intensity - active orthostatic, and professional adaptation - by studying psychophysiological reactions to a professionally significant load (for firefighters, this is a heat-smoke chamber, a fire band of psychological training and/or real conditions for extinguishing a fire or emergency). The model can be based on the method of analysis of heart rate variability (HRV), which is recognized as adequate in assessing the psychophysiological parameters of adaptation [1]. The analysis of HRV in the dynamics of loads made it possible to develop a method for assessing the professional adaptation of firefighters [5]. Later, the HRV indices for the risk of developing cardiovascular accidents [6], the significance of the development of stress-induced disease [7] were clarified, and in the "corridor" of the allocated frequencies - a method for assessing the effectiveness of professional training [8].

Aim of the Study

Description of the psychophysiological model of the risk of developing stress-induced cardiovascular disorders in various categories of professional suitability of firefighters.

Materials ad Methods

The empirical part of the study was carried out at the Ivanovo Fire and Rescue Academy of the State Fire Service of the Ministry of Emergency Situations of Russia in the period 2010 - 2017. In the course of the work, cadets of 1, 3 and 5 years of study (81 people), belonging to various categories of professional suitability, were examined. Features of vascular tone were assessed by the method of rheoencephalography (hardware complex "Reo-Spectrum" LLC "Neurosoft"). To study PWV and the peculiarities of its distribution in various groups of respondents, 65 males were examined, aged 20 to 50: full-time cadets (FEE - 30 people of one group in the same conditions, in the dynamics of classes with modeling of extreme factors of the professional environment), part-time cadets (FZO - 25 people, upon passing the test in the profile discipline "Gas and smoke protection service"), and teachers of the Ivanovo Fire and Rescue Academy of the State Fire Service of the Ministry of Emergency Situations of Russia (10 people with practical experience). Registration of HRV and PWV parameters was carried out using certified licensed domestic computer systems - "VNS-Micro" and "Poly-Spectrum 8" LLC "Neurosoft" (Ivanovo) according to standard methods with the calculation of standard indicators. All examinations were carried out in full, there were no cases of side effects and refusals from examinations for negative reasons. There was no development of local allergic reactions to the adhesive and working surfaces of adhesive disposable electrodes, components of the means used to prepare the patient's skin.

The results were processed by the methods of biomedical statistics [2,3]. Given the relatively small number of respondents in individual samples, descriptive, variance and correlation analyzes were performed using nonparametric statistical methods (F-test for comparing two populations, Man-Whitney test, Kolmogorov-Smirnov 2-sample test, Spearman's rank correlation, Kendall's Tau, Gamma). The level of significance was accepted as 0.95 ($p = 0.05$ and less). Analysis of variance was used to build the model on the IBM SPSS Statistics 23 platform.

Results

Our approach to the analysis of the vibrational structure and the search for possible correlations was based on a functional-dynamic study of the status of the autonomic nervous system, changes in PWV, the results of psychophysiological testing of firefighters and rescuers in relation to the length of service in the specialty and the characteristics of the professional route. A significant stage was a pilot study of the peculiarities of autonomic support of cardiac activity in relation to simulated and real conditions of emergency [5]. Further studies have identified markers of professional maladjustment in terms of HRV indicators and PWV indicators that are borderline for the development of stress-induced states.

The main, professionally oriented markers of maladjustment in terms of HRV were identified - the total power of the spectrum (TR), the ratio of low-frequency indicators to high-frequency indicators, characterizing the balance of autonomic reactions (LF/HF background and after orthostatic test) and the reactivity of the parasympathetic system - an indicator of 30/15. The boundary marker of the maladaptive response to the load for TR is a 50% or more decrease from the spectrum power to the load, a 30/15 decrease by 20% or more, and an increase in LF/HF AOP by 30% or more (an additional software module "Traffic light adaptation" for work in the field). The least favorable reaction (maladaptive) is a critical change in all three indicators. The results of the HRV study in the selected groups are presented in table 1.

Indicators BCP	Full-time cadets	Teachers	Part-time cadets
Background sample			
TP (мс^2)	3775,2 ± 973,80	3545,2 ± 876,80	1700,0 ± 152,0*
VLF (мс^2)	2427,1 ± 325,43&	1533,3 ± 134,76	715,2 ± 109,70*
LF (мс^2)	3405,9 ± 643,30&	2461,3 ± 287,50	1339,1 ± 543,60*
HF (мс^2)	2710,5 ± 328,90&	2172,8 ± 342,89	883,1 ± 231,09
LF/HF (y.e.)	1,26 ± 0,20	1,26 ± 0,30	1,44 ± 0,40
QRS (y.e.)	1,56 ± 0,67	1,92 ± 0,62	1,71 ± 0,81
Orthostatic test			
TP (мс^2)	5585,2 ± 789,65	4756,3 ± 953,32^	5836,9 ± 568,0*
VLF (мс^2)	2482,8 ± 765,65	3726,7 ± 453,12	2171,4 ± 321,76*
LF (мс^2)	1328,3 ± 345,78	6433,1 ± 1287,54	4481,4 ± 923,56*
HF (мс^2)	851,5 ± 256,89	3784,2 ± 985,40^	1498,8 ± 534,65*
LF/HF (y.e.)	1,56 ± 0,11	1,70 ± 0,30	2,99 ± 0,50*
QRS (y.e.)	2,75 ± 0,87&	4,48 ± 1,23^	3,89 ± 1,85
30/15 (y.e.)	1,49 ± 0,23	1,50 ± 0,34	1,17 ± 0,21*

Table 1: *HRV indices in observation groups.*

Note:

**: Significant differences in indicators of Part - time cadets and teachers.*

^: Significant differences in the indicators of Full - time cadets and teachers.

&: Significant differences in the indices of Full-time cadets and Part-time cadets.

When examining 3 groups of respondents: full-time cadets, teachers and correspondence students (firefighters), it was determined that the critical period in the formation of stress-related disorders is 5 - 10 years of work experience. At the same time, with work experience of up to 5 years, there is a gradual increase in the level of professional adaptation in the group as a whole (strengthening of the central ergotropic influences), which in general characterizes rather unstable mechanisms. After 10 years of work experience, stable adaptive processes were established in all respondents. In the group with 5 - 10 years of work experience, in more than half of the cases (56%), maladaptive critical values are observed for all selected markers, including PWV. Probably, during this period, the specialist either adapts to the conditions of activity (at the level of vegetative support of the activity) or drops out of it. It was found that the professionally significant markers of the influence of the load is the increase in PWV in the vessels of the muscular type: this indicator turned out to be significantly higher among the students of the physical education system than among the cadets of the educational institution and teachers, and above the norm. Changes in this indicator (background test) among the students of the FZO PWVM = 9.47 m/s were significantly higher than among the cadets of the FO (6.8 m/s) and teachers (7.8 m/s), and above the norm 6,17 m/s. PWV in elastic-type vessels - a generally recognized marker of cardiovascular catastrophes - in all groups did not go beyond normal values (FEE - 5.6 m/s, teachers - 5.7 m/s, FZO 5.76 s/m)... Correlation relationships between HRV and PWV indicators are presented in table 2 (analysis in the subgroup of FZO cadets and firefighters).

Indicators	Work experience up to 5 years	5 to 10 years old	Over 10 years of experience
Background sample			
Vm and TP	-0,07	-0,21	-0,05
Vm and VLF	-0,04	-0,02	0,03
Vm and LF	-0,01	-0,43	-0,02
Vm and HF	-0,07	-0,20	-0,12
Vm and LF/HF	-0,19	0,85*	-0,14
Vm and KRS	0,32	0,03	0,51
Ve and TP	-0,18	-0,35	-0,47
Ve and VLF	-0,13	-0,34	-0,56
Ve and LF	-0,18	-0,39	-0,51
Ve and HF	-0,17	-0,33	-0,37
Ve and LF/HF	-0,08	0,68*	0,18
Ve and KRS	0,24	-0,21	-0,64
Orthostatic test			
Vm and TP	-0,31	-0,56	-0,18
Vm and VLF	-0,20	-0,37	-0,14
Vm and LF	-0,34	-0,51	-0,22
Vm and HF	-0,27	-0,49	-0,02
Vm and LF/HF	-0,23	0,83*	-0,19
Vm and KRS	-0,10	-0,04	0,49
Vm and 30/15	-0,01	-0,45	-0,34
Ve and TP	-0,41	-0,53	-0,38
Ve and VLF	-0,30	-0,47	-0,33
Ve and LF	-0,41	-0,46	-0,30
Ve and HF	-0,31	-0,41	-0,37
Ve and LF/HF	-0,18	0,39	-0,10
Ve and KRS	-0,04	-0,18	0,49
Ve and 30/15	-0,13	-0,84*	-0,38

Table 2: *Correlation coefficient between indicators of pulse wave velocity and heart rate variability in part-time cadets with various work experience.*

**: Differences are reliable*

Vm-speed in muscular vessels; Ve-speed in elastic vessels.

To identify the reactions of vascular tone, rheoencephalography was performed in the subjects of 3 categories of professional suitability. It was found that an increase in the tone of the microvascular bed (hypertensive reaction) correlates with an increased LF/HF (both background and orthostatic) and a decreased 30/15. At the same time, a greater number of maladjustment markers correlating with a hypertensive reaction were found in representatives of the second category of professional suitability. Considering the greatest strength of correlations with the LF/HF indicator, the results are shown in table 3.

REG indicators	Occupational suitability categories		
	1	2	3
Thick dicrotic notch index	F.L.L. -0.22621 L.L.-0.39855 O.L.P.--0.26354 -0.38446	F.Z.L. -0.20501 O.Z.L. 0.344022 F.Z.p. -0.40133	O.Z.L. -0.40955 O.Z.p. -0.37989
Air defense venous outflow	F.L.L. 0.35843 F.L. 0.41357 F.Z.P. 0.415746	F.L.L.-0.23425 O.L.P. 0.304083 F.Z.L. -0.3076 O.Z.L. -0.21618 F.Z.p. -0.23844 Y.O. 0.252663	
Day diastolic index	L.L.-0.25412 O.L.P.--0.65707 O.Z.P. 0.273527	O.L.P. 0.239729 F.Z.L. -0.34321 F.Z.p. -0.38588 Y.O. 0.368544	F.L.L. 0.371395 O.Z.L. -0.20035 F.Z.p. 0.301472
Vcp. average speed of vessels filling	O.L.P. 0.346149 O.Z.L. -0.22332	F.L.L. 0.403533 F.L.P. 0.364951 F.Z.L. 0.528083 -0.22697 F.Z.P. 0.405717	O.z.p. -0.44655
Vmax maximum speed of fast filling	F.L.L. -0.2197 O.L.P. 0.27876 F.Z.p. 0.202156	F.L.L. 0.525539 F.L.P. 0.308824 F.Z.L. 0.560793 O.Z.L. -0.31786 F.Z.p. 0.423962	O.z.p. -0.50187
Re Rheographic systolic index	F.L.L. 0.208618 O.L.P 0.304278 -0.36248 O.Z.P. 0.212939 F.Z.p. 0,202636	F.L.L. 0.349746 F.L.P. 0.252379 F.Z.P. 0.250667	F.L.L. -0.26369 F.Z.p. -0.27228 O.z.p. -0.57274

Table 3: *Correlation coefficients between LF/HF HRV and the state of blood flow in cadets of 1 - 3 categories of professional suitability. Symbols: Note: frontal, left (л.л.); frontal, right (л.п.); occipital, left (з.л.); occipital, right (з.п.); orthostatic test (О.); background test (Ф.).*

Discussion

The results obtained indicate that the process of developing professional adaptation can be assessed using markers of changes in the autonomic support of heart activity, which significantly correlate with both generally recognized markers of cardiovascular catastrophes (PWV) and hypertensive vascular reaction (REG) and with the category of professional suitability.

In general, it can be stated that with an increase in the length of service in the specialty, there is an increase in strong and medium-strength connections between the indicators of HRV and PWV, and their direction changes. So, in the background sample, changes in the state of the sympathetic and parasympathetic parts of the autonomic nervous system, in particular the system of regulation of vascular tone, are revealed. The change in direction and an increase in strong and average correlations in the orthostatic test characterizes the change in the influence of the higher vegetative centers on the cardiovascular subcortical center, reflects the state of the neurohumoral and metabolic levels of regulation.

Specialists of the extreme profile of the 1st and 3rd categories of professional suitability (recommended in the first place and recommended conditionally) are characterized by the optimal variant of the regulation of the heart rhythm, which provides the best adaptation to professional extreme factors and a good level of the body's adaptive reserves. The group of cadets recommended in the second place, according to HRV indicators, is at risk of maladaptive cardiovascular disorders to a greater extent, which may be a consequence of the tension of the motivational psychological sphere.

Summarizing the above, risk models for the development of stress-induced cardiovascular disorders in various occupational suitability groups were proposed (discriminant analysis on the IBM Statistics SPSS 23 platform, centroid 3 - high risk):

For category 1:

F1 = -5.74 +0.387 K30/15 + 1.674 LF/HF ortho - 0.339 LF/HF background.

F2 = 1.235 - 2.476 K30/15 + 0.131 LF/HF ortho - 1.036 LF/HF background.

With a high risk determinant in the values of 3 - 5 units.

For category 2:

F1 = -3.575 +0.853 K30/15 + 0.631 LF/HF ortho - 0.269 LF/HF background.

F2 = - 6.519 + 4.476 K30/15 + 0.110 LF/HF ortho - 1.03 LF/HF background.

With a high risk determinant in values tending to 1.0 units.

For category 3:

F1 = -3.824 - 2.198 K30/15 + 1.275 LF/HF ortho + 0.785 LF/HF background.

F2 = -4.316 + 2.685 K30/15 + 0.243 LF/HF ortho - 0.945 LF/HF background.

With a high risk determinant in the values of 2.5 - 5 units.

It should be noted that the TP indicator (total spectrum power) was excluded from the analysis due to the insignificance of the contribution - less than 0.001 (which corresponds to the results of the study).

A graphical representation of discriminant analysis for the 3rd category of professional suitability, similar to the first two groups, is shown in figure 1. The priority of Function 1 for calculating the risk (significance above 99%) is clearly demonstrated, which allows, if necessary, to take into account only it (F1).

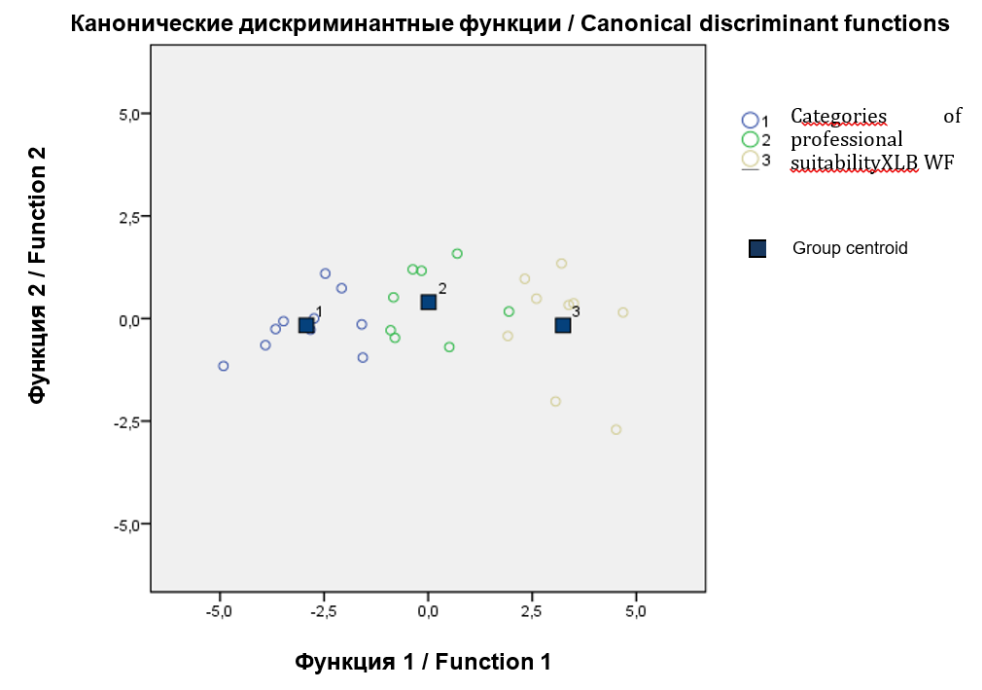

Figure 1: *Canonical discriminant functions for 3 categories of professional suitability. The risk of developing cardiovascular disorders from minimal - centroid 1 to high - centroid 3. Calculation of function 1 (abscissa) and function 2 (ordinate) - in the text.*

The results obtained make it possible to improve both the system of professional selection in the high-risk profession, and the system of medical and psychological support for the training, training and post-expedition examination of firefighters and rescuers. For widespread implementation, the confirmed hypothesis needs to be tested not only in the conditions of an educational institution, but also "on the ground" - this will be the result of our further work.

Conclusion

The subject of the study was the state of professional adaptation and the relationship with the risk of developing stressful cardiovascular disorders in firefighters. On the basis of the results obtained, models of the risk of developing cardiovascular disorders have been developed in various categories of professional suitability to perform tasks as intended, determined by the methodology recommended by the Ministry of Emergencies of Russia. The identified phenomena make it possible to make proposals for improving the system of medical and psychological support for firefighters, depending on the category of professional suitability, as well as in the system of professional selection.

Conflict of Interest

The authors declare no obvious and potential conflicts of interest related to the publication of this article.

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