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# METHODOLOGICAL APPROACHES TO THE DEVELOPMENT OF CRITERIA FOR THE DIAGNOSIS OF PREPATHOLOGICAL STATES BY PSYCHOPHYSIOLOGICAL AND MEDICAL-BIOLOGICAL INDICATORS

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*The purpose of the study* was to investigate the problem of scientific rationale for approaches to early detection of prepathological conditions among different professional contingents. For this purpose, the role of biomedical and psychophysiological indicators was investigated based on the results of our own research works.

*Materials and methods.* The method of assessing the risks of burnout was used to substantiate the role of psychophysiological indicators in determining prepathological states in workers of certain professions. The study was conducted using the Maslach Burnout Inventar (MBI-GS) questionnaire with subsequent statistical processing in the Jupiter Notebook environment. We used methods of logistic regression analysis and specialized software method “Eli-5”. To illustrate the mechanisms of action of medical-biological indicators the biological effects of electromagnetic radiation under conditions of low temperature were determined. The combined effect of these factors in a laboratory experiment for 30 days on the example of mature laboratory rats was studied.

*Results and discussion.* The authors have proved that to effectively determine the risk groups for the development of professional burnout, it is advisable to use separate criterion-significant informative indicators using the Maslach Burnout-Inventar MBI-GS questionnaire. In addition, it is advisable to additionally determine the risks of developing burnout by the frequency of manifestations of symptoms of emotional exhaustion for the group of persons with prepathology. In order to prevent stress situational disorders among students when working with digital simulators, preliminary screening of emotional-stressful states with the subsequent application of psychocorrection measures is necessary. Modeling the complex effects of electromagnetic radiation and low temperatures made it possible to determine the features of the formation of biological effects in the body according to the criteria of physiological, morphological, immunological and biochemical changes. Thus, in the formation of the adaptive and immune response of the organism to the combined effect of these factors, the reduced temperature has a dominant share of the contribution.

*Conclusion.* Our findings indicate that methodological approaches to the development of tools for the diagnosis of prepathological conditions, as the most effective element of primary prevention, should be based on the scientific basis of their structural elements. In the prevention of occupational diseases to the algorithm for determining the leading criteria for the recognition and differentiation of diseases at subclinical levels, it is advisable to include studies of a number of simple and effective medical-biological and psychophysiological indicators.

**Keywords:** prepathological conditions, psychophysiological indicators, medical and biological indicators, professional burnout, combined influence of factors.

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**Introduction.** High levels of non-communicable diseases are a significant obstacle to the country’s economic growth, especially among the young working population [1]. Among a number of urgent problems that cause this situation we can highlight those which directly concern area of professional interests of specialists in preventive medicine, namely: significant spread of risk factors against the background of imperfect monitoring systems; inconsistency of

resource provision of the health care sector with the requirements declared by the reforms; desynchronosis of the relationship between scientific advances and practical health care.

Many fundamental scientific medical studies focus on the methodology of studying prepathological conditions. They argue that the point of application with the highest efficiency is the search for effective means of diagnosing diseases in subclinical stages [2, 3]. However, these studies often do not find effective ways of implementation and remain declarative, particularly their preventive directions.

The practical significance of mass screenings prior to in-depth medical examinations is the possibility of detecting abnormalities in the initial stages of health or functional disorders without obvious symptoms. The basis for this is a system of quantitative and qualitative indicators (criteria), which can determine the presence of a particular pathological condition and which can be identified and / or calculated within the preventive examination of certain contingents. Such indicators should be relatively easy to use and at the same time should be informative to illustrate the prevalence and risks of prepathological conditions among certain groups of the population (occupational contingents, children's groups, students, etc.). Such information is the basis for an in-depth study of the health status of risk contingents, guided by knowledge of the syntropic relationship of diseases, as well as for further studies of related factors with possible adverse effects [4]. In this context, experimental studies make it possible to successfully assess the quantitative and qualitative relationships between the magnitude of the action of factors and possible health consequences, using certain individual indicators in screening procedures [5].

Considering the above, the search for effective and cost-effective mechanisms for integrating scientific developments in the field of hygiene and preventive medicine into health care practice is the foundation of its effective modern transformation. Areas of science and practice of health care should be considered exclusively as a single complex. Dynamic and balanced development of this complex ensures the achievement of the main target state programs for maintaining the health of the working population.

**The purpose of study** was to investigate the role of medical-biological and psychophysiological indicators in substantiating the criteria for early detection of prepathological conditions among different professional contingents. We examine some previous work and propose new algorithms for using these indicators in preventive medicine.

**Materials and methods.** To substantiate the role of psychophysiological indicators in determining prepathological states in workers of certain professions the method of assessing the risks of burnout was used. The study was conducted using the Maslach Burnout Inventar (MBI-GS) questionnaire [6] with subsequent statistical processing in the Jupiter Notebook environment. We used methods of logistic regression analysis and specialized software method "Eli-5".

To illustrate the mechanisms of action of medical-biological indicators the biological effects of electromagnetic radiation (EMR) under conditions of low temperature were determined. For this purpose, the combined effect of these factors in a laboratory experiment for 30 days on the example of mature laboratory rats was studied. Regularities of formation of biological effects at the combined influence of EMR and the lowered temperature by means of definition of a share of contribution each of factors are established. Fuzzy-c-means fuzzy clustering method (based on artificial intelligence) was used by calculating the degree of distance between indicators after their normalization and standardization [7]. A statistical analysis was performed by using software – a Python 3.8 package, which helps to set up machine learning classifiers and explain their predictions.

**Results and discussion.**

*Psychophysiological indicators.* One of the current problems of occupational hygiene is the prevention of burnout due to adverse working conditions. The key features of professional activity in many areas, including workers of socially significant professions, are the following: desynchronization of biological rhythms due to the changing nature of work, high level of psycho-emotional stress, intermittent influence of physical and chemical factors, etc. All these things cause a heavy load on the sensory, mental and emotional spheres with a wide involvement of neuroendocrine regulatory systems. This, in turn, leads to psycho-emotional stress and increases the risk of occupational stress / burnout. The consequences of this are a non-social effect due to the loss of interest in the profession and the growth of non-communicable diseases among the working population. Moreover, there is growing prevalence of such socially important diseases as diseases of the circulatory system, endocrine and nervous systems.

The structure of early prepathological manifestations of occupational burnout is determined by the degree of contribution to its formation of certain determinants, namely: features of socio-demographic characteristics, individual-typological features, personality types, resistance to stress, nature and intensity of the labor process, functional state of the central nervous system.

In research on this topic specialists of the Department of Hygiene and Ecology No. 2 with the involvement of mechanisms of international cooperation [8] have been proved to determine the professional

burnout of workers of socially significant professions. It was appropriate to use the questionnaire Maslach Burnout-Inventar (MBI-GS). As a result, mathematical modeling allowed to establish criterion-significant informative statements of the questionnaire by the scales of "emotional exhaustion", "depersonalization" and "reduction of personal achievements". According to these scales, respondents can be divided into the following groups: without the phenomena of professional burnout, with prepathology of professional burnout and with obvious signs of professional burnout. In addition, in the group of people with prepathology it is advisable to determine the risks of burnout by the frequency of symptoms of emotional exhaustion.

Our own research has shown the following. Workers of modern socially significant professions (employees of banking institutions, ambulances, teachers of higher education institutions), who are exposed to elements of hard work, have some symptoms of "burnout" at 42–76% depending on profession, gender, and age. In some cases, the risk of "professional burnout" is set at 3–19% depending on the profession, gender, and age [8].

The development of professional burnout, professional maladjustment and deformation is preceded by disorders of the psycho-emotional, psychophysiological state at a young age. Thus, according to the data of the Organization for Economic Cooperation and Development (OECD, 2015), the unemployment rate among people without mental health disorders is 4.4%. But in the presence of moderate psychological disorders this indicator reaches 8.9% [9, 10]. At present, economic losses due to mental and psychological health disorders are extremely high – the global cost of mental health disorders is about 3.5% of gross domestic product [2, 9].

According to modern scientific observations, psychophysiological indicators of students have a pronounced tendency to deteriorate [11]. Among many components in the formation of psychological health of young people the correct organization of the educational process in the educational institution plays an important role, which corresponds to the adolescents' psychophysiological characteristics.

Today in Ukraine among the current problems of modernization of higher medical education headliners are the issues of effective implementation of innovative teaching methods. These methods should not only complement the content of educational programs, but also meet modern requirements and international standards. One of the most effective innovative methods is simulation training, because today situational digital modeling is becoming part of almost every aspect of the education and training system for health professionals, from entry-level students to practicing professionals. However, as the experience of using digital simulators in particular in national medical education is still relatively small, there is no scientific data on the impact of these technologies on the physiological and psychological state of students. Thus mastering of practical skills with the use of digital simulators can become the catalyst of situational psychological frustration, because during such classes students may be in a state of anxiety, worry, uncertainty in their knowledge, responsibility for mistakes and so on. Without proper psychological training it is possible to accumulate short-term changes in the psychophysiological state in the steel types of nervous and mental stress, which in future can cause difficulties in the performance of professional duties and contribute to professional maladaptation, deformation and burnout [12].

The scientific achievements of the department on this issue show that as a prognostic criterion for the development of prepathological conditions among students, as a consequence of the impact of innovative conditions of the educational process, it is advisable to use a number of psychophysiological indicators. One of the simplest and fastest to use, but indicative, is the method of self-assessment of emotional state, as an important regulator of behavior and an indicator of psychological shifts. The following is the identification of signs of situational stress and individual stress lability by screening techniques. After all, emotional and psychological stress is an interacting set of mental and physiological components of health [13].

Certainly, the pathophysiological mechanisms of stress-neurotic disorders include physiologically conditioned substructure, which consists of indicators of cardiovascular, central and peripheral nervous systems, autonomic system and other vital and emotionally dependent physiological systems [11, 13]. That is why the screening of emotional and stressful situations before working with digital simulators provides an opportunity to identify people at risk of developing prepathological conditions. Another practical element of screening diagnostics is the development of effective measures for individual and group psychocorrection and rehabilitation of the relevant contingent.

*Medical-biological indicators.* The latest medical and biological studies of the complex factors of the production environment show the following: simultaneous or sequential exposure to these factors without appropriate adaptogenic measures may pose a particular risk. When determining the criteria for assessing the effects of physical factors on the body, it is important that the biological effects may be manifested in different ways: in the form of additivity, when the effect of the sum of the influence of factors is equal to the sum of the effects of isolated influence; in the form of synergism, when there is an increase in the effect of influence; in the form of antagonism – the effect of

less than expected in the summation. Also, at certain levels of influence each acting factor may become dominant in their total biological effect [14].

Knowledge of such laws is an important task not only of physiology but also of medicine for the effective analysis of production conditions and the state of health of the working contingent.

In order to establish prepathological conditions in workers, it is important to develop methodological approaches to the study of the ratio of harmful factors that can simultaneously affect the body, as well as to establish the most informative criteria for predicting the onset of pathological changes.

As a model of substantiation of the algorithm for determining the leading criteria for the development of prepathological conditions among the professional contingents with the predominant effect of physical factors, the specialists of the department studied the combined effect of electromagnetic radiation and low temperature as the most common factor in the production environment.

It is proved that low temperature is a strong stressor that causes significant physiological changes in the body to support thermogenesis. As a response to the effects of stressors non-specific reaction develops, which can also complicate the response to other factors in their combined action [14, 15].

Modeling the combined influence of factors of the production environment (EMR and low temperature) made it possible to determine the features of the formation of biological effects in the whole body of rats in the dynamics of physiological, morphological, immunological and biochemical changes.

On the example of studying the combination of these factors, a unique methodological approach based on an intelligent statistical-diagnostic neuro-phase system was developed. This system allows to determine the dominant factor in the formation of appropriate biological effects on the basis of factor analysis to assess the informativeness of biological indicators. Thanks to this approach, part of the contribution of electromagnetic radiation and low temperature to the overall biological effect under the conditions of their combined action was determined. Also, informative indicators were determined, which were based on the leading reactions of the organism to the combined influence of these factors [16, 17]. Proposed approach is based on data visualization using principal component analysis method that in both cases helps us to find separate clusters in our data. These clusters were marked as separate groups and for each of them center was calculated. For processing data about effect on white rats by different physical fields we studied clusters movements on different days of experimental research. It helps us to understand behavior of different groups and to calculate membership level of contribution of isolated influences to its combined effect. This membership level depends on distances between clusters.

Our results have shown that in the formation of the adaptive response of the organism to the combined action of factors the reduced temperature had 60% of contribution, but electromagnetic radiation only 40%. The low temperature also mainly affected the metabolic processes and the immune response (63% in comparison with the influence of EMR). For morphological changes in the internal organs, the share of contribution for EMR was 81%, and for low temperature – 19%).

By using a hybrid system, informative indicators were determined, according to the criteria of which biological effects were formed: increase in concentration of diene conjugates with a simultaneous decrease in the concentration of SH-groups, increase in very low density lipoproteins and inhibition of oxygen-dependent neutrophil metabolism by NBT-test [15]. Biological effects in response to the combined effects of EMR and low temperature, which were based on increased processes of lipid peroxidation with reduced antioxidant protection and increased atherogenicity, indicate the possibility of occupational pathologies of the cardiovascular system.

On this basis, we conclude that the low temperature aggravates the action of EMR and the priority actions to prevent the development of prepathological conditions in workers should be a set of measures to optimize microclimatic conditions.

In summary, applied methods of mathematical analysis provide an opportunity not only to determine which of the factors dominates, but also scientifically sound to develop measures to prevent adverse effects of factors. This will provide an opportunity to purposefully influence such factors to minimize their negative effects, as well as to diagnose the functional state of the body according to subtle criteria and identify prepathological conditions. For different datasets principal component analysis in combination with other methods allows to explore a contribution of initial factors to finish result.

**Conclusion and Perspectives of further research.** Our findings indicate that methodological approaches to the development of tools for the diagnosis of prepathological conditions, as the most effective element of primary prevention, should be based on the scientific basis of their structural elements. Overall, in the prevention of occupational diseases to the algorithm for determining the leading criteria for the recognition and differentiation of diseases at subclinical levels, it is advisable to include studies of a number of simple and effective medical-biological and psychophysiological indicators.

From a practical point of view, this will help to improve the algorithms of periodic medical examinations, increase the effectiveness of preventive and rehabilitation measures as a basis for the quality of the functioning of primary care. Results also provide a basis for establishment of professionally-forming criteria of professional selection, their introduction into the work of structural subdivisions of the state labor service of Ukraine for use in professional selection of persons for appropriate positions, development of adequate measures of psychological correction to prolong working longevity.

**Competing Interests.** The authors declare that there is no conflict of interest.

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## References


1. Kundyev Yu, Nahornaia A. *Professyonalnoe zdorove v Ukrayne: epydemyolohycheskyi analyz* [Occupational health in Ukraine: epidemiological analysis]. K: Avicenna; 2007. 396 s. [Russian]
2. Employee Outlook: Chartered Institute of Personnel and Development. Spring; 2017. Available from: https://www.cipd.co.uk/knowledge /fundamentals/relations/engagement/employee-outlook-reports
3. WHO. CSDH. Closing the gap in a generation: health equity through action on the social determinants of health. Final Report of the Commission on Social Determinants of Health. Geneva: World Health Organization; 2014. Available from: http://www.who.int/social_determinants/final_report/csdh_finalreport_2008.pdf
4. *Health Council of the Netherlands. Guideline for the identification and protection of high-risk groups*. The Hague: Health Council of the Netherlands, 39E. 2012.
5. WHO Regional Publications, European Series. Epidemiology of occupational health. Available from: https://apps.who.int/iris/bitstream/handle/10665/272256/9789289011112-eng.pdf?sequence=3
6. Schaufeli WB, Leiter MP, Maslach C, Jackson SE. Maslach Burnout Inventory - General Survey. In: Maslach C, Jackson SE, Leiter MP, Eds. *The Maslach Burnout Inventory – test manual.* 3rd ed. Palo Alto CA: Consulting Psychologists Press; 1996.
7. Perova I, Litovchenko O, Zavgorodnii I, Brazhnykova Y, Kovalenko A. A Mathematical Analysis of Immunological Indicator of Biological Objects under Influence of Low-Frequency Electromagnetic Radiation in Conditions of Cold Stress. *2020 IEEE Ukrainian Microwave Week (UkrMW).* 2020. p. 594-598. doi: 10.1109/UkrMW49653.2020.9252691
8. Kapustnyk V, Zavhorodniy I, Boeскelmann I, Litovchenko O, Lalymenko O. Experience of international collaboration in solving actual medical and biological problems of occupational health and ecology. *Ukr J Occ Med*. 2018;4(57):58-67. doi: 10.33573/ujoh2018.04.058
9. Mental health in organizations: four reasons to invest in the mental health of employees. Neuronews. 2017. Available from: https://neuronews.com.ua/ua/archive/2017/9%2892 %29#gsc.tab=0
10. Indicators and data on mental health and work. Organisation for Economic Co-operation and Development. Available from: http://www.oecd.org/employment/mental-health-and-work.html
11. Auerbach R, Alonso J, Axinn W, Cuijpers P, Ebert DD, Green JG, et al. Mental disorders among college students in the World Health Organization, World Mental Health Surveys. *Psychol Med.* 2016;46:2955-2970. PMID: 27484622. PMCID: PMC5129654. doi: 10.1017/S0033291716001665
12. Bockelmann I, Darius S, Zavgorodnii I, Thielmann B. Resources-based strategies for health promotion of students with different general conditions and different origins. *Inter collegas*. 2022;8(3):132-43. doi: 10.35339/ic.8.3.132-143
13. *Suchasni metody i zasoby dlia vyznachennia i diahnostuvannia emotsiinoho stresu* [Modern methods and tools for identifying and diagnosing emotional stress]. Pod red O Mintsera. K; 2010. 228 p. [Ukrainian]
14. Litovchenko O, Perova I. Osoblyvosti otsinky biolohichnykh efektiv vplyvu elektromahnitnoho vyprominiuvannia za umov znyzhenoi temperatury [Peculiarities of Evaluation of Biological Effects of the Influence of Electromagnetic Radiation in Conditions of Reduced Temperature (Experiment)]. *Ukr J Med Biol Sport*. 2021;2(30):2237-235. doi: 10.26693/jmbs06.02.227
15. Yeremenko O, Perova I, Litovchenko O, Miroshnychenko N. Framework for Developing a System for Monitoring Human Health in the Combined Action of Occupational Hazards Using Artificial Intelligence and IT Technologies. Lecture Notes on Data Engineering and Communications Technologies. *International Conference on Computer Science, Engineering and Education Applications. ICCSEEA 2021: Advances in Computer Science for Engineering and Education IV.* 2021;83:401–410. doi: 10.1007/978-3-030-80472-5_33
16. Perova I, Litovchenko O, Bodvanskiy Y, Zavgorodnii I, Mulesa P. Medical Data-Stream Mining in the Area of Electromagnetic Radiation and Low *Temperature Influence on Biological Objects Proceedings of the 2018 IEEE 2nd International Conference on Data Stream Mining and Processing.* 2018. p. 3-6. doi: 10.1109/DSMP.2018.8478577
17. Zhu Y, Yocom E, Sifers J, Uradu H, Cooper R. Modulatory effects on Drosophila larva hearts: room temperature, acute and chronic cold stress. *J Comp Physiol B*. 2016;186(7):829-41. PMID: 27209390. doi: 10.1007/s00360-016-0997-x

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**МЕТОДОЛОГІЧНІ ПІДХОДИ ДО РОЗРОБКИ КРИТЕРІЇВ ДІАГНОСТИКИ ПРЕПАТОЛОГІЧНИХ СТАНІВ ЗА ПСИХОФІЗІОЛОГІЧНИМИ ТА МЕДИКО-БІОЛОГІЧНИМИ ПОКАЗНИКАМИ**

***Завгородній І., Меркулова Т., Літовченко О., Лалименко О., Перова І.***

**Резюме.** *Мета:* дослідити роль медико-біологічних та психофізіологічних показників за результатами власних науково-дослідних робіт.

*Матеріали та методи*. Методика оцінки ризиків професійного вигорання використана для обґрунтування ролі психофізіологічних показників у визначенні препатологічних станів у працівників певних професій. Дослідження проводилося за допомогою опитувальника Maslach Burnout Inventar (MBI-GS) з подальшою статистичною обробкою в середовищі Jupiter Notebook. Використовували методи логістичного регресійного аналізу та спеціалізований програмний метод «Eli-5». Для ілюстрації механізмів дії медико-біологічних індикаторів визначено біологічні ефекти електромагнітного випромінювання в умовах низької температури. Вивчено сукупну дію цих факторів у лабораторному досліді протягом 30 діб на прикладі статевозрілих лабораторних щурів.

*Результати та висновки.* Доведено, що задля ефективного визначення груп ризику розвитку професійного вигорання, доцільно використовувати окремі критеріально-значущі інформативні показники за допомогою опитувальника Maslach Burnout-Inventar MBI-GS. Крім того, у групі осіб із препатологією додатково слід визначати ризики розвитку вигорання за частотою проявів симптомів емоційного виснаження. З метою попередження стресових ситуативних розладів серед студентів при їх роботі із цифровими симуляторами необхідним є попередній скринінг емоційно-стресових станів із подальшим запровадженням заходів психокорекції. Моделювання сполученого впливу електромагнітного випромінювання та зниженої температури надало змогу визначити особливості формування біологічних ефектів в організмі за критеріями фізіологічних, морфологічних, імунологічних та біохімічних змін. Так у формуванні адаптивної та імунної відповіді організму на сполучену дію цих факторів домінуючу частку внеску має знижена температура.

З практичної точки зору це сприятиме вдосконаленню алгоритмів періодичних медичних оглядів, підвищенню ефективності профілактичних та реабілітаційних заходів як основи якісного функціонування первинної медичної допомоги. Результати також є основою для встановлення професійно-формуючих критеріїв професійного відбору, впровадження їх у роботу структурних підрозділів Державної служби України з питань праці при відборі осіб на відповідні посади, розробки адекватних заходів психологічної корекції з метою збереження професійної працездатності.

**Ключові слова:** препатологічні стани, психофізіологічні показники, медико-біологічні показники, професійне вигорання, сполучений вплив чинників.

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