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THE IMPACT OF HORSERADISH ROOTS (*ARMORACIA RUSTICANA*) ON THE FUNCTIONAL STATE OF RAT BODY IN ACUTE HYPOXIA

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Using the "Bioscope" hardware complex, it was shown that an oxygen deficiency leads to certain changes in the statistical parameters of the integrative state of animals both during and after hypoxia exposure. However, after 10 days of using horseradish roots (*Armoracia rusticana*) as an antihypoxic food supplement, in contrast to the control, significant changes in the recorded signal are observed both during and after hypoxic exposure. These changes indicate the facilitating effect of horseradish roots in conditions of oxygen deficiency.

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Introduction.

In the dynamics of chronic cardiovascular and respiratory diseases, an endogenous hypoxia develops in the body – a violation of the processes of oxygen assimilation in tissues and cells. Oxygen deficiency develops in the body also under the action of extreme factors, such as hypoxic hypoxia, gravitational overload, high ambient temperature, physical inactivity, etc. In traditional medicine, the use of medical plants with antihypoxic properties is recommended as an aid in these pathologies. Such remedies include ordinary horseradish. Therefore, it seems relevant using ordinary horseradish (*Armoracia rusticana*) as a food supplement in condition of experimentally induced acute hypoxia in order to conduct an objective assessment of the nature of changes of the physiological state of the body.

Materials and Methods.

The study has been conducted on 8 awake white male rats weighing 200–250 *g* in two series. In the first, control series, the integrative (holistic) condition of animals has been investigated before, during and after hypoxic exposure. To assess the integrative state of the body, we used a specially developed hardware complex "Bioscope" [1], which contactlessly records a signal from the body surface and allows a non-invasive assessment of the integral state of the biological system during the study. For the second, experimental series animals

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received crushed horseradish roots as a dietary supplement with food for 10 days. After that, the effect of hypoxic exposure on the integrative state of these animals' body was evaluated.

A number of investigations demonstrated the effectiveness of using the "Bioscope" in studying the effects of various pharmacological means, stress influence, as well as functional and pathological changes in the physiological state of the body [2–5]. The recorded signal is sensitive to various impacts, and the deviations in its parameters can be used for judging the functional state of the body.

Oxygen deficiency has been modeled in a lab hypobaric chamber by pumping air from it. Acute hypoxia corresponded to a "rise" to a height of 7500–8000 *m* (pO_2 = 64–58 *mm* Hg). The "rise" and "descent" of the animal in the pressure chamber was carried out at a speed of 15–20 *m*/*s*. In both series of studies, remote registration of the integrative state of animals has been done within 30 *min* before, during and in 30 *min* after hypoxic exposure.

The analysis of the recorded signals of the "Bioscope" has been carried out by using the specially developed integrated program in the LabView environment. For each animal, the values of the successive inter-peak time intervals of the Bioscope signals (BB intervals) were assessed. For a set of BB intervals, 16 statistical indicators were calculated, but in current article the parameters of the recorded signal that underwent significant changes during hypoxia are discussed: the average value of the spectral distribution of signals (BB, min), coefficient of variation of BB intervals (CV, %), the ratio of the maximum and minimum values of the BB intervals (max/min), the average oscillation frequency of the Bioscope signals ($F_{BB}=1/<BB>$).

Both in the control and in the experimental series the changes in the averaged statistical indicators during and after the hypoxic exposure were calculated relative to the norm (before the "rise").

At all stages of the experiments the average values of the above-mentioned indicators were estimated. The significance of differences in their values in different series of studies was evaluated using Student's test with $p<0.05$ being considered statistically significant. For each series of experiments the spectral distributions of the initial signals of the "Bioscope", as well as the time sequence of their BB intervals were averaged.

The experiments, care and maintenance of animals were carried out in accordance with the recommendations of the guidelines for laboratory animals in accordance with the rules of the "European Convention for the Protection of Animals Used in Experiments" (Directive 2010/63 / EU) [6].

Results and Discussion.

Previously was shown that in conditions of acute hypoxia (at an altitude of 7500–8000 *m*), all body functions – the heart rate, respiration, the total electrical activity of the brain and impulse activity of neurons are suppressed [7–9]. In our previous studies, it was also shown that oxygen deficiency leads to deviations in a number of indicators of the integral (integrative) state of the body [10].

The goal of the present study was to investigate changes in the integrative (general physiological) state of the rat organism in norm, during and after exposure to acute oxygen deficiency as well as after using horseradish roots as an antihypoxic dietary supplement with food [10].

The experiments revealed that under normal atmospheric pressure (before hypoxic exposure), the use of horseradish roots led to certain changes in the values of the statistical indicators of the integrative state of animals (see Table).

It was shown after 10 days of using horseradish roots (*Armoracia rusticana*) as an antihypoxic food supplement, the acute hypoxia, led to significant changes (compared with the control) in statistical parameters which are the nature of the spectral distributions of the signals (BB, *min*), the coefficient of variation of the BB intervals (CV, %), the ratio of the maximum and minimum values of the BB intervals (max/min), the average frequency of oscillations of the Bioscope signals (F_{BB}=1/BB).

Due to the presence of a number of chemicals, horseradish root has antihypoxic properties, which is expressed in an increase in the life expectancy of mice from 26.5±3.7 *min* to 38.9±5.0 *min* ($p<0.01$) under conditions of oxygen deficiency [11]. At the tissue level of the body, chemical substances of medicinal plants that have antihypoxic properties help to improve oxygen use by the body and reduce the need for organs and tissues in it, which generally increases resistance to hypoxia.

Perhaps the antihypoxic effect of horseradish roots is associated with the presence of such compounds as rutin and quercetin [12], which have the antioxidant ability to prevent lipid peroxidation of cell membranes and protect capillary walls [13].

An important antioxidant role in the fight against hypoxia belongs to other substances, which are vitamin C, carotene, that make up the roots of horseradish. They also include mineral salts, nitrogenous substances, fiber, phytoncides, sugars, enzymes – aspargin, arginine, glutamine, sinigrin. Antioxidants normalize the processes of free radicals, turning free radicals into a stable molecular form (not able to participate in the auto-oxidation chain).

Statistical indicators of the "Bioscope" signals in control and experimental groups in norm, at the altitude and after descent

Parameters	Conditions	Control group	Experimental group
The average value of BB-intervals, *min*	Norm (before "rise")	0.06±0.01	0.1±0.01
	Hypoxia	0.09±0.01	0.08±0.02
	After Hypoxia	0.13±0.02	0.11±0.02
Coefficient of variation of the BB intervals, CV, %	Before "rise"	92.5±5.8	71.7±3.8
	Hypoxia	104.5±4.2	67.4±3.9
	After Hypoxia	87.5±4.9	54.5±3.6
The ratio of the maximum and minimum values of the BB intervals, max/min	Before "rise"	34.3±2.2	18.4±1.2
	Hypoxia	54.4±5.1	18.4±1.1
	After Hypoxia	29.9±1.5	13.2±0.7
The average frequency of oscillations of the "Bioscope" signals, F_{BB}, min^{-1}	Before "rise"	16.8±1.1	9.8±0.2
	Hypoxia	10.9±0.8	13.0±0.9
	After Hypoxia	7.9±0.4	10.1±0.4

An analysis of the data showed that in the control group the hypoxia leads to 1,5-fold increase of the average value of BB intervals of the recorded signal, while in the experimental group it decreases 1,2 times.

It should be noted that the negative aftereffect of oxygen deficiency in the control group of animals was observed even in two hours after the removal of the hypoxic factor (a shift in indicators: BB, *min*; F_{BB}, min^{-1}). In the experimental group, the indicators were close to normal even at the 30th minute after hypoxia, which indicates a positive effect of horseradish roots as a food supplement.

The coefficient of variation of the BB intervals (CV, %) of animals of the control group increases with hypoxia, unlike it in the second group – decreases. This tendency in experimental animals continues after hypoxic exposure.

During hypoxia exposure in animals of the first group the average oscillation frequency decreases 1,5 times, which is aggravated even after hypoxia, while in the second group of animals, on the contrary, it increases (1,3 times) and by the 30th minute after hypoxia it returns to normal.

Conclusion.

Concluding the results obtained, it can be considered that horseradish roots, due to their antioxidant and antihypoxant properties have a facilitating effect on the general functional state of the body in conditions of oxygen deficiency. Antioxidants and antihypoxants block the activation of free radical processes and lipid peroxidation of cell membranes, which occur in the development of oxygen deficiency in the body during acute myocardial infarction, ischemic and hemorrhagic strokes, acute disorders of regional and general blood circulation.

Activation of free radical processes and a peroxidation also accompanies diseases such as atherosclerosis, diabetes mellitus, chronic nonspecific lung lesions and a decrease in cellular and humoral immunity.

This suggests that the use of horseradish roots in traditional medicine in order to protect the body from the negative effects of oxygen deficiency in atmospheric air and in endogenous hypoxia and its aftereffect can be considered scientifically justified.

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ՍՈՎՈՐԱԿԱՆ ԾՈՎԱԲՈՂԿԻ (*ARMORACIA RUSTICANA*) ԱԶԴԵՑՈՒԹՅՈՒՆԸ ԱՌՆԵՏՆԵՐԻ ՕՐԳԱՆԻԶՄԻ ԳՈՐԾԱՌՈՒԹԱՅԻՆ ՎԻՃԱԿԻ ՎՐԱ ՍՈՒՐ ԹԹՎԱԾՆԱՔԱՂՑԻ ՊԱՅՄԱՆՆԵՐՈՒՄ

Առնետների գործառութային վիճակի փոփոխությունները ուսումնասիրելու համար կիրառելով “Bioscope” ապարատային սարքը՝ պազվել է, որ թթվածնի անբավարարությունը հանգեցնում է կենդանիների ինտեգրատիվ վիճակի վիճակագրական ցուցանիշների փոփոխությունների՝ ինչպես թթվածնաքաղցի ազդեցության ընթացքում, այնպես էլ՝ դրանից հետո: Սակայն հակահիպօքսիկ ազդեցությամբ օժտված ծովաբողկի (*Armoracia rusticana*) արմատների 10-օրյա նախապես կերակրումը կենդանիներին փորձի վերընշված ժամանակահատվածներում արձանագրել է ցուցանիշների փոփոխությունների զգալի մեղմացում՝ ստուգիչ խմբի տվյալների համեմատությամբ: Այս փոփոխությունները վկայում են ծովաբողկի արմատների հեշտացնող ազդեցության մասին թթվածնի անբավարարության պայմաններում:

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ВЛИЯНИЕ КОРНЕЙ ХРЕНА (*ARMORACIA RUSTICANA*) НА ФУНКЦИОНАЛЬНОЕ СОСТОЯНИЕ ОРГАНИЗМА КРЫС В УСЛОВИЯХ ОСТРОЙ КИСЛОРОДНОЙ НЕДОСТАТОЧНОСТИ

С использованием аппаратурного комплекса “Биоскоп” показано, что кислородная недостаточность приводит к определенным изменениям статистических показателей интегративного состояния животных как во время, так и после ее воздействия. После 10-дневного использования в качестве пищевой добавки корней хрена (*Armoracia rusticana*) как антигипоксического фитопрепарата наблюдаются значимые изменения показателей регистрируемого сигнала как во время, так и после гипоксического воздействия по сравнению с контролем. Эти изменения свидетельствуют об облегчающем влиянии корней хрена в условиях кислородной недостаточности.