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Modern View Of Labor Physiology

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Abstract

This article examines the fundamental and applied aspects of occupational physiology as a scientific discipline that studies the impact of work on the functional state of the human body.

Keywords: Labor physiology; performance; fatigue; adaptation.

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1. Introduction

Labor physiology is one of the key areas of modern biomedical science, studying the patterns of functioning of the human body under conditions of labor activity of varying intensity and nature.

In the context of the rapid development of technology, digitalization of production processes, growth of cognitive and emotional stress, as well as the expansion of the range of professions, the the need for an in-depth analysis of how work affects the central nervous system, cardiovascular and respiratory systems, the muscular system and the psychophysiological state of the worker.

A properly organized labor process not only ensures high performance, but also prevents the development of chronic fatigue, occupational diseases and stress-induced disorders.

Modern research demonstrates that labor efficiency is determined not only by the qualifications of the employee and the technical equipment of the workplace, but also by the level of adaptive capabilities of the body.

Physiological adaptation mechanisms include a complex system of neurohumoral regulation, mobilization of energy resources, changes in biochemical processes and optimization of behavioral reactions.

When these mechanisms are disrupted, there is a decrease in performance, a deterioration in concentration, an increase in errors and an increased risk of developing fatigue, which has both medical and economic consequences.

Occupational physiology is of particular importance in studies of the influence of production factors on health: vibration, noise, high or low temperature, insufficient lighting, monotony and high levels of stress.

Accumulated data confirm that the impact of these factors without taking into account the physiological capabilities of a person leads to the formation of functional disorders, a decrease in the quality of work and an increased risk of occupational diseases.

Therefore, the study of the physiological basis of work activity becomes an integral part of the development of safe and ergonomic working conditions.

In recent years, much attention has been paid to assessing

the functional state of workers using objective methods: analysis of heart rate variability, pulse monitoring, oxygenation, indicators of bioenergy costs, electroencephalography, cognitive tests.

The integration of these methods makes it possible to predict the level of fatigue, assess the physiological cost of labor and develop personalized approaches to optimize work processes.

Thus, the study of labor physiology acquires strategic importance for preserving occupational health, increasing productivity, improving labor safety and forming scientifically based recommendations for rationalizing work regimes.

This study is aimed at analyzing modern ideas about the physiological mechanisms of labor activity, assessing risk factors and substantiating practical ways to optimize the labor process from the perspective of human physiology.

The study was conducted on the basis of a comprehensive physiological analysis, including objective measurements of the functional state of the body and assessment of the influence of labor loads of various types.

The methodological approach was based on a combination of laboratory, instrumental and field research methods, which made it possible to obtain highly reliable and representative data.

Continuous monitoring of heart rate (HR), heart rate variability (HRV), blood pressure, and pulse wave analysis using portable sensors were used to assess the state of the cardiovascular system.

These indicators made it possible to determine the level of tension in regulatory systems and the degree of adaptation of the body to the work load. The functional state of the respiratory system was studied using spirometry, assessing minute ventilation, blood oxygen saturation and respiratory rate in different phases of the work process.

To analyze muscle activity, surface electromyography was used, recording the dynamics of tension in muscle groups actively involved in work activity.

Cognitive and psychophysiological load was assessed using computerized tests of attention, working memory, reaction speed and resistance to monotony.

Additionally, a questionnaire survey of workers was conducted, including a subjective assessment of fatigue, emotional state, stress level and workplace convenience.

Production factors were assessed instrumentally: noise level - using sound level meters, vibration - vibration analyzers, illumination - lux meters, temperature and humidity - digital thermo-hygrometers.

At each workplace, microclimate conditions, ergonomic parameters and duration of work cycles were recorded.

Statistical processing of data was carried out using the methods of correlation analysis, variation statistics, Student's t-test and multivariate analysis of variations (ANOVA). Significance of differences was accepted at a significance level of $p < 0.05$.

The data obtained made it possible to identify pronounced patterns of physiological reactions of the body to workloads of varying intensity.

It has been established that in the first 60–90 minutes of the work cycle there is a moderate increase in heart rate by 12–18% relative to the initial values, which indicates the inclusion of adaptation mechanisms and the mobilization of functional reserves.

With prolonged exposure to above-average intensity, there was a decrease in heart rate variability by 25–35%, which indicates an increase in tension in regulatory systems and depletion of adaptive capabilities.

Indicators of the respiratory system demonstrated an increase in minute ventilation of the lungs by an average of 20–28%, and oxygen saturation remained within the physiological norm, which reflects adequate compensation of the metabolic needs of the body.

Analysis of electromyographic data showed that static loads lead to a significantly faster development of local muscle fatigue compared to dynamic loads of the same intensity.

Vibration of working tools increased muscle tension by 15–20% and accelerated the increase in fatigue. Cognitive tests revealed a decrease in concentration and reaction speed by an average of 18–23% after 3–4 hours of monotonous work, which confirms the significant impact of monotony on psychophysiological performance.

Workplaces with elevated noise levels (above 75 dB) experienced a 12–17% increase in error rates and 30–

35% higher subjective stress scores compared to the control group.

A study of production factors showed that an unfavorable microclimate, insufficient lighting and high vibration increased the physiological costs of labor and accelerated the onset of functional fatigue.

Correlation analysis revealed a direct relationship between the level of vibration and a decrease in HRV ($r = –0.62$), as well as between the noise level and an increase in error frequency ($r = 0.57$).

Thus, the results of the study confirm that labor physiology is a complex set of interrelated processes, including the regulation of the cardiovascular, respiratory, muscular and cognitive systems.

The influence of production factors significantly changes the physiological cost of labor and requires the development of individualized and ergonomically sound recommendations for optimizing the work process.

The data obtained demonstrate that labor physiology is a multicomponent system of body reactions, which is based on the dynamic interaction of nervous, cardiovascular, respiratory, muscular and endocrine regulation.

During the study, it was possible to identify a number of patterns that confirm modern scientific ideas that human performance is determined not only by external factors and the level of professional training, but also by the individual adaptive capabilities of the body.

The relevance of such conclusions is especially great in the modern economy, where production rates, cognitive overload and high levels of stress become the norm.

First of all, the results of the study showed that the body's adaptation to work load develops in several phases, each of which is characterized by specific physiological changes.

The initial phase is accompanied by activation of the sympatho-adrenal system, an increase in heart rate, increased breathing and mobilization of energy resources.

This reaction reflects the physiologically normal mechanism of "quick inclusion" in activity. However, with prolonged exposure to stress factors, a transition to a stress phase is observed, in which the body's ability to compensate for the load decreases.

A decrease in heart rate variability, an increase in muscle fatigue and a deterioration in cognitive functions indicate that the limits of adaptive reserves are approaching.

The identified connection between production factors and the functional capabilities of workers deserves special attention.

High levels of vibration, noise and monotony have a pronounced negative impact on the physiological cost of labor. Our data are consistent with current research showing that Chronic exposure to vibration leads to disruption of microcirculation, decreased sensitivity of peripheral nerve endings and the formation of professional angioneuropathies.

Likewise, excess noise causes acoustic analyzer overload, increased levels of stress hormones and impaired cognitive performance, which we also observed in workers with noise exposure above 75 dB.

Thus, the results of the study confirm that even moderate deviations of the working environment from regulatory requirements can lead to a significant increase in physiological load.

An important aspect of the discussion is the problem of professional fatigue. Our data show that the development of fatigue depends not only on the intensity of work, but also on its structure.

Static loads lead to rapid depletion of the energy resources of muscle fibers, disruption of local hemodynamics and accumulation of metabolites, while dynamic loads of the same power cause a significantly lower degree of fatigue due to the alternation of phases of tension and relaxation

These results highlight the importance of rational distribution of labor, including the rotation of dynamic and static components, which must be taken into account when designing work processes. The body's cognitive reactions to work activity require special consideration.

Decreased attention, increased reaction time, and an increased number of errors in workers with long-term monotonous workload confirm neurophysiological data that the resources of the cortical structures of the brain are limited and subject to depletion.

Monotonous work reduces the level of activation of the reticular formation, which leads to a decrease in the speed of information processing and weakening of control over the actions performed. Combined with

emotional stress, this creates a high risk of professional burnout and production-threatening errors.

The results of the study are of particular significance for occupational safety practice and the development of ergonomic recommendations. The analysis showed that rational distribution of working time, optimization of the microclimate, the use of vibration and noise-absorbing technologies,

Providing a sufficient level of lighting and proper organization of workplaces can significantly reduce the physiological cost of labor.

The availability of objective methods for assessing the functional state - such as monitoring of heart rate, HRV, EMG, cognitive testing - opens up opportunities for the introduction of early warning systems for fatigue.

Such systems are already actively used in aviation, transport and large-scale industry, and the results of our research confirm their effectiveness.

One of the key findings is the need for a personalized approach to workload management. People differ in their level of fitness, type of nervous system, resistance to stress, age and health status.

Therefore, uniform load standards do not always reflect the real physiological capabilities of a particular employee. Individual monitoring of the body's condition makes it possible to create adapted work regimes, which is especially important in the conditions of modern production rates and high intensity of information flows.

From the point of view of theoretical physiology, the results of the study confirm the position that performance is a dynamic indicator that depends on the balance between energy expenditure and recovery processes.

The more efficiently recovery mechanisms function—from sleep regulation to hormonal balance—the higher the body's ability to withstand work loads without the risk of fatigue.

Therefore, the rationalization of the work regime should include mechanisms for optimizing rest, recovery, alternating activities and preventing chronic stress.

Thus, a discussion of the research results allows us to assert that occupational physiology should be considered not only as an area of medical knowledge, but also as a key tool for designing safe, productive and ergonomic human activities.

An integrated approach that takes into account physiological, psychophysiological, production and technological factors is the only way to achieve high performance and maintain professional health.

The study made it possible to comprehensively assess the physiological characteristics of human labor activity and identify key patterns of body functioning under the influence of various types of loads.

The findings confirm that performance and fatigue resistance are determined by a finely balanced interaction of the cardiovascular, respiratory, nervous, muscular and endocrine systems, each of which plays a critical role in maintaining optimal levels of physiological adaptation.

The study showed that the initial phase of work activity is accompanied by the activation of adaptation and regulatory mechanisms aimed at mobilizing energy resources.

However, with prolonged exposure to unfavorable factors - vibration, noise, monotony, static loads, microclimate disturbances - the physiological cost of labor increases and the development of functional fatigue accelerates.

A decrease in heart rate variability, an increase in muscle tension, a deterioration in cognitive performance and an increase in the frequency of errors confirm the depletion of the body's adaptive reserves.

Analysis of production factors revealed their significant influence on the physiological capabilities of workers. It has been established that rational organization of the work process, adjustment of work and rest regimes, improvement of ergonomics and optimization of microclimate conditions allow significantly reduce physiological stress and prevent the development of professional fatigue and stress-induced disorders.

Of particular importance are modern methods of monitoring the functional state - heart rate variability, electromyography, cognitive testing, pulse wave analysis, oxygenation.

Their use creates the basis for personalized approaches to the assessment and management of work activity. Integrating physiological data with ergonomic principles enables science-based workplace design and improved work efficiency.

Thus, the results of the study confirm the need for a systematic approach to the study of labor physiology, including assessment of the body's adaptive capabilities, control of production factors and the introduction of personalized measures to prevent fatigue.

The scientific and practical significance of the work lies in creating a basis for the development of modern labor protection programs, optimization of work processes, increasing professional performance and preserving the health of workers in the long term.

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