

Pre-pathological Diagnostic Criteria for Professional Burnout in Healthcare Workers

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Abstract

The work is devoted to identifying significant changes in the individual and psychological characteristics of medical workers with the initial level of professional burnout according to the MBI-GS questionnaire. 28 respondents (emergency medical services staff: doctors, paramedics) took part in the questionnaire to determine the level of professional burnout, as well as testing psychophysiological reactions of the central nervous system for a comprehensive assessment of the respondents' general condition. The proposed mathematical approach enabled us to determine a group of pre-pathological states of professional burnout and to establish informative psychophysiological criteria, which will make it possible to substantiate and implement preventive measures against the professional burnout development.

According to the "visual-motor reaction with counting" method, significant criteria indicators are an increase in the "number of mistakes made", "attention span and working memory" and a decrease in the "root mean square deviation of the sensorimotor reaction rate". According to the "choice reaction" method, all indicators had the same low level of information content. According to the "choice reaction" method, only a decrease in the "number of clicks" indicator is informative. The indicators of the "critical flicker fusion frequency" method are quite informative compared to the indicators of the "memory for images" method.

Keywords¹

professional burnout, emergency medical care, pre-pathology, prevention, psychophysiological indicators, logistic regression, explanator, Eli5

1. Introduction

The dynamic development and intensification of production processes, the increase in the social component of a person's environment is characterized by an additional psychological burden in professions of the socio-economic type, which activities are based on the "person-to-person" communication [1,2]. The development of neuro-emotional stress during the intensive communication with a client, constant provision of professional assistance, being in an emotionally charged atmosphere creates a state of tension with changes in the psychophysiological parameters of the body. This can lead to the development of professional stress, as a result of the internal accumulation of negative emotions by the individual and the depletion of personal, emotional, energy resources, with the subsequent development of the professional deformation and depersonalization of the individual, which is interpreted by scientists as "professional burnout" [3].

The professional burnout syndrome is included in the 11th revised version of the International Classification of Diseases (ICD 11) dated May 28, 2019. This syndrome is classified as "Factors affecting the state of public health and referrals to health care institutions" (Z00- Z99), which contains the reasons for the population referral to health care institutions, which are not classified as diseases or medical

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conditions (WHO, 28 May 2019). Specialists of the Center for Disease Control (CDC, Atlanta, USA) and the Prevention National Institute for Occupational Safety (NIOS) annually review and supplement the list of professional specialties related to the control of the chronic fatigue syndrome ("burnout") and its prevention measures (CDC, NIOS, 2019) [4,5].

In modern literature there are data characterizing the development of stress at work [4,6]. Different categories of workers, first of all, workers in the social sphere (doctors, bank workers, teachers, law enforcement officers) showed various manifestations of stress reactions to the professional burnout syndrome [6-10]. The UK annual Labor Force Survey (LFS) statistical estimate shows that the total number of work-related stress, depression or anxiety in 2020/2021 was 2,480 per 100,000 workers at a prevalence rate. Healthcare and Social Work were identified as fields with the highest levels of stress, depression or anxiety [6]. The frequency of professional burnout among employees of "helping", socially significant professions is quite high, which is associated with the significant involvement of the specialist in interpersonal communication, the constant ability to empathize and understand the problems of another person [11]. Healthcare workers are a professional group of people who are an integral part of any society, whose activities are aimed at providing highly qualified medical care, implementing preventive measures in order to protect and improve the public health. The work of healthcare personnel is associated with complex mental work, which unites people with both secondary and higher medical education, as well as various specialties employed in the field of healthcare, which are characterized by specific working conditions for each medical specialist separately [12].

The study of functions that affect professional medical activity is becoming more and more relevant in the social aspect, which is due to the great practical interest in the effective work of physicians. In particular, the professional burnout syndrome in emergency medical staff develops as a result of constantly being in situations related to communication, urgent decision-making, responsibility for the life and health of the patient, variability in work and other organizational factors [13]. The consequences of working in conditions of high labor intensity include suffering from psycho-emotional stress, which leads to functional changes of the central nervous system (CNS), which can initially be characterized by headaches, sleep and memory disorders, loss of attention and concentration, etc. In the future, functional disorders may change to persistent psychosomatic disorders and as a result of professional burnout. The literature review sufficiently illuminates the problem of the nature of burnout of emergency medical staff, with full consideration of the entire link of professional training: doctors, paramedics, nurses [12,13]. All of the above confirms the relevance of a detailed study of the impact of the tension of the labor process on psychological and physiological processes in the body and manifestations of industrial stress among emergency medical staff, as the primary link of patient care. Recent changes in the provision of health care in the context of the COVID-19 pandemic caused by the SARS-CoV-2 [14], the beginning of the war on the territory of Ukraine in 2022, also raise concerns about the professional exhaustion of emergency medical care workers. In these conditions, the risk of professional burnout increases, it can affect the quality and safety of health care as a whole and additionally negatively affect the economic status of the state [9].

The general scheme of the problem is shown in Figure No. 1. It provides factors of the labor process that are triggers for the appearance of psycho-emotional stress in medical workers, which subsequently lead to the development of symptoms of professional burnout. It is clear from the given scheme that the task of our research was to develop an approach that will help to identify a complex of early criteria of pre-pathological conditions in order to prevent the occurrence of symptoms of psycho-emotional stress, and therefore to prevent the development of professional burnout.

The relevance of this issue is sufficiently highlighted in the above. The given data indicate the state and relevance of the problem and do not offer measures and algorithms to prevent the professional burnout development, do not determine the criteria for diagnosing pre-pathological states development in such a socially significant category of workers as healthcare workers. Therefore, it is important to search for adequate and informative criteria using modern mathematical tools, which allow to identify with a high degree of objectivity the criteria for the pre-pathological states of the professional burnout syndrome in specialists of the emergency medical care center.

Therefore, the aim of this study is to develop a scheme of a mathematical approach to establishing the information criteria for the early diagnosis of the professional burnout development in healthcare workers, using the example of emergency medical care to form a group of pre-pathological states of professional burnout.

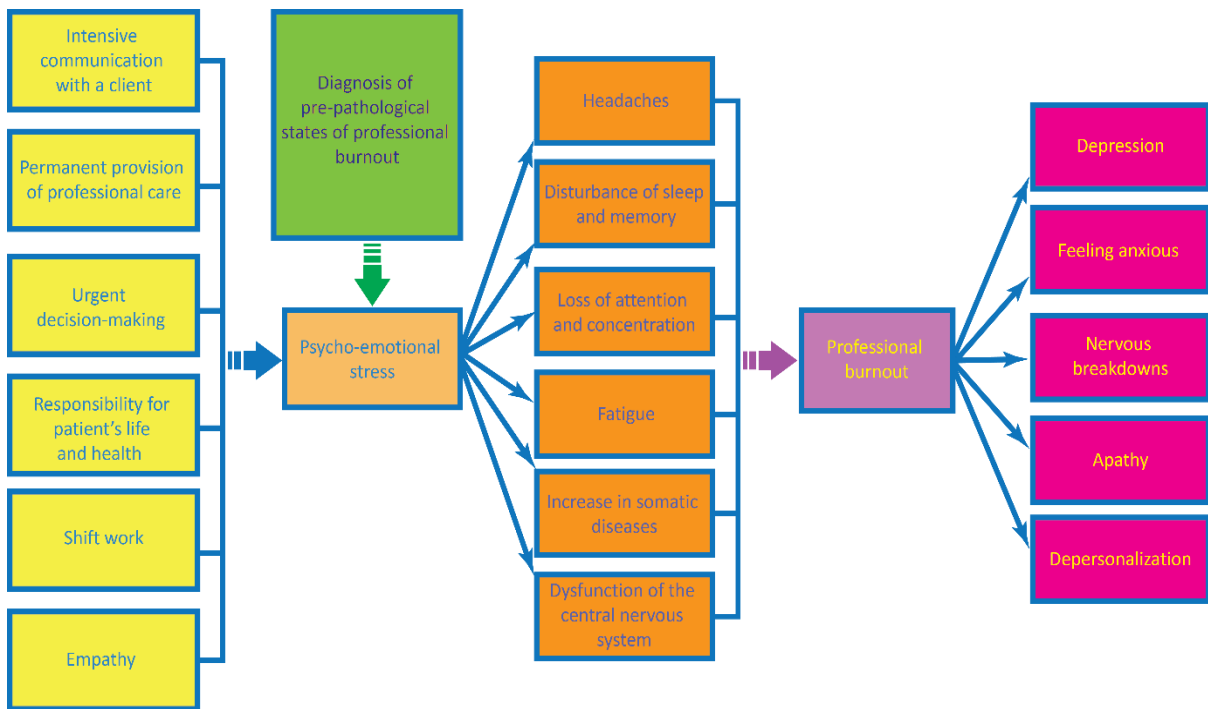


Figure 1: General scheme of research

2. Materials and methods

The study of emergency medical care staff was conducted in two stages. At the first stage, a medical and psychological questionnaire was conducted as a means of diagnosing the development of professional burnout and assessing the individual and psychological qualities of respondents using the questionnaire "Maslach Burnout Inventory - General Survey" (MBI-GS) in order to identify the levels of professional burnout based on the three-factor model of the professional burnout syndrome development. The second stage is the study for a comprehensive assessment of the psychophysiological and psychological properties and functions of the respondents' body based on the results of performing test tasks, namely: a simple visual-motor reaction, a choice reaction, a difference reaction, a critical blinking fusion frequency, memory for images, a visual-motor reaction with a score. For a comprehensive assessment, a computer complex of psychophysiological testing NS-psychotest (certificate of state registration No. 2017618884 dated August 10, 2017) was used. The representative sample included 28 respondents – specialists in emergency medical care (doctor, paramedic) Fig. 2.

The biggest part of Artificial Intelligence (AI) methods for classification tasks can be presented as black-box-models. It means that special methods should be used for understanding reasons of such decisions made by classification system. Explainable Artificial Intelligence [16-17] is the way to explain and understand predictions made by black box models. This approach can be used for detecting those psycho-physiological indicators that affect to dividing respondents by the level of professional burnout. Explainable Artificial Intelligence has been developing rapidly in recent years and is represented by a variety of systems. The most part of such algorithms, methods and approaches were described in [18]. For our research we've been choose Eli5 explainer. Eli5 is based on Permutation Importance method and LIME explainer [19].

The main idea of Permutation Importance method is how much any score as accuracy, f1, R^2 etc. decreases when a feature is not available. On each step one feature is replaced by random noise (to make feature column presented in dataset, but it no longer contains useful information), the estimator re-trains and algorithm checks the score. So, it shows what features are important within a dataset, not what is important within a concrete trained model. Eli5 in combination with lgbm-model shows high accuracy for explaining model results for covid-19 data [20].

2.1. Pipeline For Defining Informativeness of psycho-physiological indicators

Mathematical approach is based on classification method (logistic regression) with explainer Eli5 [15]. Eli5 is specialized Python library for visualizing and debugging various machine learning models based on calculating the contribution of each feature to the prediction. As it was mentioned, principal goal is to define those psycho-physiological indicators that affect to the level of burnout. The basic view of pipeline is presented in Fig. 3.

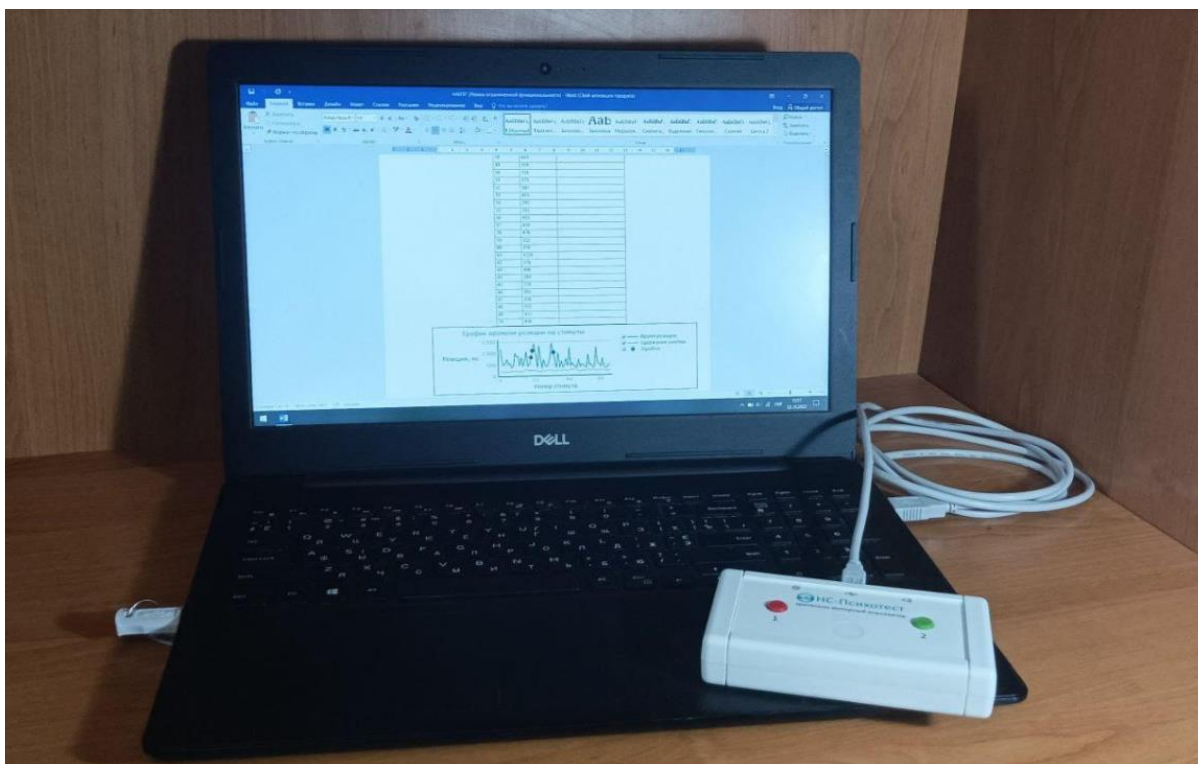


Figure 2: Computer complex for psychophysiological testing «NS-Psychotest»

It consists of MBI-GS questionnaire and professional burnout type that was calculated based on special methodology. Classification model training combining with explainer is needed for defining information indicators of MBI-GS questionnaire. Measured psycho-physiological indicators are fed to second classification model as a training vector and results of calculation professional burnout level for the same respondent – as a target vector. After models were trained, explainer analyses trained model and explain result.

2.1.1. Defining a level of professional burnout based on MBI questionnaire

At first step professional burnout level have to be defines for each respondent. The methodology of those calculating was modified in [12]. The MBI-GS questionnaire contains 16 questions describing various work-related experiences. The method of assessing the emotional state of the respondents involved the distribution of answers according to scales regarding the risk of developing burnout: "emotional exhaustion" (ee), which corresponded to the answers to questions 1, 2, 3, 4, 6; "depersonalization" (zy) – answers to questions 8, 9, 13, 14, 15; "reduction of personal achievements" (ef) – answers to questions 5, 7, 10, 11, 12, 16. Results of three scales were defined in points and each of them were transformed to professional burnout level:

- 0 group – no burnout;
- 1 group – initial manifestation of professional burnout process (it can be initial changes by one of three scales but it cannot be a complete burning out by any of them);
- 2 group – severe symptoms of professional burnout (it can be also a complete burning out by one

Eli5 explainer helps to determine the information indices that demonstrate the development of depersonalization phenomena according to the answers to questions 13, 14, 15 (MBI_14_zy, MBI_13_zy, MBI_15_zy) (Fig. 5).

Weight ^r	Feature
+0.738	MBI_13_zy
+0.340	MBI_16_ef
+0.275	MBI_02_ee
+0.234	MBI_12_ef
+0.227	MBI_11_ef
+0.197	MBI_05_ef
+0.166	MBI_07_ef
+0.166	MBI_06_ee
+0.134	MBI_04_ee
+0.074	MBI_10_ef
+0.031	MBI_09_zy
+0.013	MBI_01_ee
-0.090	MBI_08_zy
-0.157	MBI_03_ee
-0.356	MBI_15_zy
-1.023	MBI_14_zy
-1.134	<BIAS>

Figure 5: Eli5 explainer results

These indicators are most informative ones for the presented division into groups. The accuracy of the logistic regression model is $0,96 \pm 0,13$ (based on 10-fold cross-validation).

2.1.2. Dependence of psycho-physiological indicators on the level of professional burnout

The next part of research is based on defining the dependencies between psycho-physiological indicators and level of professional burnout. Psycho-physiological indicators consist of six subgroups: Simple visual-motor reaction (SVMR), Choice reaction (CR), Discrimination reaction (DR), Visual-motor reaction with counting (VMRC), Critical flicker fusion frequency (CFFF) and Memory for images (MI). Psycho-physiological indicators for each of subgroups are presented in Table 1 and Table 2. It should be noted that the number of psycho-physiological indicators is close to the number of respondents. That's why each type of psycho-physiological indicators was processed separately. Results presented in Fig. 6. The most important features have higher value of weight.

Table 1
Psycho-physiological indicators (Part1)

No	Sensorimotor reaction rate (SVMR)	Choice reaction (CR)	Discrimination reaction (DR)
1.	Sensorimotor reaction rate	Average reaction time	Average reaction time
2.	Root means square deviation of the sensorimotor reaction rate	Root means square deviation of the reaction time	Root means square deviation of the reaction time
3.	Number of mistakes made	Number of mistakes made	Number of mistakes made
4.	Number of passes made	Number of premature clicks	Number of premature clicks
5.	Number of premature clicks	Number of passes made	Number of passes made
6.	Whipple's precision index	Number of false reactions	Number of false reactions
7.	Functional level of the system	Whipple's precision index	Whipple's precision index
8.	Reaction resistance		
9.	Functionality level		
10.	Performance evaluation by the reaction rate		
11.	Performance evaluation by the functional level of the system		
12.	Performance evaluation by the reaction resistance		

Table 2
 Psycho-physiological indicators (Part 2)

No	Visual-motor reaction with counting (VMRC)	Critical flicker fusion frequency (CFFF)	Memory for images (MI)
1.	Average reaction time	Average frequency with increasing flicker frequency	Number of correct answers
2.	Root mean square deviation of the reaction time	Average frequency with decreasing flicker frequency	Number of mistakes
3.	Number of correct reactions		Memory capacity
4.	Number of mistakes made		
5.	Number of passes made		
6.	Number of false reactions		
7.	Number of premature clicks		
8.	Attention span and working memory		

Weight'	Feature	Weight'	Feature
+0.519	SVMR_fu_level_system	+0.354	VMRC_num_mistakes
+0.429	SVMR_smr	+0.351	VMRC_attention_span
+0.427	SVMR_eval_reaction_rate	+0.282	VMRC_num_clicks
+0.356	SVMR_num_mistakes	+0.257	VMRC_num_correct
+0.353	SVMR_eval_func_level	-0.079	VMRC_num_false
+0.332	SVMR_resistance	-0.097	VMRC_num_passes
+0.332	SVMR_eval_resistance	-0.178	<BIAS>
+0.262	SVMR_num_clicks	-0.251	VMRC_av_reaction_time
+0.141	SVMR_rmsd_smr	-0.513	VMRC_rmsd_srr
+0.125	SVMR_passes		
-0.258	SVMR_Whipple_index	Weight'	Feature
-0.360	SVMR_func_level	+0.178	<BIAS>
-0.849	<BIAS>	+0.104	CR_Whipple_index
		+0.010	CR_rmsd_reaction_time
		-0.010	CR_num_passes
		-0.034	CR_num_mistakes
		-0.123	CR_av_reac_time
		-0.186	CR_num_false_reactions
		-0.657	CR_num_clicks
		Weight'	Feature
		+0.456	CFFF_av_freq_increasing
		+0.033	<BIAS>
		+0.020	MI_memory_capacity
		-0.043	MI_num_correct
		-0.487	CFFF_av_freq_decreasing

Figure 6: Eli5 explainer results for different types of psycho-physiological indicators

3. Results

According to the results of the medical and psychological survey, a group of workers with pre-pathological conditions was identified, for which significant criteria questions from the MBI questionnaire were determined. The analysis of the obtained data proved that the workers from the prepathology group feel exhausted at the end of the working day (emotional exhaustion), strive to fulfill only their direct duties, have manifestations of cynicism (depersonalization), doubts about the significance of their work, but at the same time have confidence that the work is performed effectively (reduced personal accomplishment).

During the study of psychophysiological changes in the body using the "simple visual-motor reaction" method among the emergency medical staff, it was established that the significant criteria indicators are an increase in the "visual-motor reaction rate" indicator; an increase in the "performance evaluation by reaction rate" indicator; an increase in the "functional level of the system" with a simultaneous decrease in the "level of functional capabilities" indicators.

According to the "visual-motor reaction with counting" method, the criterion-significant indicators

are an increase in the "number of errors", "attention span and working memory" and decrease in "root mean square deviation of the sensorimotor reaction rate". According to the method of "difference reaction", all indicators had the same low level of informativeness. According to the "choice reaction" method, only a decrease in the "number of clicks" indicator is informative.

Indicators of the "critical frequency of flicker fusion" method are sufficiently informative compared to the indicators of the "memory for images" method.

The general characteristic of the comparison of methods and the dynamics of changes in indicators shows that the establishment of the most significant changes from the CNS was determined using the "simple visual-motor reaction" method. Therefore, the decrease in the efficiency of visual-motor reactions is provoked by the formation of inertia of the nervous processes due to the decrease in the sensorimotor reaction rate, which is probably related to the branching of neural connections between the frontal parts of the cerebral cortex and the motor areas of the cortex, subcortical structures responsible for the motor reaction formation. These changes can be considered as the instability of the visual-motor response to external stimuli against the background of the suppression of the functional stability of the brain structures work, their reduced strength, balance, which is caused by a high level of work intensity. The above-mentioned changes are the triggers for declining performance levels, developing fatigue, and reducing sensory memory capacity.

4. Conclusions

1. The establishment of early diagnostic criteria for the prenosological state of the professional burnout development in healthcare workers (on the example of the emergency care staff) should be considered a necessary stage in the preventive measures development.

2. According to the results of selection of the cluster of the pre-pathological state group based on the MBI-GS questionnaire using a mathematical model based on artificial intelligence, it was established that the phenomena of emotional exhaustion and state of reduced personal accomplishment were observed in the group of pre-pathology, while the most informative indicators were the development of depersonalization.

3. The use of an original mathematical approach made it possible to establish objective psychophysiological indicators by which it is possible to determine the pre-pathological state from the CNS functioning, namely: a simple visual-motor reaction (according to the criteria of "visual-motor reaction rate", "performance evaluation by reaction rate", "functional level of the system", "level of functional capabilities"), visual-motor reaction with counting (according to the criteria "number of errors", "root mean square deviation of the sensorimotor reaction rate").

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