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Molecular Genetic Technologies for Improving Occupational Safety in Extreme Conditions

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ABSTRACT

The purpose of the research in this article is to justify the need for screening genotyping when selecting candidates for work in extreme conditions. Materials and methods: analysis of literature sources on genetics, psychology, and occupational safety; Russian and international biomedical and genetic databases; protocols and reports of accident investigation, accidents, and catastrophes. Results. Based on the analysis of literature data, protocols of investigation of the causes of air crashes, accidents on highways, mines, chemical enterprises, etc., it can be concluded that many causes of accidents, accidents and catastrophes caused by the so-called "human factor" can be eliminated or leveled with proper organization of psychophysiological testing during professional selection, appropriate physical and psychophysiological training of employees. However, one of the key reasons for reducing occupational safety in extreme conditions is almost impossible to correct, since it is genetically determined. This is fatigue, the degree and speed of development of which when performing professional activities directly depend on endurance. No amount of training can increase endurance above a genetically determined level, and therefore can not reduce the speed and degree of fatigue. You can only reduce the subjective feeling of fatigue – fatigue. But at the same time, fatigue remains, and hidden, which significantly increases the risk of inappropriate reactions and erroneous actions in the event of danger and, ultimately, leads to an accident, a catastrophe. It is shown that at the stage of professional selection, the determination of alleles is sufficient as screening indicators of an increased risk of fatigue D, 34T, S and 3R gene ACE, AMPD1, 5HTT and MAOA associated with General, physical, and neuropsychic endurance, respectively. Conclusions. 1. screening genotyping of candidates for work in extreme conditions in order to identify nucleotide polymorphisms associated with endurance-fatigue is a key condition for improving labor safety by preemptively reducing the role of the "human factor" in the occurrence of accidents, accidents and catastrophes in hazardous industries. 2. identification of alleles is sufficient as screening indicators of an increased risk of fatigue when working in extreme conditions D, 34T, S and 3R gene ACE, AMPD1, 5HTT and MAOA, accordingly, they are associated with an increased risk of rapid development of General, physical and neuropsychiatric fatigue.

Introduction

Most of the professions of budget-forming, defense and many other enterprises and industries that ensure state security and economic independence of the country are associated with working in extreme conditions, respectively, with a high risk of accidents, accidents and catastrophes. However, despite multimillion-dollar investments in the development and implementation of measures to improve occupational safety in extreme conditions, the trend towards increasing cases of serious and fatal injuries, man-made accidents and catastrophes with numerous human casualties and colossal destruction has not yet been eliminated. In 2000-2014, there were 8,588 emergencies in Russia, in which irreplaceable losses amounted to 14,826 people, and sanitary losses – 5,841 million people [1]. Analysis of the results of many years of research shows that at least 60-70% of accidents, accidents and injuries in industry and transport are caused by the so-called "human factor", i.e. the main culprit of accidents is, as a rule, not the equipment, not the organization of labor, but the working person himself, who for one reason or another committed erroneous actions, especially in emergency situations. According to Russian researchers and various analytical and expert centers in the United States, about 90% of car accidents are caused by drivers [2, 3]. Based on this, it becomes obvious that when selecting applicants for jobs associated with increased danger, with extreme mental and physical stress, it is necessary to take into account the peculiarities of the psychophysiological qualities of applicants, which some employers paid attention to at the beginning of the last century [4, 5].

As early as 1919, it was established that 85-90% of all industrial accidents occur in a very small part of workers (10-15% of the total number), which, according to researchers, indicates a different predisposition of people to dangers and mistakes, which may be innate [6, 7].

Together with the results of further research, there is every reason to conclude that the safety of a person's work in extreme conditions depends not only on the social environment, length of service and work experience, but also on their innate psychophysiological qualities. Therefore, psychophysiological testing aimed at identifying these qualities in the selection of candidates for work in extreme conditions will improve labor safety. Taking into account that many psychophysiological qualities that affect labor safety in extreme conditions are innate, it seems appropriate to identify genetic factors (nucleotide polymorphisms) associated with these qualities during professional selection. Therefore, the question naturally arises whether it is possible to limit oneself to traditional and widely used psychophysiological testing, or whether it is still necessary to develop and implement molecular genetic technologies when selecting applicants for work in extreme conditions.

The purpose of the study is to justify the need for screening genotyping when selecting candidates for work in extreme conditions.

Materials and Methods

Analysis of literature sources on genetics, psychology, and occupational safety; Russian and international biomedical and genetic databases; protocols and reports of accident investigation, accidents, and catastrophes.

Results

Analysis of the results of numerous studies on various aspects of improving occupational safety in extreme conditions has shown that psychophysiological testing allows us to quantify the psychophysiological qualities of a person that determine the safety of their professional activities in extreme conditions. If these qualities do not meet the requirements of the profession, a person constantly works at the limit of physiological capabilities, which inevitably leads to the development of fatigue, unwillingness to work, injuries and accidents. Therefore, it is necessary to identify applicants whose psychophysiological qualities do not meet the requirements of the chosen profession and restrict their access to activities associated with increased danger and extreme conditions [8.10].

For example, the assessment of the type of higher nervous activity allows us to identify individuals with a strong nervous system who, unlike applicants with a weak nervous system, will be able to maintain self-control in an extreme situation, correctly assess the situation and find the optimal solution [11-15].

It is also important to assess the level of anxiety among applicants. Individuals with low levels of anxiety tend to underestimate a particular situation in a critical situation and act late. Individuals with high levels of anxiety usually react to changes in the environment quickly, but unusually violently, which can lead to erroneous actions and, consequently, to accidents and injuries.

However, when implementing psychophysiological testing in the practice of professional selection, certain difficulties arose that still cannot be overcome. In particular, there were some contradictions in the interpretation of the prognostic significance of the type of nervous system associated with a predisposition to accidents. People with a weak nervous system are not recommended to choose professions associated with the occurrence of extreme situations. The nerve cells of these individuals do not withstand prolonged and strong arousal, and quickly pass into a state of protective inhibition [16].

People with a mobile type of nervous system, characterized by rapid switching from one type of work to another, high speed of work, good distribution of attention between different types of activities, in conditions of lack of time and in extreme situations, have a low risk of accidents. However, such people are characterized by haste, carelessness, the desire to quickly move to another type of work, without finishing the job, they often do not delve deeply into the essence of problems, instructions, with prolonged stress, they quickly get tired and lose all interest in work, which ultimately creates the prerequisites for accidents and emergencies when working in extreme conditions.

Their opposite, people with an inert type of nervous system, which is characterized by slowness, slowness, poor switching, as if "lag behind" in their adaptation to rapid changes in the environment and therefore in extreme situations have an increased risk of accidents. However, such people are able to withstand long-term stress, and their performance only increases during work. They tend to work more thoughtfully and strive for order. Having a good long-term memory, when performing new tasks, past knowledge is attracted, which ultimately reduces the risk of accidents, however, only in the absence of a time deficit, when you do not need to quickly choose the right solution [15, 16].

Thus, determining the strength and type of the nervous system using psychophysiological techniques does not always allow us to unambiguously predict the safety of work in extreme conditions.

It should be particularly noted that psychophysiological testing only States the degree of phenotypic manifestation of professionally significant psychophysiological qualities of the subject at the time of testing, while the recorded indicators only indirectly reflect the innate predisposition to accidents and do not always adequately reflect the innate predisposition to accidents [17].

In particular, quantitative indicators of the phenotypic manifestation of genetically determined low endurance qualities can be improved as a result of special training. However, in some cases, this can be achieved due to the almost complete depletion of adaptive and compensatory mechanisms. But the risk of rapid development of fatigue, which is genetically determined by low endurance, remains, which, despite good results of psychophysiological examination, can lead to accidents, accidents and catastrophes. The opposite conclusion is not excluded, when in the absence of a genetic predisposition to accidents, the impression of its presence is created due to the negative impact on the psychophysiological indicators of various factors – family quarrels, socio-industrial conflicts, climatic conditions, lack of sleep, etc.

Thus, only the direct determination of genetic factors that determine the formation of psychophysiological qualities necessary for safe work in extreme conditions will allow to optimize professional selection and thereby reduce the role of the "human factor" in the occurrence of emergencies, accidents and catastrophes. Based on this, in many countries over the past few years, molecular genetic methods of professional selection of applicants for work in extreme conditions have been actively introduced, in particular, in the practice of selecting special constants of the armed forces and cadets of military educational institutions of NATO countries, Russia, the Republic of Belarus, etc., as well as in the practice of selecting and specializing athletes [18-22].

Working in extreme conditions is often associated with extreme physical and mental stress, with a constant awareness of the presence of potential, and often real danger, i.e. with constant stress, a sense of anxiety and anxiety. In turn, the degree of adaptation to extreme loads is genetically determined, and if the functional reserves of the body do not match the required loads, adaptation and compensatory mechanisms are rapidly depleted, fatigue develops, which is often the cause of injuries, accidents and catastrophes [23-31].

As a result of the study of performance when driving cars over long distances, it was found that professional skills of drivers are quite well preserved in normal, "normal" conditions, but long, strenuous work or the occurrence of "abnormal", emergency situations accelerate the development of fatigue [32-35].

With the development of fatigue occurring disorders of perception, reduced attentiveness, diminishing memory and thinking, reduces visual acuity, the intensity and stability of attention, speed switch, the degree of automaticity of previously developed skills, impaired precision, and coordination, reduced speed of information processing increases rapidly as the time of sensorimotor reactions and detection of danger, a possible wrong assessment of the situation, disturbed and commitment to action in case of an unexpected change in the situation. Decision-making processes are dominated by ready-made stereotypical forms. Not only does the number of errors increase, but their structure also changes: the first is dominated by a small quantitative error then be a serious, quality.

When working in extreme conditions, the neurons of the brain become fatigued much earlier than the working muscles. At the same time, fatigue is the result not so much of the physical or mental load itself, but of insufficient implementation of functional reserves (energy, physiological, psychological, etc.) in response to this load, which have individual differences. Therefore, the conditions of occurrence and the nature of fatigue in one person are not necessarily the same in another [36]. The more the ratio between the use of resources during work and their recovery is disrupted, the faster fatigue develops [37]. Insufficient activation of energy resources and reserves may be due to low adaptive capabilities of the muscular, cardiovascular and Central nervous systems. Based on this, it seems appropriate for screening genotyping when selecting applicants for work in extreme conditions to limit the definition of those polymorphisms that are associated with the adaptive capabilities of these systems, in particular polymorphisms C34T gene AMPD1, I/D gene ACE, L/S gene 5HTT and 3R/4R gene MAOA.

Product of the gene **AMPD1** is an adenosine monophosphate deaminase of skeletal muscle (AMPD1 or AMFD-M), which catalyzes the deamination AMP before IMP and, being one of the integral enzymes of adenylic nucleotide metabolism, it determines the energy potential of muscle cells [38]. The carriers of allele 34T gene AMPD1 a shortened catalytically inactive enzyme is synthesized, which reduces the maximum rate of contraction and increases the relaxation time of skeletal muscles.

Presence of an allele 34T negative impact on well-being in physical activity (weakness, fatigue and muscle cramps even after a medium intensity exercise) and is used in sports medicine as prognostic sign of fatigue during prolonged high-intensity exercise [39, 40]. The frequency of the T allele is 19% in African Americans, 11-12% in the European population, about 15% in the Russian and 0% in the Japanese population [41, 42]. Consequently, at least 10-15% of the Russian population has an increased risk of developing rapid fatigue during prolonged physical activity.

In cases where blood circulation does not meet the body's need for oxygen and nutrients during increased physical activity, a number of mechanisms are activated to increase the IOC, in particular, the activation of the renin-angiotensinaldosterone system, in which the key role is played by the angiotensin-converting enzyme (ACE), which catalyzes the conversion of low-activity angiotensin I into one of the most powerful vasoconstrictors angiotensin II (at II) [43].

Carriers of the D allele of the ACE gene form at II significantly more, and the ability to perform long-term physical work is 7-8 times less than in homozygous carriers of the I allele. This is due to the fact that carriers of the D allele have muscles and the cardiovascular system that are evolutionarily adapted to intense but short-term loads [44-49]. During prolonged exercise, homozygous carriers of the D allele experience a subjective feeling of discomfort, and the heart, which is not predisposed to prolonged exercise, begins to increase compensatorily (myocardial hypertrophy), which can lead to disability and death [44, 50, 51], including during professional activities (for example, pilots during a flight, drivers driving a car, etc.).

The effectiveness of serotonin stimulation in the brain is of leading importance in resistance to neuropsychic stress. Termination of the action of serotonin after release into the synaptic cleft is carried out by its active transfer by the serotonin Transporter protein 5NTT back to the neuron from which it was isolated and by inactivation under the action of the enzyme monoamine oxidase A (MAOA). Changes in any of these links affect the effectiveness of serotonin stimulation - small amounts of serotonin excite synapses, while large amounts, on the contrary, paralyze synaptic transmission. There are two alleles of the serotonin Transporter gene (5 NT), designated as long (L) and short (S), associated with the efficiency of serotonin return to the presynaptic neuron.

Carriers of the S allele synthesize less of the serotonin Transporter, resulting in increased basal serotonin levels in the synaptic cleft and may have a less favorable self-perception throughout life, in particular a feeling of fatigue.

Carriers of the S allele show increased sensitivity to emotional stimuli, have less control over their behavior, are more susceptible to stress, are more prone to anxiety reactions during social interaction, and develop fatigue during intense physical and mental stress. Even before physical activity, they assess themselves as more tired, less active, with a reduced mood and well-being compared to carriers of the L allele [52-56]. There is no doubt that the combination of these qualities does not meet the requirements of working in extreme conditions.

At the same time, there is evidence that military carriers of the S allele demonstrate better indicators of neurodynamic properties under high physical loads and are characterized by faster recovery of neurodynamic properties after multi-day extreme physical exertion [57, 58]. Along with other factors that require further study, this may be due to the fact that the effectiveness of serotonin stimulation also depends on the activity of the enzyme monoamine oxidase A (MAOA), which catalyzes the inactivation of serotonin through its oxidative deamination [59-61]. The more active the MAOA enzyme, the faster the disorders of higher nervous activity caused by a stressful situation are neutralized and the faster a person is able to make the right decisions. MAOA activity depends on the number (from 2 to 5) of repeated sequences of 30 BP in the promoter region of the MAOA gene. The fewer repeats (R), the less the enzyme is synthesized, hence the lower the rate of serotonin inactivation. Carriers of the 3R allele synthesize MAOA in 5 times less than carriers of the 4R allele [62, 63]. A low-activity allele (3R) was shown to be associated with a tendency to antisocial behavior, increased aggressiveness, a lower intelligence coefficient, and a low coefficient on the "damage avoidance" scale compared to carriers of high-activity gene variants [64-71]. Carriers of a low-activity allele are more anxious and impulsive, prone to feelings of guilt, and tend to overestimate the dangers that threaten them [72-74]. It is quite obvious that a low-activity allele is associated with qualities that are not compatible with working in extreme conditions. In the European population, the low-activity 3R allele occurs with a frequency of 32-35% [62], i.e. at least 1/3 of the population does not meet the requirements of working in extreme conditions due to its innate psychophysiological qualities.

Thus, the introduction of screening genotyping into the practice of professional selection, aimed at identifying candidates with nucleotide polymorphisms associated with an increased risk of rapid development of fatigue, is one of the necessary measures to improve labor safety in extreme conditions by preventive reduction of the role of the human factor.

Conclusions

1. screening genotyping of candidates for work in extreme conditions in order to identify nucleotide polymorphisms associated with endurance-fatigue is a key condition for improving labor safety by preemptively reducing the role of the "human factor" in the occurrence of accidents, accidents and catastrophes in hazardous industries. 2. As screening indicators of an increased risk of fatigue when working in extreme conditions, it is sufficient to identify alleles D, 34T, S and 3R of the ACE, AMPD1, 5NTT and MAOA genes, respectively, associated with an increased risk of rapid development of General, physical and neuropsychiatric fatigue.

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