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INFORMATION SUPPORT COMPLEX FOR STUDYING THE RELIABILITY OF WORK OF CONTINUOUS COOPERATION SYSTEM OPERATOR UNDER INCREASED SITUATIONAL STRESS

To research the reliability of operator's work under heightened situational stress, the weak link model has been proposed. Software has been designed to study the work reliability of military transport drivers and pilots under heightened situational stress.

Keywords:reliability of organism functioning, mathematical model of functional respiratory system, heightened situational stress, and weak link model.

While assessing reliability of operator's work under time pressure, in emergency conditions, and in stressful environment, it is necessary to take into consideration not only the natural human traits and specific features of human nervous, but also the organism adaptability to various stresses (sharp temperature fluctuations, very low or very high barometric pressure). The human operator is a very sophisticated system working inside other complex system *the human being–the machine–the environment* consisting of various interconnected subsystems. The natural properties of nervous system, capabilities, traits, level of development of cognitive, emotional, communicative, and regulative capacity, readiness to act, all these different characteristics should be regarded when addressing issues related to reliability of operation of military vehicle drivers and aircraft pilots under increased stresses, inasmuch as any their fault can cost a lot of lives [1]. Naturally, this type of job requires good organization, survivability, and fast recovery. Currently, the studies are focused mainly on psychophysical aspects. Some researchers note that the assessment and control of operator's functional condition are directly connected to the data showing the stress level of main organism physiologic systems, including the cardiorespiratory one. In the majority of researches, EEG, ECG, and respiratory frequency are recorded. Some researchers assume that heightening operator's emotional stress causes an increase in magnitude of high-frequency rhythms, frequency of heartbeat, and respiratory frequency. In particular, in [2], the authors mention substantial fluctuations in such parameters as heart rate, respiratory frequency, skin temperature, local sweat production while performing control tests on decision-making. In [3], it is stated that the most informative indicators of pilot skills are heartbeat frequency, residual attention, lung ventilation rate, and grasp of hand controllers. In [4], for the purpose of effective assessment of operator's qualification and work capacity the complex techniques have been proposed. They include the following factors:

- Health quality, including the integral criterion;
- Special operator's capabilities at a certain moment;
- Work capacity under stress conditions;
- Recovery;

- Latent functional reserves;
- Adaptability to new conditions and increased stresses.

STUDY OF OPERATOR WORK UNDER HEIGHTENED STRESSES

The human factor engineering uses a wide spectrum of methods and special techniques designed by experts in labor psychology, physiology, cybernetics, mathematics, etc. In [1], the authors propose to classify the research methods by way of obtaining the data on operator's activities (Fig. 1):

- *The physiological methods* are used for studying the functional condition, reaction of various organism systems on external and internal stresses that may arise in connection with operator's activities (analysis of data of physiological survey enables determining how the operator's organism performs current and extreme activities);
- *The mathematical methods* are used for the statistical processing of results, the search of regularities, and the development of operator's activity models.

The simulation methods deal with the artificial objects that correlate in a certain way with the real things instead of manipulating the real processes.

The physical simulation is focused on the operator's activities in laboratory conditions with the help of special equipment (simulators, test facilities, models, pilot plants, etc.). It is a sort of human factor engineering test to reproduce the psychological structure and specific features of real operator's activities in laboratory conditions. The mathematical simulation deals with the operator's activities using mathematical models describing the real processes. In this case, there are certain limitations on the use of obtained results. The simulation is based on mathematical models representing the human activities in dynamics, under various external and internal stresses.

The human factor engineering distinguishes the continuously interacting systems to which the *driver–car* type systems belong [1]. The operator's job is associated with controlling the moving objects and deals with fast speeds, sudden critical situations, and varying parameters of the environment, etc. For the operators working on the very objects the crucial factors is emotional tension. In addition, they depend on acceleration, temperature and pressure fluctuations, vibrations, oscillations, noises, and so on. In some cases, the operators have to work in special equipment and stay in small-sized premises. In particular, this concerns the pilots and the drivers of tank and armored vehicles. Hence, the very system puts very strict requirements for the operator's health condition and physical fitness.

MATHEMATIC MODELLING OF RELIABILITY OF UNINTERRUPTED INTERACTION SYSTEM OPERATOR

Having analyzed the problems of reliability theory of sophisticated engineering systems [5] and methods of their solution [6] with respect to the animated nature, including the human organism, one can conclude that they describe the processes taking place in the populations and in the society in adequate manner in order to assess the reliability of collective actions. As regards the use of these methods for assessing the parameters of reliability of specific individual, there are some reservations. In particular, unlike the inanimate nature objects whose life cycle can be determined certainly, the set of functions performed by the human organism is diluted insofar as the human evolution and the civilization development always place the human organism before new challenges [7], with some functions such as nutrition, respiration, reproduction, and protection of organism remaining unchanged. The present-day engineering have many self-organized highly reliable systems operating in the conditions foreseen by the designer but failing under unexpected extraordinary conditions. The living system has to operate (quite reliably) in constantly varying internal and external environments and to make optimal decisions necessary for highly reliable life-sustaining activities. For instance, the main

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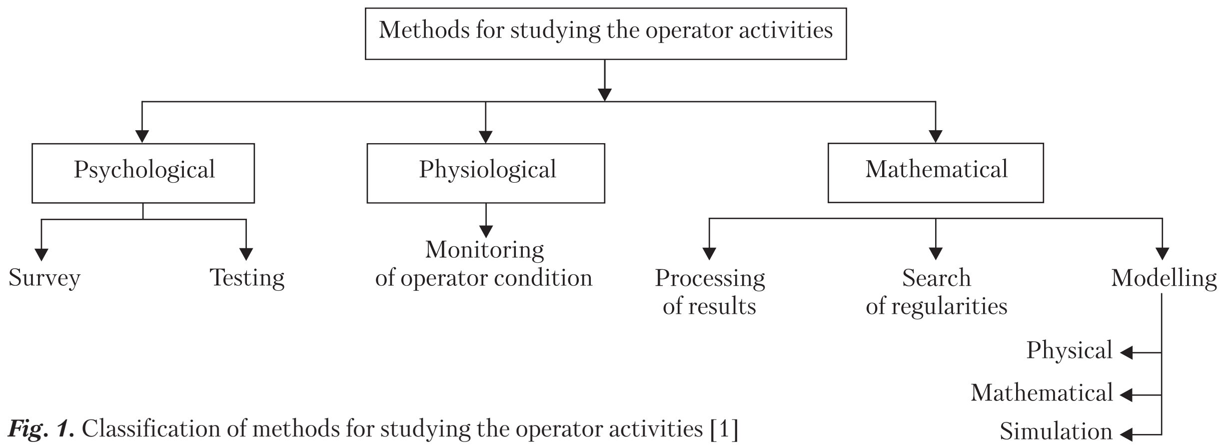

Fig. 1. Classification of methods for studying the operator activities [1]

function of respiratory system in the human organism is to supply oxygen to the tissues involved in metabolism and to remove the generated carbon in due time and in adequate manner. This function is controlled by the system consisting of central, local, and humoral mechanisms closely interacting to each other. The living system is a purpose-driven one, it sets the targets and criteria and can either sacrifice the life safety for the sake of achieving the goal or refuse to operate in order to have the normal living conditions.

On the one hand, there many other important aspects to be taken into consideration when modelling and determining the reliability of the living systems using the reliability theory method. On the other hand, the living system being a sophisticated dynamic system, the general principles of conduct and reliability of operation of complex systems can apply to it. Practically, in the living systems, the three stages of failure risk function $R(t)$ can be distinguished:

- Incidental (deliberate) failures caused by organism diseases and congenital pathologies;
- Labor effectiveness. At this stage, all physiological systems operate normally, without pathology. The reliability of the whole organism depends on the specific features of psychophysiologic system and the targets. The average time of fail-safe operation can essentially depend on the cost of target. Sometimes, it is impossible to reach the target since it would lead to the full exhaustion of organism's internal reserves. In this case, the systems responsible for suspension of operation make respective decision. Also, the average time of fail-safe depends on the living conditions of the human being. That is why, the assessment of living system operation reliability under various stresses is of paramount importance;
- Failure risk associated with ageing or developing pathology.

Hence, the reliability theory models can be used for assessing the reliability of operator's work under increased situational stresses.

The task of reliability models is to connect the system elements and their effect on the system operation. The functional structure of system determines the interaction of elements in the established sequence.

If the system is structured in such a way as for its successful operation all elements should be involved, this type is called *the series system*. If in the case of failure of any element, there is the other one capable of performing its functions, this system is *the parallel one*. The living systems being too sophisticated, they should be referred to the series and parallel systems [8]. Practically, some functions of the living systems can be compensated, at least, partially, by more intensive operation of the other systems (blood pooling, erythropoiesis, local and central mechanisms for respiratory system regulation, etc).

In [7], a failure model for the living system has been proposed. In this model, is the event of the system operating smoothly and keeping itself viable, S_j is the event of the subsystems operating smoothly, without failures. Let's assume that for this system is always the case if S_j, $j = \overline{1, n}$, i.e.

$$S = S_1 \cap S_2 \cap S_3 \cap .... \cap S_n, \quad (1)$$

hence

$$P(S) = P(S_1 \cap S_2 \cap S_3 \cap ... \cap S_n),$$

$$P(S) = \left[\prod_{j=1}^{n} P(S_1 \cap S_2 \cap S_3 \cap ... \cap S_n)\right] P(S_n). \quad (2)$$

If S_j are assumed to be independent in the population,

$$P(S) = \prod_{j=1}^{n} P(S_j) \quad (3)$$

The reliability function is defined as

$$R = \prod_{j=1}^{n} R_j. \quad (4)$$

For the independent series systems the weakest link model is used as well.

Let's consider a series system in which the failure takes place only if one or more subsystems fails:

$$F = F_1 \cup F_2 \cup F_3 \cup .... \cup F_n. \quad (5)$$

Let's assume that as the system fails so does a certain marked subsystem. This assumption can be written as

$$F \subset F_1. \quad (6)$$

However, since $F \supset F_1$, the events F and F_1 are identical and have the same probability:

$$P(F) = P(F_1). \quad (7)$$

Since any F_j leads to F, then

$$F \supset F_1,\ j = \overline{2, n}. \quad (8)$$

Thus

$$P(F) = P(F_1) = \max P(F_j) \quad (9)$$

or

$$R = R_j = \max R_j. \quad (10)$$

If the marked subsystem is the weakest link of the series chain, the failure mechanism of this subsystem is deemed as the failure mechanism of the chain. The chain consists of links among which one or several elements are the weakest ones, i.e. their strength is minimum. The weakest link model can apply to the calculations of reliability of both the whole system and its subsystems.

Let us assume that the strength of individual link is set by probability distribution. Let the population of link strengths has density $f(x)$ and respective distribution function $F(x)$

$$F(b) - F(a) = \int_a^b f(x)\, dx \quad (11)$$

Showing the probability of the link strength ranging between a and b ($b>a$).

Let us assume that strain per link is characterized by density $g(y)$ and distribution function $G(y)$ as

$$G(d) - G(c) = \int_c^d g(y)\, dy. \quad (12)$$

If positive random values X — link strength and Y — load (strain) then one can write:

$$P(X \le x) = F(x),$$

$$P(Y \le y) = G(y). \quad (13)$$

The link reliability is defined as probability of the link not being broken

$$R = P(X > Y),$$

$$R = \int_0^\infty \int_0^\infty f(x) g(y)\, dx dy \quad (14)$$

або

$$R = \int_0^\infty g(y)\, [1 - F(y)]\, dy. \quad (15)$$

For the chain consisting of n links one can assume that its strength is equal to the strength of the weakest link, i.e. the strength Y_n of n-link chain is the minimum of X_i, $i = \overline{1, n}$.

The reliability theory shows [6] that for any strain Y_n, applied to the chain having probability density $g(y)$, the probability of strength Y_n exceeding the strain Y is

$$R_n = P(Y_n \supset Y) = \int_0^\infty g(x)\, [1 - F(x)]\, dx$$

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or

$$R_n = \int_0^{\infty} g(x)\,[1-F(x)]\,dx. \qquad (16)$$

Thus, the reliability of n-link chain is equal to R. Considering the reliability model for the entire organism as a chain one can assume that the weakest links are the respiration and blood circulation subsystem and the psycho-physiologic functions. Insofar as the organism workability mainly depends on the reliability and effectiveness of the respiration and blood circulation (the weak link), let us further consider this subsystem. The initial characteristics of the respiration and blood circulation system are quantified in terms of main function of the respiration system that is timely and adequate supply of oxygen to the organs involved in metabolism and withdrawal of exhaust carbon.

One can assume that the system performs its function in due manner, if the pressure of oxygen p_aO_2 and carbon dioxide p_aCO_2 in the arterial blood and tissues ($p_{t_i}O_2$ and $p_{t_i}CO_2$) ranges within the limits:

$$\begin{aligned} p_a^{min}O_2 &< p_aO_2 < p_a^{max}O_2, \\ p_a^{min}CO_2 &< p_aCO_2 < p_a^{max}CO_2, \\ p_{t_i}^{min}O_2 &< p_{t_i}O_2 < p_{t_i}^{max}O_2, \\ p_{t_i}^{min}CO_2 &< p_{t_i}CO_2 < p_{t_i}^{max}CO_2. \end{aligned} \qquad (17)$$

The minimum values of oxygen and carbon dioxide pressure in the blood and in the tissues determine the thresholds. This parameter being under the threshold leads to blood and tissue pathology which eventually can entail a failure. The functional scheme of main function of the respiratory system is given in Fig. 2.

In [7], the authors have justified that for the purpose of determining the reliability, the structural and functional scheme of the respiratory system should be considered as series system with individual elements being external respiratory subsystem, pulmonary circulation, cardiac and vascular functions, regulation and blood subsystems.

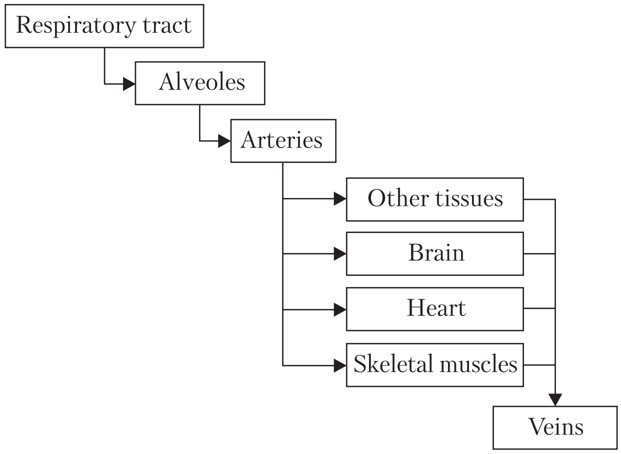

Fig. 2. Diagram of main functions of the respiratory systen

The design of methods for establishing the regimes, selecting the properties to ensure the optimal operation and searching the optimal techniques for identification of disorders, establishing their causes is known to be among the key problems of the reliability theory of complex systems [6].

For solving these problems the reliability theory uses the results of physical and chemical processes underlying the phenomena related to quality deterioration. The same problems exist in physiology of labor, sport, and leisure. To understand comprehensively the organism mechanisms ensuring a high level of reliability of all its functional systems and the organism as a whole, it is advisable to use mathematical models of the respiratory system to design which there has been enough physiologic knowledge of respiratory and blood circulation [9–12]. The analysis of these models enables identifying the regularities of respiratory and blood circulation processes, role of regulatory mechanisms in providing and maintaining the main function under various conditions of human life and activities and the crucial properties of the process under review. In particular, the human organism, including the respiratory system, has been known to be able to resist both external and internal excitations (stresses). The mathematical simulation of the main function of respiratory system not only has confirmed this property, but also has discovered the mechanisms of its manifestation.

The stability of respiration and blood circulation are very important factors for assuring the reliability of functional system. In the case of short-term or constant stress of the inner environment, the supply of oxygen to the tissues / the withdrawal of exhaust carbon enters the area of relative equilibrium where the rate of oxygen supply (carbon withdrawal) is equal to the rate of its consumption (production). Hence, the organism undergoes a short- or medium-term adaptation to stress [7]. In this case, the reliability of functional system is kept at a high level. However, it is true if the stress does not entail reducing oxygen pressure in the tissues below the critical point (in the case of the chain model, the stresses exceed the link strength). The model shows that the process is stable within a quite wide range of stresses and can be kept by passive mechanisms of self-regulation by oxyhemoglobin, myoglobin, etc. However, the process stability is only the necessary, but insufficient condition for the system to keep the performance of its function in a reliable manner.

It has been established that for ensuring the reliable operation of the individual organs and tissues the oxygen pressure in this organ should be kept high. For example, for the brain tissue it should amount to 33 mm Hg. The mechanisms that keep the respiration stability at the expense of biological regulators only can ensure the required level not under all stresses. High level of oxygen homeostasis in the tissues is provided by active regulation mechanisms, in particular due to adjusting adequate ventilation, blood circulation, distribution among the tissues in accordance with need for oxygen. The mechanisms create conditions for normal operation of the respiratory system under varying environment, i.e. facilitate keeping the reliability at a quite high level rather than maintain the stability of respiration and blood circulation.

Hence, the mechanisms of active regulation of respiration and blood circulation are the mechanisms of short- and medium-term adaptation to varying inner and outer environment [7]. Both short- and medium-term adaptations and their effect not always can guarantee a high reliability of organism for various activities because of psychophysical, structural, and morphologic specific features of the organism. The organism long-term adaptability is very important as well. At this stage, the structure of subsystems, individual organs and tissues undergoes transformations and the organism sensitivity to hypoxia and hypercapnia changes as well.

Among the organism mechanisms stimulating the reliability of the respiratory system and the organism as a whole, those that maintain the stability of short-, medium-, and long-term adaptation are the central, local and humoral regulation of stability of psycho-physiological functions.

It is clear that high reliability of operator's organism operation can be kept only all organism systems (respiratory and blood circulation, thermoregulation, immune, central and peripheral nervous systems) operate reliably [8]. If to assume that all organism systems operate in a normal way, the reliability considerably depends on the condition of psycho-physiologic functions and the ability of respiratory and blood circulation system to ensure the required level of metabolism in tissues. As a rule [4], in order to assess the operator psychological condition various functional tests and physical exercises are used for determining the individual typological properties of higher nervous function, functional mobility of nervous system, brain working capacity, and functional condition of vegetative, cardiorespiratory, hematopoietic, immune, and hormonal systems. As regards the tension of regulation mechanisms of external respiratory and blood circulation systems it is very difficult to get experiment data on the respiratory system regulation mechanisms, but the situation partly improves due to the computational experiments based on mathematical models describing the respiratory functional system in excited inner and outer environment.

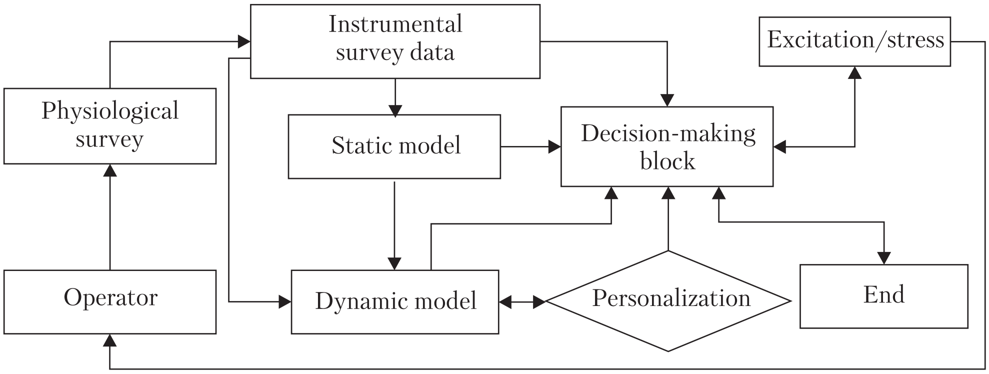

Fig. 3. Structure of the complex for mathematical support of the study

SOFTWARE FOR STUDYING THE OPERATOR WORK UNDER INCREASED STRESS

This section deals with application of simulation for estimating the reliability of functional respiratory system during operator's activity under heightened stress.

The functional respiratory system (FRS) is a self-organized dynamic system. The object is mass transfer and mass exchange of respiratory gases. This self-regulation is realized by the physiologic mechanisms involving the central, local, and humoral links [9]. This self-regulation is aimed at maintaining the gas homeostasis under various stresses of inner and outer environment. The key parameters to assess the FRS condition are partial pressures of oxygen pO_2 and carbon dioxide pCO_2 in alveolar space, blood, and tissues. Functionally, these links are united into the external respiratory, cardiovascular and blood systems.

The strenuous operator work is associated with intensification of metabolic processes in the brain. Varying intensity of this activity can be connected to changing oxygen consumption q_tO_2 by brain tissues, respiratory factor RQ and rate of carbon dioxide release q_tCO_2. The parameters of the condition of object can be oxygen $p_{t_i}O_2$ and carbon dioxide $p_{t_i}CO_2$ pressure in the tissues and blood flowing about them: $p_{ct_i}O_2$, $p_{ct_i}CO_2$. However, the current level of $p_{t_i}O_2$, $p_{t_i}CO_2$, $p_{ct_i}O_2$, $p_{ct_i}CO_2$ essentially depends on volume velocity of local blood flux Q_{t_i}, pulmonary and alveolar ventilation $\dot{V}$ and vascular smooth muscle tone. To assess the condition of functional respiratory system, a mathematical model of respiratory gas transport and regulation of main function of the respiratory and blood circulation system is used [9].

The software for study of operator's work under heightened stress is structured as showed in Fig. 3.

The iteration for applying the proposed software is as follows: the experimental data are based on instrumental survey required for computing the organism oxygen regimes using the static model [11].

As a result, one can obtain data on efficiency, effectiveness, intensity of organism oxygen regimes, acid-base and hypoxic condition, blood oxygen, and cardiac activity. The model inputs are the experimental and data and the results of the static model (respiratory gas pressure in arterial blood, hemoglobin content, rate of oxygen consumption, regional blood flows, etc). On the model basis, the respiratory gas pressure in the tissues of working organs are computed. These data enables assessing the organism adaptation to stresses. The assessment of regulatory reactions of cardiac and respiratory muscles and hypoxia depth enables concluding on the human organism reserves against stresses.

The theoretical study was conducted on the model with four tissues (the cerebral tissue, the cardiac tissue, the skeletal muscle tissue, ect.) (Fig. 2). The simulations were made for average person of a 75 kg weight with known parameters of the rest functional condition: the oxygen pressure amounts to 95 mm Hg in the arterial blood, 38 mm Hg in the brain tissue, and to 30 mm Hg in the cardiac muscles. The rate of oxygen consumption by the brain tissue is 0.62 ml/s, that by the cardiac muscle is 0.33 ml/s, and by the organism as a whole is 4.3 ml/s. The hemoglobin content in the blood is 140 mmole/l, the concentration of buffer bases is 0.479 g/l. The computational experiment was aimed at measuring the regulatory parameters ensuring oxygen pressure in the brain tissue at a level of, at least, 33 mm Hg. The intensification of operator's work was modelled as an increase in oxygen consumption by the brain tissue by 10; 20; 30 and more %. The respiratory factor was assumed to be equal to 0.8, at rest, and to 1.2, at the load. The computations have showed that maintaining the required level of pO_2 in the cerebral tissue while increasing the rate of oxygen consumption up to 20% of the rest one is possible without using compensatory reactions of the respiratory and the blood circulation systems. At rest, the volume velocity of blood flow in the system makes up 95 ml/s, whereas that in the brain is 14.88 ml/s.

An increase in the brain load by 30% requires involvement of regulatory mechanisms. Otherwise, pO_2 in the brain would decrease down to 31.77 mm Hg. The computations have showed that an increase in blood flow in the brain by 10% would lead to oxygen pressure in the brain tissue upping to 33 mm Hg. It should be noted that increasing blood flow in the brain tissue is possible either due to escalating volume velocity of the system blood flow, which entails an increase in the cardiac muscle load or due to redistributing the system blood flow in the tissues and organs, which lead to hypoxia in other tissues [8].

The computations have showed that to keep the average level of pO_2 in the brain tissue (33 mm Hg) while the intensity of the brain load growing by 30–70% as compared with the state of rest is possible due to a linear increase in volume velocity of brain blood flow by 10–50%. Further intensification of operator's work (by 80–150%) requires nonlinear increase in blood flow for ensuring the oxygen homeostasis of brain structures. An increase in the rate of oxygen consumption by the brain structures by 90% requires an escalation of local blood stream by 90%; an intensification of operator's efforts by 130% can be compensated by an increase in volume velocity of blood flow in the brain by 150%; a 2.5-time increase in qO_2 in the brain (by 150%) requires a triple growth of Q_t in the brain tissue. The hypoxic states of the brain structures should be compensated not only due to the cardiovascular but also the respiratory system. According to the computations, if to escalate only the volume velocity of blood flow in the brain tissues for keeping pO_2 at 33 mm Hg, this will lead to arterial hypoxemia. The escalation of blood flow for compensating hypoxia in the brain tissue when the brain activity getting 2.5 time more intensive will cause a decrease in pO_2 in the arterial blood from 95 down to 75.05 mm Hg. In the case of operator's concerted work the arterial hypoxemia is removed by involving the regulation mechanisms of external respiration system.

In order to keep pO_2 in the brain tissues at 33 mm Hg while the intensity of operator's work increasing by 30% it is enough to simultaneously increase the volume of respiration per minute by 10% as compared with the state of rest and the volume velocity of brain blood flow by 5%. In this case, pO_2 in the arterial blood is kept at 95 mm Hg. This example shows that combined involvement of regulation mechanisms reduces load on the regulation organs and does not impair oxygen supply to other tissues and organs.

CONCLUSIONS

The weak link mathematical model has been proposed to be used for studying the reliability of operator's work.

The reliability of functional respiratory system has been showed to be ensured by mechanisms of stability and adaptation to varying living conditions.

The computation results have showed the compensatory capacity of the regulation mechanisms of functional respiratory system only. However, the proposed method enables identifying then main trends in cardiorespiratory system operation and can be useful for developing recommendations on the basis of physiological survey and individual input data for the dynamic model.

REFERENCES

1. Trofimov Ju.L. *Inzhenerna psyhologija*. Kyiv: Lybid', 2002 [in Ukrainian].
2. *Psihofiziologija operatora v sistemah chelovek — mashina*. Pod red. K.A. Ivanova-Muromskogo. Kyiv: Nauk. dumka, 1980 [in Russian].
3. Zhevchina A.I., Kuznecov V.G. O metodah ocenki psihofiziologicheskih vozmozhnostej letchika. *Problemy inzhenernoj psihologii i jergonomiki*. 1974. Vyp 2: 59—60 [in Russian].
4. Biloshyc'kyj P.V., Kljuchko O.M., Onopchuk Ju.M, Kolchyns'ka A.Z. Rezul'taty vyvchennja vyshhoi' nervovoi' dijal'nosti ukrai'ns'kymy vchenymy v Pryel'brussi. *Visnyk NAU*. 2009. no 2: 105—115 [in Ukrainian].
5. Llojd D.K., Lipov M. *Nadezhnost': organizacija issledovanij, metody, matematicheskij apparat*. Moskva: Sov. radio, 1964 [in Russian].
6. Gnedenko B.V., Beljaev Ju.K., Solov'ev A.D. *Matematicheskie metody v teorii nadezhnosti*. Moskva: Nauka, 1965 [in Russian].
7. Onopchuk Ju.N., Beloshickij P.V., Aralova N.I. K voprosu o nadezhnosti funkcional'nyh sistem organizma. *Kibernetika i vychislitel'naja tehnika*. 1999. Vyp. 122: 72—82 [in Russian].
8. Biloshyc'kyj P.V., Onopchuk Ju.M., Marchenko D.I., Aralova N.I. Matematychni metody doslidzhennja problemy nadijnosti funkcionuvannja organizmu za ekstremal'nyh umov vysokogir'ja. *Fiziologichnyj zhurnal*. 2003. 49(3): 139—143 [in Ukrainian].
9. Onopchuk Ju.N. Gomeostaz funkcional'noj sistemy dyhanija kak rezul'tat vnutrisistemnogo i sistemno-sredovogo informacionnogo vzaimodejstvija. *Biojekomedicina. Edinoe informacionnoe prostranstvo*. 2001: 59—81 [in Russian].
10. Novosel'cev V.N. *Teorija upravlenija i biosistemy*. Moskva: Nauka, 1978 [in Russian].
11. Aralova A.A., Aralova N.I, Koval'chuk-Himjuk L.A, Onopchuk Ju.N. Avtomatizirovannaja informacionnaja sistema funkcional'noj diagnostiki sportsmenov. *Upravljajushhie sistemy i mashiny*. 2008. no 3: 73—78 [in Russian].
12. Dickinson C.J. *A computer model of human respiration*. Lancaster: Medical and Technical Publishing, 1977.

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КОМПЛЕКС ІНФОРМАЦІЙНОЇ ПІДТРИМКИ ДОСЛІДЖЕННЯ НАДІЙНОСТІ РОБОТИ ОПЕРАТОРА СИСТЕМ НЕПЕРЕРВНОЇ ВЗАЄМОДІЇ В УМОВАХ ПІДВИЩЕНОЇ СИТУАЦІЙНОЇ НАПРУГИ

Для дослідження надійності роботи оператора в умовах підвищеної ситуаційної напруги пропонується модель ланцюга зі слабкою ланкою, зокрема програмний комплекс для дослідження надійності роботи водіїв військового транспорту та льотчиків при роботі в умовах підвищеної ситуаційної напруги.

Ключові слова: надійність функціонування організму, математична модель функціональної системи дихання, підвищена ситуаційна напруга, модель ланцюга зі слабкою ланкою.

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КОМПЛЕКС ИНФОРМАЦИОННОЙ ПОДДЕРЖКИ ИССЛЕДОВАНИЯ НАДЕЖНОСТИ РАБОТЫ ОПЕРАТОРА СИСТЕМ НЕПРЕРЫВНОГО ВЗАИМОДЕЙСТВИЯ В УСЛОВИЯХ ПОВЫШЕННОГО СИТУАЦИОННОГО НАПРЯЖЕНИЯ

Для исследования надежности работы оператора в условиях повышенного ситуационного напряжения предлагается модель цепи со слабым звеном, в частности программный комплекс для исследования надежности работы водителей военного транспорта и летчиков при работе в условиях повышенного ситуационного напряжения.

Ключевые слова: надежность функционирования организма, математическая модель функциональной системы дыхания, повышенное ситуационное напряжение, модель цепи со слабым звеном.

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