

NASA Contractor Report 3922(37)

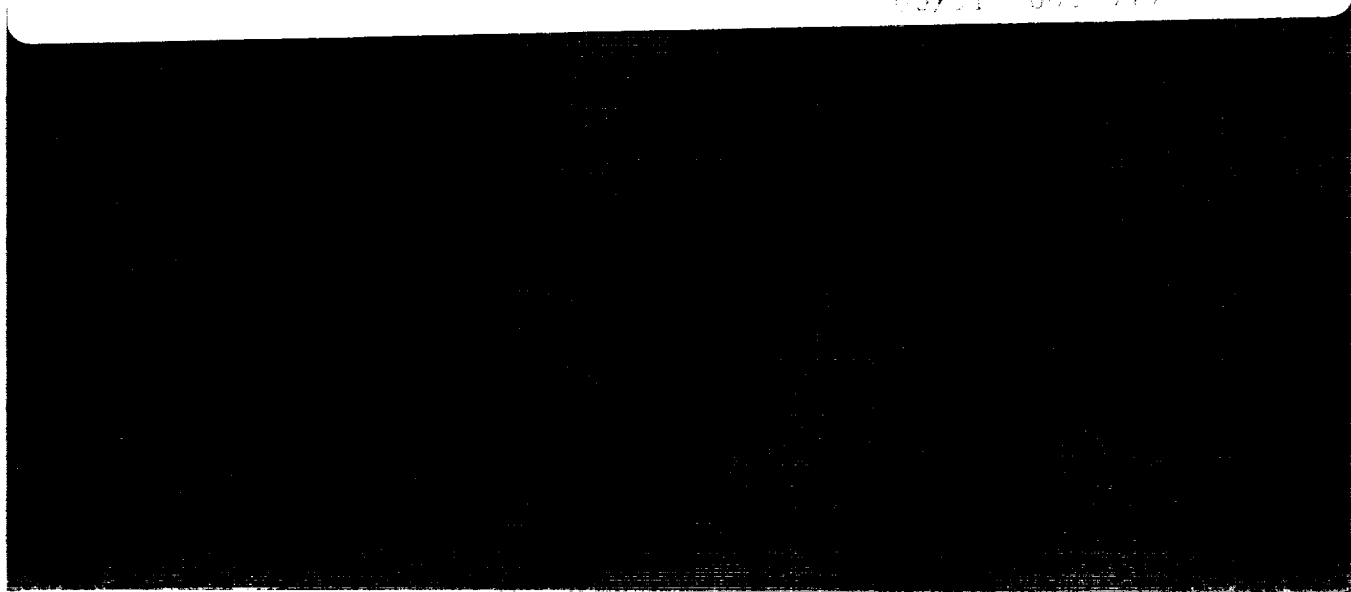
USSR Space Life Sciences Digest

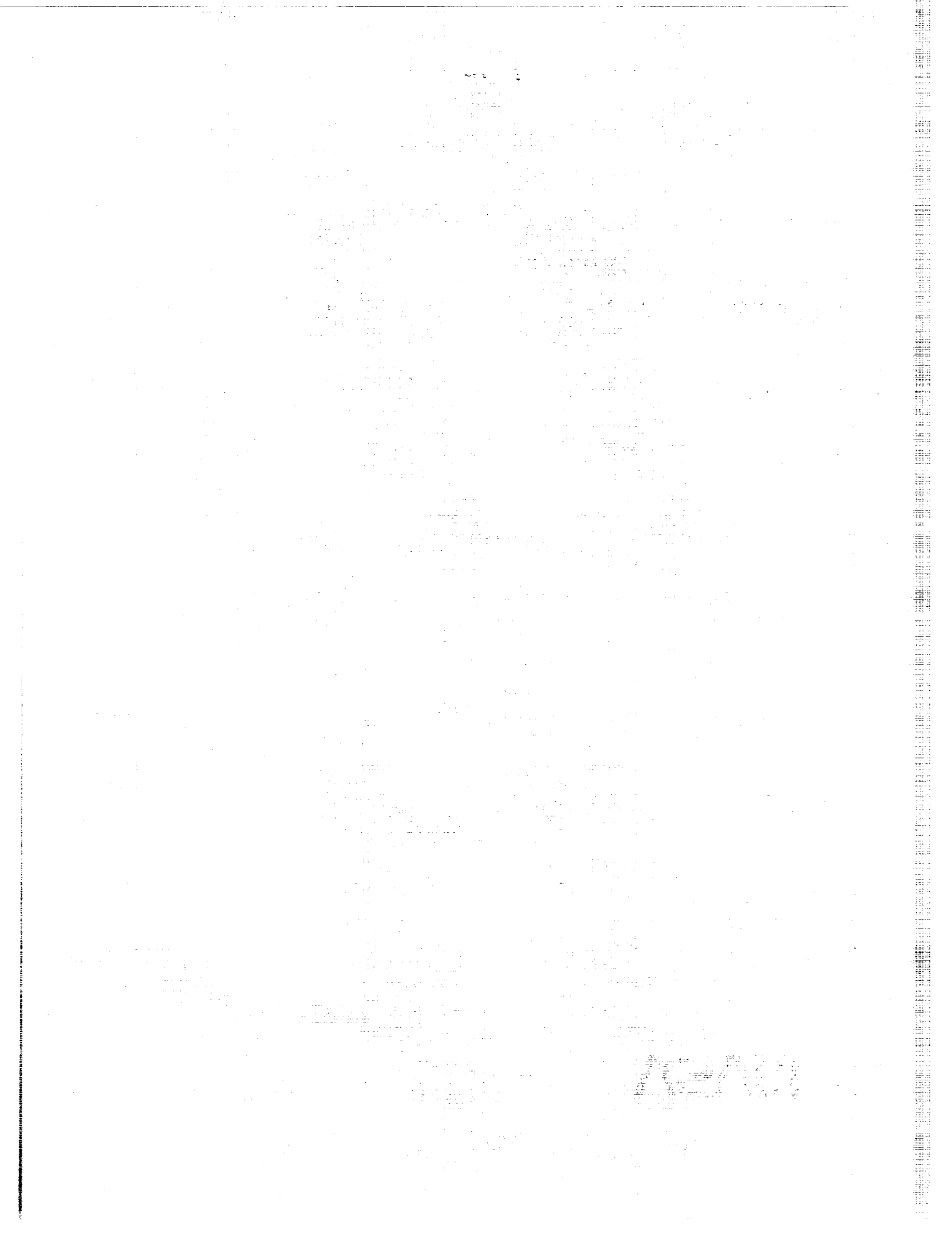
Issue 31

CONTRACT NASW-4292
SEPTEMBER 1991

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09/91 09102135





NASA Contractor Report 3922(37)

USSR Space Life Sciences Digest

Issue 31

Edited by

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Library of Congress
Washington, D.C.

Prepared for
NASA Office of Space Science and Applications
under Contract NASW-4292



National Aeronautics and
Space Administration
Office of Management
Scientific and Technical
Information Program

1991

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USSR Space Life Sciences Digest: Issue 31 Reader Feedback Form

To our readers: We are working in a large number of highly technical, specialized areas for which adequate Russian-English glossaries have yet to be compiled. We ask your help in improving the accuracy and specificity of our English terminology. Please fill out the form below whenever you encounter an incomprehensible, incongruous, awkward or otherwise inappropriate term. While we solicit all suggestions for improved renderings, the statement that a term is inappropriate provides us with useful information, even when no better alternative can be suggested. A copy of this form will appear in all future issues of the Digest. Thank you for your help.

Abstract Number rendering	Incorrect or inappropriate term	Suggested

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PAPERS:

P1408(31/91) Delone NL, Antipov VV.

Cytogenetic aspects of study of the mechanisms of physiological adaptation to space flight.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 300-301.

Adaptation, Cytology, Cytogenetics, Nucleus
Botany, Onion, *Tradescantia*, Hepatocytes, Oocytes
Space Flight, COSMOS-1887, Mir

Abstract: Physiological adaptation utilizes mechanisms inherent to a number of levels. The authors discuss adaptation at the cytogenetic level using the example of response of the nucleus to the effects of space flight factors.

The authors studied the effect of space flight factors on meristem nuclei of seeds of the napiform onion, in *Tradescantia*, in hepatocytes of tortoises, oocytes of triton lizards, and peripheral oocytes of monkeys and humans. They measured the size of the cells, nuclei, and nucleoli, and evaluated chromatization of nuclei using light and electron microscopy; they also identified blocks of heterochromatin in metaphase chromosomes (C-disks?).

Analysis of results showed that in all the studies the cell nuclei stained less brightly and increased in size after space flight. Number and size of nucleoli also increased. Thirty flight experiments with *Tradescantia* microspores revealed effects on cell shape and an increase in size compared to control. Two weeks after flight on COSMOS-1887 during the stages of previtellogenesis, oocytes of tritons and their nuclei were enlarged and number of nucleoli was elevated. However, additional multiplication of oocytes was not stimulated (joint research with T.V. Ostromovaya, et al.). In rhesus macaque monkeys exposed to space on the same biosatellite, lymphocytes displayed an increase in the number of associations of nuclei-forming chromosomes due to adhesions of zones of heterochromatin located adjacent to the nucleoli organizers (joint study with V.P. Zhvalikovskaya, et al.).

Lymphocyte chromosomes of a cosmonaut completing a 1-year flight on the Mir station displayed significant differences in the size of C-disks in blood samples taken pre- and postflight. During flight, chromosomes lost a portion of their facultative heterochromatin, "cleaning out" the adjacent euchromatic areas (joint study with V.G. Solonichenko, et al.).

These data support a hypothesis concerning the mechanism of adaptation to space flight factors at the chromosome level. Briefly, whole blocks of genes may be repressed during heterochromatization of euchromatic regions. The denser packing of chromatin could serve to regulate the process along with genes of ribosomal RNA. Introduction of a large number of these genes in a state amenable to specific activation would result from the availability of rather extensive regions of euchromatin. A greater amount of transcribed rRNA would create the prerequisites for organization of a large number of ribosomal "protein factories," which would then lead to intensified cell activity. Thus, the cell increases its adaptive potential. A cytogenetic approach can be used to test for this level of adaptation.

P1416(31/91) Serova LV.

Compensatory-adaptive potential of mammals in weightlessness and hypergravity.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 339-341.

Adaptation, Psychology, Stress Response, Reproductive System, Pregnancy; Neurophysiology, Developmental Biology

Rats, Male and Female

Space Flight, COSMOS, Hypergravity

Abstract: This paper summarizes materials obtained in experiments with rats (male and female Wistar rats from the "Stobovaya" vivarium and the vivarium of the Institute of Experimental Endocrinology, of the Czechoslovak Academy of Sciences, Bratislava, Czechoslovakia) on COSMOS series biosatellites, and also in ground-based simulations under conditions of hypergravity of 2-g.

It was established that a nonspecific stress response plays a major role in the reactions of mammals to changes in gravity of ± 1 -g that of the Earth. The magnitude of the stress response is approximately equal in weightlessness and hypergravity of 2-g.

In male rats the symptoms of a stress response after space flight were moderate. The animals maintained the ability to react appropriately to additional stressors (acute and chronic) and to satisfactorily endure severe stress tests starting on day 1 of readaptation. Pregnant female rats exposed to weightlessness showed more severe stress-related changes than males. However, in this instance the reactions did not exceed the bounds of "physiological stress," allowing the pregnancy to proceed normally. Compensatory-adaptive potential of the rats' nervous system was adequate to maintain a pattern of conditioned responses acquired before the flight, and allow the normal development of the fetal nervous system.

Longevity of animals (males and females) returning to Earth after space flight lasting approximately 1/50 of their normal life-span was unchanged. The level of dominant lethal mutations in mature spermatozooids and spermatogenesis stem cells found in adult animals exposed to weightlessness did not differ from control. Exposure to weightlessness was accompanied by activation of catabolic processes — to a moderate degree in males and to a significant degree in pregnant females. Despite this, the female flight rats were capable of activating anabolic processes associated with the growth of their fetuses, to the same extent as control pregnant females.

Compensatory-adaptive potential of pregnant female rats exposed to weightlessness, was adequate for supporting fetal homeostasis. There were no teratogenic effects of weightlessness; however, there was a slight delay in the development of the fetuses during flight, which was rapidly compensated after return to Earth. Thus animals exposed prenatally to space flight are capable of proceeding through a complete cycle of postnatal ontogenesis up to attainment of sexual maturity and production of offspring, without significant deviations from the norm in rate of growth and development, structure and metabolism of internal organs, motor activity, or behavior.

ADAPTATION

Exposure of the animals to hypergravity (2-g) did not impede the completion of a full cycle of prenatal ontogenesis (from insemination to birth). At various stages of development, the effects of hypergravity varied: increased duration of contact of animals before insemination, interruption of development in some rats when they were centrifuged starting on day 7 of pregnancy, and slight developmental delay in response to centrifugation starting on day 14 of pregnancy. In the last case, the reaction of the mother-fetus systems to hypergravity was virtually analogous to changes observed under conditions of weightlessness.

The results obtained support a rather high evaluation of the compensatory-adaptive potential of mammals in adaptation to weightlessness and hypergravity and a positive prediction of the potential for a full cycle of prenatal development and long-term (lifetime) survival in weightlessness for animals of this species and species having similar levels of resistance and reactivity.

MONOGRAPH:

M177(31/91) Kaplan YeYa, Tsyrenzhapova OD, Shantanova LN.
Optimizatsiya Adaptivnykh Protessov Organizma, Оптимизация Адаптивных Процессов
Организма; [*Optimization of Adaptive Processes of the Body*].
Moscow: Nauka; 1990.

[94 pages]

Affiliation: Buryat Scientific Center, Siberian Division, USSR Academy of Sciences

Key Words: Adaptation, Drugs, Herbal Medicine, Liver

Annotation: This monograph considers current ideas on the mechanisms underlying adaptation and the principles of regulation of adaptive processes. Results of pharmacological studies of a Tibetan multicomponent herbal preparation with a broad spectrum of adaptogenic effects, are cited.

Information from Tibetan and modern medicine concerning the role of the liver in the body, and also experimental data on adaptogenic properties of hepato-protective herbal preparations are presented. It is demonstrated that the use of these preparations combined with adaptogens foster improvement in non-specific physiological resistance.

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PAPER:

P1405(31/91) Stepanova SI, Lkhagva L.

Chronobiological approaches to preflight and inflight evaluations of cosmonaut state.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 276-277.

Biological Rhythms, Diurnal, Monthly, and Seasonal Rhythms, Operational Medicine, Inflight Monitoring, Sleep Disturbance, Thermoregulation
Humans, Cosmonauts
Space Flight, Salyut-4, Salyut-6

Abstract: One of the approaches to evaluating the results of inflight medical support of cosmonauts is comparison of data obtained during a flight with the corresponding parameters recorded on the ground preflight. It is obvious that preflight information must provide a complete and reliable picture of the characteristics of the baseline norm. This dictates the need for dynamic observations preflight with multiple recordings of each parameter. Only in this way can we obtain information about the range of normal variations and thus avoid problems in classifying inflight data as normal or pathological. The formation of a correct picture of the preflight norm requires consideration of diurnal, monthly and seasonal dynamics of the parameters studied, since the range of normal variations of each is determined, to a great extent, by periodic changes in diurnal, monthly and seasonal rhythms. Moreover, the conditions under which preflight examinations were performed must also be considered. The data obtained by the authors during the 1983 "Biorhythm" flight demonstrates that obtaining physiological information immediately preflight, when stress factors are intense, is undesirable since preflight stress factors will unavoidably affect the parameters measured, distorting the picture of values of the inflight norm. Morning-evening dynamics of axillary temperature recorded in the Mongolian cosmonaut, when repeated on days 6, 5, and 4 preflight were significantly altered from values measured 1 month preflight and, instead of a smooth curve increasing from morning to evening, displayed alternations of unusually high increases and equally extreme decreases, in which it was virtually impossible to recognize normal temperature dynamics.

It is no less important to use a chronobiological approach to evaluate cosmonaut status during space flight. It would be useful, in particular, to periodically record cosmonaut body temperature throughout a day, to provide a chronobiological criterion for evaluating state, which unquestionably would provide more information than isolated measurements. It is interesting that such an approach was already used once in the flight of the second crew of Salyut-4, during which sleep-wake schedules were shifted from the normal terrestrial one, when one of the cosmonauts showed extreme drowsiness during the second half of the wake period (7:00-13:00 Moscow time), as a result of which he reported that he fell asleep during physical exercise on the bicycle ergometer. It is noteworthy that during the first half of the wake period, during the actual night, this cosmonaut felt wide awake and ready to work. When axillary temperature was recorded at 2-hour intervals it was found that body temperature dropped during the period of drowsiness (to 35.7-35.9°C) and increased during the period of alertness (36.4-36.8°C). This relationship is normal: drowsiness during the night is regularly associated with decrease in body temperature, and activity during the day with its increase. In this case, however, this association was displaced in phase: drowsiness and

BIOLOGICAL RHYTHMS

decreased body temperature were noted during the first half of the actual (terrestrial) day, and alertness and increased body temperature at night. Thus, we observed a disruption of the natural diurnal rhythm of activity and a synchronous disruption of diurnal temperature rhythm evidently due to the use of a shifted diurnal schedule during flight. In this case, the phase shifts noted were not suited to the routine imposed in flight, since they included drowsiness during the wake period, which would not have occurred if the cosmonaut was adapted to this schedule.

The use of chronobiological approaches to recording body temperature of the Mongolian cosmonaut during a 5-day flight (measurement during the period of wakefulness at 2-hour intervals) showed a decrease in axillary temperature by a mean of 0.4°C compared to baseline and suggested the desirability of further study of the thermoregulating effects of weightlessness.

PAPERS:

P1403(31/91) Nikulina GA.

Results of Holter monitoring of cosmonauts of the fourth Mir prime crew.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 143-144.

Cardiovascular and Respiratory Systems, Holter Monitoring, EKG, Adaptation, Biological Rhythms, Diurnal Dynamics, Synchronization, Neurophysiology, Parasympathetic and Autonomic Nervous Systems

Humans, Cosmonauts

Space Flight, Mir, Prime Crew 4

Abstract: The method of continuous 24-hour recording of electrocardiograms was developed to identify and evaluate latent cardiac rhythm disorders and EKG abnormalities associated with coronary insufficiency (Holter, 1964). Starting in 1979, this method has been used for monitoring Soviet cosmonauts before, during and after long-term flights (R.M. Bayevskiy, Zh. V. Barsukova, G.A. Nikulina, et al.1984. G.A. Nikulina, 1989) Here the main emphasis is on evaluating the adaptive potential of the cardiovascular system on the basis of mathematical analysis of cardiac rhythm. The state of regulatory mechanisms estimated on the basis of such analysis, including tone of the sympathetic and parasympathetic autonomic nervous systems, may alter during the course of the monitoring period as a function of work and rest schedule, and "sleep-waking" cycle. One of the important evaluation criteria of diurnal dynamics of heart rhythm is mutual synchronization of changes in individual, mathematical/statistical parameters. Thus, the higher an individuals physiological adaptive potential, the more coordination there is between changes in the sympathetic and parasympathetic components of regulatory mechanisms.

The present paper presents results of evaluating dynamics of mean daily values of the major mathematical/statistical parameters of heart rhythm before (A) and after (B) long-term flights of the fourth prime crew of space station Mir (PC-4). During the readaptation period, C-1 displayed the most pronounced adaptive response, and C-2 the least. Individual differences in types of autonomic status must be taken into account here. On the basis of baseline data, C-1 may be classified as a sympathetic type, C-2 a normotonic type, and C-3 a vagotonic type. In C-2 the adaptive response of regulatory systems was inappropriate (inadequate), as manifested by heart rate and mathematical/statistical parameters of cardiac rhythm changing in different directions. A reaction of this type indicates a mismatch between humoral and neural channels for regulating the cardiovascular system. The differences in the severity of the response in C-1 and C-3 are most likely due to individual differences associated with age.

Thus, Holter monitoring makes it possible to draw conclusions about adaptive physiological responses on return to Earth after long-term space flight, which has major practical significance for optimal planning of prophylactic measures during the rehabilitation period.

P1437 (31/91)*Gansburgskiy AN.

The state of the aorta in rabbits after orthostatic stimulation.

Kosmicheskaya Biologiya i Aviaksomicheskaya Meditsina.

24(6): 34-36; 1991.

[17 references; none in English]

Cardiovascular and Respiratory Systems, Aorta, Cytology

Rabbits

Orthostatic Position

Abstract: Experiments were performed on 42 sexually mature chinchilla rabbits (of which 8 were controls). Rabbits were maintained in an orthostatic position using an undescribed method for an unstated period. Animals were studied immediately after this treatment and on days 1, 1.3, 1.8, 2.3, 3, 4, 5, 7, 9, 12, 15, 20, 30, 40, and 50. The aorta was removed and fixed, and film preparation of the endothelium made and stained with iron hematoxylin. Sections 5 mm thick were prepared and stained with hematoxylin and eosin. Morphometric analyses were performed on the film preparation of the endothelium. For every animal, 8,000-10,000 cells were examined for shape, reflecting damage and death of the endotheliocytes (vacuolization of cytoplasm and nuclei, karyopyknosis, karyolysis, and elements without nuclei); parameters of cellular and intracellular regeneration (mitotic activity, number of nucleoli, and nuclei); and also functional state of the endothelium (orientation of nuclei in the cell, number of adjacent? cells, nuclear folds). The stereological field method with an ocular micrometer with 27 equidistant points was used to measure the mean areas of endotheliocytes, and their nuclei and cytoplasm; the ratio between them was computed. Data were processed using the moving average method and tested against the Wilcoxon-Mann-Whitney criteria.

The orthostatic position induced destructive changes in the aorta, which were noted immediately after treatment and continued for 1.5 months. The number of endotheliocytes with vacuolized cytoplasm and nuclei, and with symptoms of karyopyknosis and karyolysis increased significantly. Number of elements without nuclei, an indicator of cell death, increased. The number of monocytes, and lymphocytes in the endothelial layer increased. Starting on day 4, microplatelets were found on the inner surface of the tunica intima. As early as 3 hours after treatment sections of the aorta displayed edema of the subendothelial layer, and in some cases smoothing of the tunica elastica. Over the course of 1-4 days there was crumbling and destruction of elastic and collagen fibers of the tunica media, and starting on day 7 areas of necrosis in this membrane. Starting on day 20, one could observe marked hyperplasia of the tunica intima, and the absence of a tunica media for some distance, leading to deformation of the aortic wall. Starting on day 1 there was a significant increase in the number of endotheliocytes with nuclei oriented perpendicular to the long axis of the vessel.

In addition to destructive changes, activation of compensatory processes could also be observed through increased mitotic activity and intracellular regeneration (as indicated by increases in the size of the nuclei, the number of nucleoli in the nucleoli and nuclei in the endothelium). Through analysis of coefficient of variation, a number of phases were identified in post-orthostatic changes: an early phase of orthostatic response (days 1-2) associated with hemodynamic changes, a phase of adaptation and compensatory shifts (days 3-15), and a phase of remote effects and normalization.

Figure 1: Dynamics of morphometric parameters of the aortal endothelium after orthostatic stimulation

Figure 2: Microplatelets on the inner surface of the tunica intima of the aorta on day 4 after orthostatic stimulation

Figure 3: Necrosis of the wall of the aorta 20 days after orthostatic stimulation

Figure 4: Dynamics of morphometric parameters of the endothelium after orthostatic stimulation

P1440 (31/91)*Varosyan MA, Martirosyan MF, Tatinyan NG, Petrosyan VP.
Some characteristics of the contractile function of a hypertrophic heart during readaptation after adaptation to high altitude hypoxia.
Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.
24(6): 42-45; 1991.
[17 references; 6 in English]

Cardiovascular and Respiratory System, Hypertrophic Heart, Contractility
Rabbits
Adaptation, High Altitude, Hypoxia, Readaptation

Abstract: Experiments were performed on 150 chinchilla rabbits born and raised at 1000 m above sea level. The experimental group was exposed to an altitude of 3250 m above sea level for 30 days. After return to the initial altitude, the dynamics of de-adaptation were studied on days 2, 7, 15, and 30. Methods used included electrocardiography in 12 standard leads and computation of accepted criteria for hypertrophy of the left and right ventricles. Hemodynamic parameters were recorded using radiocardiography with human serum albumin labeled with ^{131}I . The radiocardiogram was read for the following parameters: cardiac output, stroke volume, volume of circulating blood, and coefficient of circulatory efficiency. Myocardial coronary blood flow was computed using the radioisotopes $\text{Na } ^{131}\text{I}$ or ^{133}Xe . Morphological investigations involved visual inspection and separate weighing of each ventricle. A cardiac index was computed as the ratio of heart weight to body weight.

Immediately after descent cardiac output, stroke volume, volume of circulating blood and circulatory efficiency all decreased. From day 15 to 30 of readaptation these parameters returned to normal.

Table 1: Changes in hemodynamic parameters during readaptation of rabbits adapted to high-altitude hypoxia

Table 2: Dynamics of EKG criteria of hypertrophied left and right ventricles during readaptation of rabbits after adaptation to high-altitude hypoxia

Figure 1: Ratio of myocardial and coronary blood flow of the left ventricle and cardiac index in % of control during readaptation

Figure 2: Absolute weight of the right and left ventricles of the heart in % of control values during readaptation

P1441 (31/91)*Aytbayev KA, Madaminov YaK, Meymanaliyev TS, Shleyfer YeA, Kim NM.
The effects of migration to high altitudes on the lipoprotein system.
Kosmicheskaya Biologiya i Aviaksomicheskaya Meditsina.
24(6): 42-45; 1991.
[17 references; 6 in English]

Cardiovascular and Respiratory System, Metabolism, Lipoprotein, Heart Disease, Risk Factors
Humans, Males
Adaptation, High Altitudes, Periodic Short-Term Exposure

Abstract: A random representative sample of men, aged 40-59, living in the regions served by two clinics, were interviewed, underwent a clinical examination, including measurement of blood pressure and an EKG. Blood lipids were also measured. Subjects were divided into two groups. The first group, the migrants, contained individuals born and living at low altitudes but periodically traveling to high (>1600 m) altitudes for no less than 2 weeks at least 3 times a year. The remainder were individuals remaining close to sea level. Subjects were classified with regard to incidence of ischemic heart disease and its risk factors, including occurrence of myocardial infarction, arterial hypertension, obesity, low physical activity and smoking. Blood for lipid count was taken from the ulnar vein after 12 hours of fasting. It was found that migrants had lower levels of total cholesterol and low density lipid, and higher levels of high density lipids. Migrants were less likely to suffer from ischemic heart diseases. However, they were more likely to be hypertensive and did not differ from nonmigrants with respect to other risk factors. The authors conclude that short-term trips to high altitudes may have the effect of decreasing cholesterol-associated predisposition to ischemic heart diseases.

Table 1: Mean values of lipid parameters of blood in men aged 40-59 as a function of migration to mountains

Table 2: Prevalence of ischemic heart disease and associated risk factors among men aged 40-59 as a function of migration to mountains

P1449(31/91)* Artamonova NP, Zakharova TS, Morukov BV, Arzamazov GS, Semenova VYu.
Dynamics of electrocardiographic parameters and blood electrolytes in apparently healthy men exposed to long-term hypokinesia and the use of various prophylactic measures.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 64; 1990.

[13 references; none in English].

Translation of abstract of paper on deposit at the All-Union Institute for Scientific and Technical Information.

Cardiovascular and Respiratory Systems, EKG Parameters, Blood Electrolytes

Humans, Males

Hypokinesia With Head-Down Tilt, Long-Term, Metabolism, Mineral, Correction, Exercise, Drugs

Abstract: Under conditions of long-term hypokinesia, there is some decrease in the bioelectrical activity of the heart, and metabolic changes in the myocardium are possible. There is information about the study of human cardiac activity under conditions of hypokinesia using various types of prophylactic countermeasures, mainly physical exercise. However, there are virtually no data on the response of the heart to hypokinesia under conditions of correction of mineral metabolism and simultaneous monitoring of blood electrolytes. The current work is devoted to study of the dynamics of bioelectric cardiac activity and blood electrolytes in apparently healthy males under conditions of long-term hypokinesia using various prophylactic measures [evidently including exercise and use of a Ca channel blocker].

The bioelectrical activity of the heart and levels of the major blood electrolytes was studied in 21 apparently healthy men, aged 35-40, exposed to a 120-day period of hypokinesia with head-down tilt at an angle of -4.5° .

During long-term 120-day hypokinesia with head-down tilt for both the first and the second groups, the most indicative parameters were changes in the phase of EKG regularization (decrease, flattening, and, less often, deformation of T waves of the bimodal type) and development of relative tachycardia at the end of hypokinesia and especially during the acute period of readaptation.

In the first (control) group (n=9) during the period of hypokinesia there was a correlation between changes in the bioelectrical activity of the heart (primarily, the repolarization phase) and a tendency for levels of total calcium, ionized calcium, magnesium to increase, and a simultaneous decrease in concentration of potassium. The absolute values of the electrolytes did not go beyond the limits of acceptable values. Level of sodium in blood was not significantly altered.

In the second group (n=12), who were given prophylactic treatment, the deviation in electrocardiographic parameters and the levels of blood electrolytes were lower than in the control groups, especially in individuals who were also exercising or were treated with nifedipine (a Ca-channel blocker) or were given both treatments.

P1450(31/91)* Badakva AM, Cherkasov GV.

Oxygen consumption and central hemodynamics in rats exposed to a constant magnetic field.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 64; 1990.

[13 references; none in English].

Translation of abstract of paper on deposit at the All-Union Institute for Scientific and Technical Information.

Cardiovascular and Respiratory System, Central Hemodynamics

Rats, Males

Radiobiology, Constant Magnetic Field

Abstract: The goal of the current work was to study central hemodynamics and the arteriovenous oxygen gradient (AVG) during a 24-hour exposure to the effects of constant magnetic field with magnetic induction of 0.4 T. The study was performed on 83 white outbred male rats, weighing 220-290 g. Experiments were performed using the SO-15A electromagnet. The first experiment determined AVG in rats after 3 and 24 hours of exposure to the field of 0.4 T. It was shown that the AVG gradient increased at the end of the 3 hours exposure up to 114.9% ($p < 0.05$), while after the 24-hour exposure it decreased to 87.2% ($p < 0.05$) of control level. Increase in the AVG is one of the characteristic reactions to development of circulatory hypoxia. It was thus of interest to study central hemodynamics of rats exposed to a constant magnetic field. After the 3-hour exposure, heart rate decreased to 82.9% of control ($p < 0.02$) and after the 24-hour exposure this parameter normalized. After both the 3- and the 24-hour treatments there were increases in stroke volume, to 117.6 and 117.7%, respectively ($p < 0.05$). Cardiac output of experimental animals was unchanged [after 3 hours?], and after 24 hours of exposure to the field increased to 123.2% of control ($p < 0.01$). Thus, changes in heart rate and stroke volume did not lead to decrease in cardiac output. This was due to the fact that after 3 hours of exposure the decrease in heart rate was compensated by an increase in cardiac output [sic.] Increase in stroke volume after 24 hours of exposure to the field led to an increase in cardiac output, since by this time heart rate was unchanged. The results suggest that the increase in AVG cannot be explained by development of circulatory hypoxia during the first few hours of exposure to a constant magnetic field, but is associated with changes in utilization of oxygen by the tissues.

P1453(31/91) Osadchiy LI, Baluyeva TV, Sergeev IV.

Participation of the cardiac, vascular, and coronary components in the development of cardiovascular reactions to a head-down position.

Fiziologicheskii Zhurnal SSSR im I.M. Sechenova

76(2): 219-225.

[18 references; 7 in English]

Cardiovascular and Respiratory Systems, Cardiac Output. Blood Pressure, Coronary Blood Flow
Cats
Head-Down Tilt

Abstract: The goal of this work was to study development of responses of cardiac output, blood pressure, and coronary blood flow on initial exposure to a head-down tilt position. Subjects were anesthetized cats with open chests, artificially respired. Head-down tilt was created using a tilt stand to -15° , -30° , and -45° . Tilt lasted 120 seconds. Cardiac output (systemic fraction) was estimated on the basis of cardiac output of blood flow measured using a vascular sensor for an electromagnetic flowmeter in the ascending aorta distal to the separation of the coronary arteries. Coronary blood flow was estimated from outflow from the coronary sinus, multiplied by 3/2. Mean blood pressure was recorded in the femoral artery using a sensor at the level of the chest cage. Head-down tilt was studied in 10 sessions. In three additional sessions, blood flow was measured in the posterior vena cava using a sensor of an electromagnetic flowmeter. A catheter was introduced into the posterior vena cava through the cusp of the right atrium. Outflowing blood passed through the sensor and returned to the right atrium of the animal through a catheter implanted in the atrium. Results were evaluated using Student's t statistic.

At all tilt angles, the majority of tests revealed decreases in blood pressure (BP) (61, 58 and 70% of the cases for angles 15, 30, and 45°), with increases in 14, 25, and 19% of the cases. Frequency of depressor reactions was not a function of tilt angle, but was associated with initial level of BP. Higher BPs decreased and lower ones increased. Extent to which BP decreased was not a function of tilt angle. Where BP decreased, cardiac output increased by 75, 85, and 71 % at the three angles. Thus, neither occurrence nor magnitude of increase depended on tilt angle. At angles of 15 and 30° , in the group in which BP decreased and output increased, coronary blood flow increased in 50 and 28% of the cases and decreased in 25 and 28%. Tilt of 45° always led to decreased coronary blood flow.

In cases in which BP increased, output and coronary blood flow changed in the same direction. In 80% of the cases these parameters increased and in the rest decreased. Increases in cardiac output were more extreme (by a factor of 2) than increases in BP. This group showed a tendency for coronary blood flow to increase with angle of tilt.

In cases where blood pressure was unaltered, cardiac output always increased, but coronary blood flow changed in either direction.

In the three additional tests with recording of blood flow in the vena cava, there was always an increase in blood flow, which was most extreme at the greatest tilt. Both BP (initially low) and output increased in response to tilt.

Thus, in response to head-down tilt, BP decreased in the majority of cases and output increased regardless of direction of change in BP. Increased output was associated with increased venous return to the heart. As tilt angle increased, the number of instances of decreased coronary blood flow increased (to 100% at an angle of -45°).

CARDIOVASCULAR AND RESPIRATORY SYSTEM

Figure 1: Effect of head-down tilt on blood pressure, coronary blood flow and cardiac output (depressor reaction)

Figure 2: Effect of head-down tilt on blood pressure, coronary blood flow and cardiac output (pressor reaction)

Figure 3: Changes in mean BP, cardiac output and coronary blood flow in head-down tilt as a function of tilt angle

Figure 4: Effect of head-down tilt on blood flow in the posterior vena cava vein, BP, and cardiac output

PAPER:

P1451(31/91)* Vorobyev DV, Larina IM.

Glucocorticoid hormone reception under normal and extreme conditions.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 4-11; 1990.

[92 references; 68 in English]

Endocrinology, Glucocorticoid Hormone Reception

Review Article

Normal and Extreme Conditions

Abstract: This paper reviews results on the interaction of glucocorticoids and their receptors in humans and animals under normal and extreme conditions, as well as certain pathological states. The authors note in conclusion that any study of physiological effects of extreme factors that neglects impairment of receptor binding is not consistent with modern research goals and understanding. Data concerning the phased nature of changes in glucocorticoid receptors in stress and hypokinesia and adverse implications of sharp decreases in receptor binding undoubtedly opens up new potential for understanding changes occurring in the human body under exposure to these factors.

PAPER:

P1406(31/91) Beloozerova IN.

Activity of mitochondrial enzymes of peripheral lymphocytes of monkeys after flight on biosatellite COSMOS-2044.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 287-288.

Enzymology, Mitochondrial Enzymes

Monkeys

Space Flight, COSMOS-2044

Abstract: Activity of succinate dehydrogenase (SDH) and α -glycerophosphate dehydrogenase (α -GPDH) were measured using R.P. Nartsissov's quantitative cytochemical methods (1969) in the peripheral lymphocytes of rhesus macaque monkeys completing a 14-day space flight on COSMOS-2044. Blood for the study was taken on days 60 and 30 preflight (baseline), during the first hours after landing (day 0), and on days 5, 8, and 14 postflight.

SDH activity during the baseline period did not differ from mean values in the control group; immediately postflight there was a tendency for its activity to increase. On day 5, parameters of SDH activity decreased significantly in flight animals compared with baseline values and day 0 and remained at this level through day 8. On day 14 postflight SDH activity had returned to baseline.

Baseline activity of α -GPDH was consistently higher than control in one subject and lower in the other, which may have been due to individual differences and stress caused by the blood sampling procedure. Presumably this accounts for the difference in α -GPDH activity being significant only on day 0, since on the subsequent days α -GPDH activity was not significantly changed.

Since SDH is an important enzyme of the internal membrane of the mitochondrion, participating in the process of oxidative phosphorylation, while α -GPDH plays a significant role in supporting the NAD/NADH system necessary in the process of glycolysis, one might hypothesize that under space flight conditions there may be inhibition of processes of phosphorylation in the respiratory chain (cycle?) and of ATP synthesis, with a relatively stable level of anaerobic oxidation. This is suggested by the results of enzyme activity measurement on days 5-8 postflight, since data obtained on day 0 probably reflects the stress of readaptation to conditions on Earth. The changes noted were transitory in nature and on day 14 postflight had returned to baseline levels.

PAPER:

P1417(31/91) Smirnova AV, Dobrokvashina Yel.

Genetic aspects of space flight safety.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 346-347.

Genetics, Safety

Humans, Cosmonauts, *Drosophila melanogaster*

Space Flight, Long-Term, Radiobiology, Ionizing Radiation, Weightlessness

Abstract: One of the important problems of space biology and medicine is the study of the effects of space flight factors on genetic structure and processes. The timeliness of the problem for the practice of cosmonautics is obvious, when we consider the incremental increase in the duration of space flights. Even now it is very important to evaluate the genetic risk to cosmonauts on long-term flights. In addition, genetic abnormalities in somatic cells, and the mechanisms through which they occur, like those for generative cells, have at least two negative consequences: they increase the frequency of malignant neoplasms and decrease expected longevity. Thus, frequency of genetic changes represent a risk not only to the offspring, but to the participants in space flight, themselves. Potentially the most dangerous space flight factors are weightlessness and ionizing radiation. For space biology, the joint effects of these two factors are of special significance and the nature of their interaction is extremely important.

The accepted method of evaluating genetic risk involves use of data obtained on various biological species from bacteria to mice. *Drosophila* are of particular importance among these species. The overwhelming majority of data used for developing practical recommendations in the area of radiology and radiation genetics were obtained using *Drosophila melanogaster*.

At the present time there is evidence that living systems interact with one of the factors of the environment -- the force of gravity (O.G. Gzenko, G.L. Parfenov, A.V. Smirnova, 1983). In many experiments on COSMOS series biosatellites and in ground simulations using centrifuges and clinostats, in which these factors were combined with irradiation, it was established that there is no direct mutagenic effect of altered gravity and weightlessness (G.P. Parfenov, 1983; Smirnova, A.V., 1985). However, it is not impossible that there is an indirect effect of weightlessness on the genetic apparatus, which will manifest itself in data obtained in the study of mitotic crossing over in *Drosophila*. The disruption of transmission of inherited information has been established for conditions of altered gravity (A.V Smirnova, 1988). Thus, it would seem extremely important to perform genetic population experiments on long-term space flights using multiple generations of *Drosophila* populations in weightlessness.

PAPER:

P1454(31/91) Bodrov VA, Tretyakov NV.

Evaluation of psychological compatibility of flight crews.

Psikhologicheskiy Zhurnal.

11(3): 50-59; 1990.

[24 references; 4 in English]

Group Dynamics, Compatibility, Human Performance, Sociometry

Aviation Medicine, Flight Crews

Personnel Selection, Psychology

Abstract: A total of 135 4-person flight crews were evaluated for observed compatibility and effectiveness and the results were correlated with sociometric evaluations. Each crew consisted of a pilot, co-pilot, navigator, and operator. Of the measures of actual compatibility that were possible, three — observed crew effectiveness inflight, self-rated satisfaction of each crewmember with on-the-job interactions with the other crewmembers, and ratings by crewmembers of the personality traits of the others — were used for further study. A total of 39 crews with high scores on all three dimensions were selected as a high compatibility group, and a total of 37 crews with low ratings on all three as a low compatibility group.

Standard sociometric procedures were shown to successfully predict actual compatibility in 70% of the total 135 crews. Diagnostic error appeared to stem from underestimation of the importance of pilot-navigator compatibility. When sociometric measures were adjusted by weighting crewmembers for importance, in descending order — pilot, navigator, co-pilot, operator — and by assigning weighted importance to pilot and navigator interactions, the diagnostic accuracy of the sociometric results increased to 81% correct prediction. The modified sociometric index of compatibility of actual high compatibility crews was 0.76, and for low ones was -0.27. While it was found that data on agreement on values and interpersonal perceptions provided useful information on compatibility, it is difficult to use such data to optimize crew selection.

Table 1: Evaluation of levels of psychological compatibility of crewmembers

Table 2: Values of the sociometric index of psychological compatibility

Figure: Variants of sociometric selections in flight crews

PAPER:

P1447(31/91)* Ushakov VF, Solomin GI, Savina VP, Pashin SS, Marchenko LV, Gorshunova AI, Shukhno EI, Zinovyev VM, Ostasheva NYe, Demchenko YeA, Lyubarskaya II, Mikos KN, Pepelyayev YuV, Sukhorukov OA, Azarova MV, Nolde TV..

Evaluation of the toxicological risk from local fires in a pressurized environment.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 58-60; 1990.

[10 references; 1 in English].

Habitability and Environment Effects, Toxicological Risk, Neurophysiology

Rats, Mice

Polymers, Combustion, Pressurized Environment

Abstract: Because of potential emission of toxic substances when burned, the threat of local fire in closed environments containing nonmetallic materials is important. This study investigated such fire hazards with polymer materials used in transformers for long-distance communication. The consequences of local fire were modeled for a pressurized environment of 80 m³. The total weight of the polymers in the transformer was 25.15 g, the most common materials were polyamide-6 and type B getinax (paper-based laminate). A special device was built to study the sanitary-chemical and toxicological aspects of the products of thermal destruction of the polymers. The device consisted of a polymer heating and burning chamber, an exposure chamber, and a system of air pipes connecting the two. Samples of polymers were burned at 800°C. Sanitary and chemical analysis required 10 minutes of exposure. Air samples were analyzed with gas chromatography, chemically, and using color indicator tubes. Toxicological studies were performed on male outbred white rats (40) and mice (40). Duration of inhalation by the animals of the products of polymer combustion was 15 minutes. The following parameters of the animals' functional state were evaluated: behavior and general appearance; weight changes; orienting reflex; blood count; activity of serum cholinesterases; detoxification function of the liver.

All these methods were used to measure a number of toxic substances in the combustion products. The amounts measured by the rapid indicator tube method tended to correspond to those measured through the more complex methods, leading to a recommendation that the former be used. The concentrations of most of the substances did not exceed those considered acceptable for closed environments. However, concentration of prussic acid and carbon monoxide exceeded the standards. Although exposure to such levels of the individual substances for short periods would probably be harmless, this might not be the case for combined exposures to a large number of products. Experiments with animals did not reveal outward signs of intoxication. Weight was unaltered. CNS signs were generally normal, as were blood count and activity of serum choline esterases. Liver function was unaffected.

Table: Maximal concentration of products of combustion of polymer materials in a transformer measures by different methods

Figure: Diagram of the experimental device for studying products of combustion of nonmetallic materials

PAPERS:

P1407(31/91) Bluma RK, Kalinya IE, Okun' KV, Ivanovna SM, Sominskiy VN.
Structural/functional properties of erythrocyte membranes of monkeys after space flight and in a synchronous ground condition.
 In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina. Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina. Tezisy Dokladov IX Vsesoyuznoy Konferentsii. [Space Biology and Aerospace Medicine: IXth All-Union Conference]
 Kaluga: 19-21 June 1990.
 Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health
 Page 289-291.

Hematology, Erythrocyte Membrane
 Monkeys
 Space Flight, COSMOS-2044?, 14-day

Abstract: It is well known that heterogeneous space flight factors lead to significant changes in the humoral and receptor components of the sympathetic adrenal systems, and also in the structural/functional organization of erythrocyte membranes. To investigate the development of adaptive reactions in two monkeys (rhesus macaques) after a 14-day space flight and after exposure to synchronous conditions on the ground for the same duration, the authors studied the binding of a DSP-6 probe with the erythrocyte membrane and conducted an antihemolytic test (effect of propranolol on hypotonic hemolysis of erythrocytes). The results on day 30 after space flight, taking account of the error inherent in the method (10.0 and 10.9%, respectively), did not differ from the results obtained in the control group of monkeys and thus were used as the baseline.

Using the antihemolytic tests, the authors measured the following parameters: Hill coefficient (h), coefficient of dissociation (K_d), minimal dose (X_{min}) of propranolol inducing the effect, maximum dose of propranolol (X_{max}). The change in baseline hemolysis and the antihemolytic effects on the mean (2.5×10^{-4} mole) concentrations of propranolol were also computed ($E_{2,5}$).

There was an increase in initial hypotonic hemolysis of erythrocytes on days 0 and 7 postflight and on day 0 after the synchronous condition. This may indicate an increase in erythrocyte membrane brittleness. On day 0 there was an increase in $E_{2,5}$ and X_{max} and a decrease in h and X_{min} ; on day 7 postflight there was also a decrease in K_d , indicating an increase in erythrocyte membrane sensitivity to the β -adrenergic blocker propranolol.

Parameters of the antihemolytic test during the 14-day period after the synchronous control condition changed in different directions in the two subjects, suggesting individual differences in membrane sensitivity and a less pronounced influence of experimental factors on the parameters studied.

Using the DSP-6 probe, the following parameters were measured: 1) quantity of bound probe (R), 2) binding constant (K), and 3) concentration of binding sites (N). On days 3-7 postflight and the analogous days after the synchronous conditions, the values of probe binding parameters were depressed compared with baseline. The most marked changes were in the value of parameter K (70-90%) for day 3 postflight, and N (60-65%) on day 3 after the synchronous control. Changes in parameter R correlated with the dynamics of parameters N . On day 7 postflight there was a tendency for results to normalize. On the same day after the

synchronous experiment, parameters of probe binding were close to baseline in both monkeys (with the exception of K). On day 14 results were at baseline or even somewhat above it.

Changes in parameters of probe binding attest to the fact that postflight and even after exposure to a synchronous condition, there are clear changes in the structure of the erythrocyte membrane — membrane viscosity ? increased, its hydrophobia decreased, and evidently the effective negative charge decreased.

Thus the methods described above used after space flight and a synchronous condition revealed structural and functional changes in the erythrocyte membrane, manifested in an increase in rigidity and brittleness of the membrane and changes in its adrenoreactivity. The changes found are characteristic of adaptive processes in stress, with changes after space flight being more pronounced.

P1411(31/91) Ivanovna SM, Sominskiy VN, Arzamazov GS, Zazerov AYe, Brantova SS, Labetskaya OI, Spitsina NYe, Ushakov AS.

Biochemical description of blood cells of monkeys exposed to space on COSMOS-2044 and in a synchronous condition.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 309-310

Hematology, Blood Cells, Erythrocyte Membrane, Biochemistry, Metabolism, Adaptation, Cellular
Monkeys
Space Flight, COSMOS-2044

Abstract: Blood cells (erythrocytes, lymphocytes) are a convenient model for studying the effects of extreme factors on the mechanisms of cellular adaptation and shift at the membrane level. Studies were performed of the membrane status of erythrocytes in monkeys preflight, immediately postflight (day 0) and on days 8, 14, and 30 postflight, and at the same periods in a synchronous group.

A spectrophotometric method was used to study parameters of energy forming and redox systems in erythrocytes isolated from venous blood and washed twice. To evaluate functional status of the membrane, the following methods were used: acid erythrogram, measurement of the activity of transport ATPase, lipid and phospholipid spectra, parameters of binding of a fluororeceptor probe, and sensitivity of β -adrenoreceptors. A cytohistochemical method was used to study activity of mitochondrial enzymes — succinate dehydrogenases (SDH) and α -glycerophosphate dehydrogenase (α -GPDH).

The results obtained revealed shifts in erythrocyte metabolism on days 0 and 8 postflight, manifest in an increase in ATP, a significant increase in concentrations of lactate and a decrease in the level of glutathione reductions, which are associated with changes at the membrane level and confirmed by data obtained in study of functional state of the cell membrane. Thus, at this time there was a shift of the erythrogram to the left, increase in rate of hemolysis and a change in the time for 100% hemolysis to occur, attesting to decreased resistance of the erythrocyte membrane. A significant decrease in activity of Na^+ and K^+ -ATPase was found, most likely due to disruption of ion homeostasis and leading to some decrease in concentration of intracellular potassium and an increase in the levels of sodium ions. Alteration of ATPase activity may be due to changes in the lipid composition of the erythrocyte membrane, as indicated by shifts in the spectra of total lipids, phospholipids, and parameters of binding of the fluorescent probe with the membrane.

Study of activity of mitochondrial enzymes revealed some activation of SDH on day 0 and significant decreases on days 5 and 8 of the readaptation period. Changes in α -GPDH were not significant. On days 14 and 30 postflight, almost all parameters studied had recovered. Changes in the same direction in erythrocyte metabolism and functional status of the erythrocyte membrane were observed in monkeys of the control group.

Thus, the results obtained revealed changes in cellular homeostasis and the functional state of membranes. Decreased activity of SDH in mitochondrial lymphocytes and significant increase in

concentration of lactate in erythrocytes attest to a decrease in rate of energy metabolism. Considering the presence of a correlative functional unity?? of lymphocytes with cells of a number of organs and tissues, one might speak of decreased processes of energy formation at the organ level.

P1431(31/91)* Ivanovna SM, Brantova SS, Labetskaya GS, Arzamazov GS, Delenyan NV, Turkina TI.

The effect of long-term space flight on erythrocyte metabolism and the functional state of the membrane.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 18-21; 1990.

[21 references; 3 in English]

Hematology, Metabolism, Erythrocyte Metabolism, Erythrocyte Membrane, Enzymology
Humans, Cosmonauts
Space Flight, Mir Long-Term

Abstract: This paper describes the study of erythrocyte metabolism and membrane structure and function in two cosmonauts: cosmonaut 1 completed a 326-day space flight and cosmonaut 2 a 160-day flight. Subjects were studied preflight and on days 1 and 9 postflight. Erythrocytes were isolated from peripheral blood and twice rinsed with a normal saline solution. Metabolic parameters (ATP, 2,3-DPG, glycolysis, lactate dehydrogenase activity) were studied in an erythrocyte suspension containing the erythrocytes and normal saline in a 1:1 ratio, using spectrophotometric methods. The results were computed per 1 g hemoglobin, which was measured using the cyanomethemoglobin method. Activity of superoxide dismutase was measured by an undescribed method. Activity of glutathione peroxidases was determined in a bound glutathione-reductase system using hydrogen peroxide as a substrate. Activity of glutathione was estimated from oxidation of NADH, and activity of catalases using an undescribed method. Activity of transport ATPase (total, Na⁺-, K⁺-, Mg²⁺-, Ca²⁺-dependent) was studied in a hemolysate made from frozen erythrocytes and was evaluated on the basis of level of inorganic phosphorus forming after dephosphorylation of ATP under conditions of hemolysate incubation over a period of 1 hour at 38°C. The method of thin layer chromatography was used to measure lipids in erythrocytes. The amounts of lipid fractions and phospholipids were determined densitometrically. Intracellular levels of Na⁺ and K⁺ were measured using flame photometry and a photometer. Erythrocyte resistance to acid hemolysis was evaluated through kinetic recording of hemolysis by the method of acid erythrograms. Erythrocyte deformability was estimated from the index of filterability of cells through a filter 4 μm in diameter.

Results revealed a significant decrease in rate of glycolysis and some decrease in level of ATP in both subjects on day 1 postflight. On day 9 both these parameters showed a tendency to decrease further in cosmonaut 1 and to normalize in cosmonaut 2. With respect to the redox system there was a significant decrease in level of reduced glutathione in both cosmonauts; in cosmonaut 1 on both days 1 and 9, and in cosmonaut 2 only on day 9 postflight. This may be associated with decreased glutathione synthesis as well as increased oxidized forms due to increased rate of oxidation process in the cell, which might lead to activation of free radical processes and oxidative destruction of the cell. The possibility of intensified oxidation is confirmed in cosmonaut 1 by data obtained in study of activity of enzymes providing protection against oxidation. Decrease in reduced glutathione was accompanied by decreased activity of glutathione peroxidase, catalase, and glutathione reductase. In cosmonaut 2 changes in activity of these enzymes were in different directions. There was some decrease in superoxide dismutase, and increase in activity of glutathione peroxidase and reductase and catalase, which could be considered an adaptive reaction protecting the structural integrity of the cell.

The shifts identified in metabolic status of erythrocytes were accompanied by changes at the membrane level. Changes were found in the lipid composition of the membrane and its phospholipid spectrum, more pronounced on day 9 postflight. There was an increase in free cholesterol and its ether and a decrease in phospholipids. As a consequence, the free cholesterol/phospholipid ratio increased in both cosmonauts on days 1 and 9 postflight. Study of

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the phospholipid spectrum revealed a significant increase over baseline in level of phosphatidyl ethanolamine and an increase in level of lysophosphatidyl dicholine in cosmonaut 1 and in cardiolipin in both subjects. These and other changes shown in the table attest to an increase in the microviscosity of the membrane, which might lead to increased rigidity, decreased cell deformability, and thus changes in the rheological characteristics of blood. Direct study of deformability of erythrocytes revealed a decrease in filtrability index in both subjects, especially cosmonaut 1 (on day 1 - 0.30 and 0.37, compared to a norm of 0.72).

Changes in the functional state of the membrane are also suggested by the increased cell resistance to acid hemolysis found in cosmonaut 1 on both postflight measurement days, as well as change in ATPase activity. The increase in Ca^{2+} and Mg^{2+} -ATPase may be viewed as a compensatory mechanism to eliminate excess Ca^{2+} and leads to increased rigidity of the cell membrane and changes in its form. Shifts in lipid composition of the erythrocyte membrane might also be adaptive in nature, since under extreme conditions increased membrane cholesterol and resulting increasing cell resistance to acid hemolysis may decrease the potential for disrupted permeability. That permeability was not disrupted is indicated by the virtually unchanged levels of K^+ and Na^+ in both cosmonauts postflight.

The authors conclude that the shifts noted in the erythrocyte membrane leading to decreased cell deformability and possible changes in the rheological properties of blood (especially after the longer flight) suggest the need for prophylactic measures stabilizing the cell membrane at certain stages of flight and during the readaptation period.

Table: Lipid and phospholipid composition of erythrocyte membrane

Parameter	Cosmonaut 1			Cosmonaut 2		
	- 1	+ 1	+ 9	- 1	+ 1	+ 9
Lipids, %						
phospholipids (PL)	45.8	40.0	38.6	48.8	39.3	38.0
free cholesterol (FC)	33.6	40.4	52.6	38.0	45.9	56.3
nonesterified fatty acid	2.6	2.0	2.6	1.8	1.6	0.7
triglycerides	0.9	7.0	0.9	--	1.6	--
cholesterol esters	7.0	10.1	5.3	11.3	11.5	4.9
Phospholipid spectrum, %						
lysophosphatidylcholine	1.1	3.4	1.3	1.5	3.0	0.8
sphingomyelin (SPM)	11.6	15.9	22.6	12.3	27.0	20.7
phosphatidyl choline (PTC)	48.6	51.1	47.1	46.2	39.0	46.2
phosphatidylethanolamine (PEA)	27.6	20.7	22.7	24.6	6.0	9.9
cardiolipin	11.1	6.8	6.3	15.4	25.0	22.3
Ratios						
FC/PTC	0.69	0.79	1.12	0.82	1.18	1.22
FC+SPM/PTC+PEA	0.60	0.78	1.08	0.71	1.62	1.37
SPM/PTC	0.20	0.30	0.50	0.26	0.60	0.40
FC/PL	0.73	1.00	1.36	0.78	1.17	1.48

MONOGRAPHS:

M175(31/91) Lomov BF, Ponomarenko VA, Vasilets VM.
 Voprosy Kibernetiki: Imitatsionnoye Modelirovaniye Deyatel'nosti Operator V Aviatsii i Kosmonavtike; Вопросы Кибернетики: Имитационное Моделирование Дейтельности Оператор В Авиации и Космонавтике [*Issues in Cybernetics: Simulation Modeling of Operator Performance in Aviation and Cosmonautics*].
 Moscow: USSR Academy of Sciences, Scientific Council on Cybernetics; 1990.
 [140 pages;]

KEY WORDS: Human Performance, Man-Machine Systems, Mathematical Modeling, Simulation Modeling, Cosmonaut Performance, Pilot Performance

Annotation: This book considers a wide range of issues relating to modeling of complex human-machine systems, the design of experiments in engineering psychology, and the analysis of their results. Materials in the collection are divided into two parts. The first describes the authors' methods and principles of modeling operator performance during control of various flight vehicles. The second discusses engineering psychology experiments in aviation and cosmonautics. This collection is published by the Scientific Council on the Integrated Problem of Cybernetics.

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M176(31/91) Dikaya LG, Zankovskiy AN, Sukhodoyev VV, Maslova YeP.
Metodika Issledovaniya i Diagnostiki Funktsional'nogo Sostoyaniya i Rabotosposobnosti
Chelovka-Operatora v Ekstremal'nykh Usloviyakh
Методика Исследования и Диагностики Функционального Состояния и Работоспособности
Человка-Оператора в экстремальных Условиях
**[Methods for Studying and Diagnosing Functional State and Performance Capacity
of a Human Operator in Extreme Conditions.]**
Moscow: Institute of Psychology, USSR Academy of Sciences; 1989.
[265 pages]

KEY WORDS: Human Performance, Operator Performance, Extreme Conditions, Group Dynamics, Functional State

Annotation: This collection is devoted to the methodological problems of studying and diagnosing functional state and performance capacity of a human operator in extreme conditions. It considers principles for devising diagnostic and experimental methods, and describes the major approaches to evaluation of functional state. It describes new and modified diagnostic procedures and methods, and cites the results of research performed using original methodologies.

D.G. Dikaya. Some methodological and theoretical problems in the comprehensive diagnosis of the performance capacity and functional state of operators (in lieu of an introduction) (6)

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PAPERS:

P1419(31/91)Abakumova IA, Gur'yeva TS, Tresvyatskaya NA, Lebedneva ZN, Dadasheva OAA, Mednikova Yel, Dmitriyeva IA, Naydina VP, Zharkovskaya YeYe.

Study of potential for long-term maintenance of quail on pastelike feed during space flights.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 396-397.

Life Support Systems, CELSS, Nutrition, Pastelike Feed
Quail
Space Flights, Long-Term

Abstract: Long-term space flight and prolonged human stays on planetary stations are only possible if a life support system is developed which is based on a material cycle that includes production of food. One of the possible candidates for production of animal food within bioregenerative life support systems is the Japanese quail. A pastelike feed has been developed to maintain the birds in space that meets physiological needs for nutrients, energy, and water. This work is devoted to study of the potential for using the pastelike food for quails under conditions of long-term flight.

In the experiment with the birds, standard methods were used to assess the biological value of pastelike feed. Factors were the birds' growth dynamics and their productivity, and the birds' acceptance of the feed. At the end of the experiment, the birds were sacrificed, the carcass underwent complete anatomical dissection, and the organs were weighed. Levels of protein, fat, glycogen, and ash content were measured in samples of muscle and liver. In blood serum, fatty acid composition was determined using the Tsvet-110 chromatograph; serum protein and total protein were measured using an IRF-22 refractometer; and blood sugar was measured using an anthrone reagent.

The effects of the pastelike feed on quail growth and development was evaluated. The control group consisted of birds maintained on the standard dry feed. The experiment duration was selected to accord with the requirements of the projected flight program (up to 135 days).

The results showed that until the age of 20 days, the experimental group consumed significantly less feed than the control. The cost of the pastelike feed consumed was initially 25-30% lower than in the control group. At the end of month 1, this parameter was the same as for the control, and when the birds grew older it exceeded that in the control. The weight of the experimental birds was higher at all experimental periods compared with the control, and by day 53 this difference became statistically significant. The consumption of pastelike feed had a positive effect on the birds' weight gain, increasing it by the end of the experiment to 120 g for females and 102 g for males, compared with the control group values of 113 and 88 g, respectively. The duration of feeding with the pastelike feed did not have a significant effect on egg-bearing or the quality of eggs produced. The age at which egg-bearing started and the first fertilized eggs appeared was equivalent for the experimental and control groups, equalling 41-43 days. Between 41 and 90 days the percentage of birds bearing eggs was 70.0 ± 3.2 and $73.0 \pm 2.7\%$ in the experimental and control groups, respectively. The mean weight of the eggs during the egg-bearing period was 8.8 ± 0.05 g and 8.9 ± 0.05 g in these groups.

To investigate the physiological status of the birds, biochemical tests were made on the blood, liver, and muscles. The concentration of total serum protein was no different in experimental and control females, while this parameter was higher in experimental males. Levels of serum albumin did not differ in the experimental and control groups, while study of serum lipids showed that they were higher in females than in males. There was also a tendency for the level of linolenic acid to be depressed in the serum of experimental quails, which evidently is associated with changes in process of assimilation of this acid by the body. Serum sugar was virtually the same in both groups. This rather high level was associated with mobilization of carbohydrate reserves in the body during the oviparous period. The level of glycogen in the liver was higher in the experimental group (by 36% in females and 18% in males) compared with controls. Pathoanatomical dissection of the birds revealed no abnormalities.

Thus, the data obtained support the conclusion that the feed is suitable for feeding the birds under conditions of weightlessness.

P1420(31/91)* Ananikova AA, Nefedova Yel, Livanskaya OG, Gaydadiymov VP.

Use of electrodialysis in a system for correcting the electrolyte composition of culture fluids of microalgae in a biological life support system.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 398-399.

Life Support System, CELSS

Microbiology, Algae, Chlorella

Culture Medium, Electrodialysis, Urine Desalination

Abstract: Recovery of liquid human waste products using microalgae is only possible if sodium chloride has been removed, since algobacterial cenosis used as the photosynthetic component of the biological life support system, cannot utilize this substance. Sodium chloride in urine must be returned to the natural consumer in the system -- humans. The other substances in urine that are not utilized by the microalgae or concomitant bacteria may be eliminated through electrodialysis in a system to correct the electrolyte composition of the culture fluids. With this purpose, culture fluids were desalinated where there was a virtually total absence of biogenic elements in a suspension of algae, enabling the use of the biogenic elements in urine without substantial losses.

Electrodialysis of culture fluids was performed in a multichamber apparatus with electrodes of platinum/titanium and ion exchange membranes MK-40 and MA-40 in a circulation mode. During the process, the performance of the apparatus was studied as a function of current strength through it. The degree of desalination was estimated from changes in electroconductivity of the dialysate containing chlorides and sodium; the amount of osmotically transported water was also measured. The requisite degree of desalination was obtained with mean current strength of 1.95 mA/cm². The yield for the current required to eliminate sodium chloride was 53.7%, the direct expenditure of electricity for desalination was 4.9 W/hr/l. The dialysate had a specific electroconductivity of 3.0-3.3·10⁻⁴ Cm/cm, with 97-98% extraction of sodium chloride, 10% uric nitrate, 83% ammonium nitrate?, 97% phosphorous, 96% sulfur, and 43% organic substances.

To verify the potential for using electrodialysis in a system to correct the electrolyte composition of culture fluids of microalgae, the authors performed a biological experiment with one-celled *Chlorella* algae. The *Chlorella* were cultured under extensive conditions with medium replacement. The source of nitrogen nutrients was the dry residue of lyophilized urine; the deficient biogenic elements were added as a component of the correcting solutions. There were two conditions. In the experimental condition once on day 2 a portion of the culture fluid was desalinated and the dialysate returned to the culture fluid. In the control condition, the culture fluid was not desalinated. The experiment ran for 71 days.

During the experiment the stability of the major characteristics of the electrodialysis process — yield per current, energy expenditure, and also time required to process a portion of culture fluid — were recorded. The method used to correct the electrolyte composition of culture fluids by electrodialysis made it possible to support the level of sodium chloride in it at 1088±245 mg/l, which is within the range supporting optimal growth and development of algae in a continuous culture. In the condition without electrodialysis, concentrations of sodium chloride

in the culture fluid reached 8935 mg/l, which is close to its level in urine. It was established that the use of electrodialysis for correction of the electrolyte composition of a culture fluid did not have a toxic effect on productivity and morphophysiological characteristics of the *Chlorella*.

Thus, the potential for using electrodialysis in a system for correcting the electrolyte composition of the culture fluid of *Chlorella* containing urine, has been established. The use of this technique may prevent loss of biogenic components of urine when it is purified of sodium chloride.

P1421(31/91) Antonyan AA, Geodakyan RO, Sukhova NI Zharkovskaya YeYe.

The perennial tropical plant *Bazella rubra* — a possible component of space greenhouses.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 400-402.

Life Support Systems, CELSS

Botany, *Bazella rubra*, Leafy Vegetable

Space Greenhouses, Nutrition, Nutritional Value

Abstract: An important problem in the creation of space greenhouses for bioregenerative life support systems involves the selection and study of new species of plants suitable for human consumption. The possibility of the use of nontraditional perennial tropical leafy vegetables for these goals has not previously been considered, although data in the literature suggest that many of them are nonfastidious and have a number of advantages, in particular, high yields and efficiency of cultivation.

As a result of preliminary comparative studies, three species of a tropical leafy vegetable, the perennial *Bazella rubra* (vine spinach) from the family Cruciferae, never before studied under closed cultivation conditions, were selected.

One of the major criteria determining the efficacy of one or another species for inclusion in a human bioregenerative life support system involved characteristics of the composition of the biomass. The goal of our research was a comprehensive study of the composition of the biomass of *Bazella* as a potential component of space green houses, under a variety of cultivation conditions.

The study was performed on a number of substrates differing in composition, based on the natural zeolite "Balkanin" with various additives of humic substances. We used "Balkanin+soil," "Balkanin+humus," and "humus+sand." All substrates were matched for levels of mineral nutrients. The plants were cultivated in a hermetically sealed greenhouse at an air temperature of $30 \pm 2^\circ\text{C}$ during the "day," and $21 \pm 1.0^\circ\text{C}$ during the "night." Concentrations of carbohydrates were maintained within an interval of $1.0 \pm 0.1\%$, with oxygen at $20 \pm 2\%$ and intensity of illumination of 50 and 70 W/m^2 PAR. Duration of illumination was 12 hours per day, rate of air flow in the area where the plants were located was 0.5 m/second, and relative humidity was $65 \pm 5\%$.

Judging from the results, the biomass of *Bazella* has normal composition of mineral salts for leafy vegetables. The level of ash in the biomass was $18.8 \pm 0.9\%$ dry weight. There were high levels (mg/g) of potassium (34-47), calcium (9-17), phosphorus (8.3-10.0), sulfur (6-7), magnesium (4.0-5.0), and sodium and iron (2.0-3.0) per unit dry biomass. Study of individual components of the *Bazella* plant (leaves, stems) showed that the levels of potassium and calcium in the stalks were twice as high as in the leaves. No significant differences were found in the other components. This is important, since *Bazella* is a perennial plant with high regenerative capacity. Systematic trimming of the tops of the plant yields a constant harvest of leaves and young shoots. This harvesting technique substantially increases the specific productivity of the plant and its efficiency of use of radiant energy.

Study of the biochemical composition of *Bazella* showed that it was marked by a high level of certain groups of organic substances: protein up to 20%, carbohydrates up to 30%, and lipids between 3-5% of dry biomass. The presence of a large quantity of the physiologically active polyunsaturated fatty acids C18 and C20 among the lipids attests to the high biological value of its lipids. A significant percentage (25% of dry biomass) is comprised of organic acids and other components that were not identified.

Comparison of the biomass composition data of *Bazella* with data obtained earlier on certain traditional leafy green vegetables showed that they were similar. The composition of the substrates and the levels of illumination used did not significantly affect the characteristics of the biomass. There was only a tendency for biogenic elements to decrease in the biomass and a tendency for carbohydrate to increase (from 28 to 38 percent) when illumination was greater. This issue requires further study.

The data obtained suggest that *Bazella* is a promising leafy vegetable to include in space greenhouses.

P1424(31/91) Gur'yeva TS, Popov VV, Pepelyayev YuV, Romanenko LA, Nol'de TV, Miroshicheva AF.

Study of the atmosphere when Japanese quails are maintained in a pressurized environment.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 430-431.

Atmosphere, Closed Environment, Pollution

Quails

Life Support Systems, CELSS

Abstract: Investigation of the potential use of animals in biological life support systems for spacecraft requires solution of the problem of maintaining them in a closed environment. Japanese quail were selected as objects of study. To perform an experiment on board, it is important first to study the atmosphere formed by the birds.

The current experiment used a device for maintaining six quail as a part of the "Inkubator-2" unit. The experiment was performed in a 1.3 m³ pressurized space. Parameters studied included gas exchange in the quails, the major principles underlying formation of the living environment, and the gaseous contaminants emitted by the birds.

It was established that for every 100 g of living body mass, the birds on average emitted 4.1 l/day of carbon dioxide and utilized 5.3 l/day oxygen. The respiratory quotient was 0.77 ± 0.03 . Multiple experiments in the pressurized chamber revealed the major principles (patterns) underlying formation of the bird's living environment, particularly the dynamics of trace element accumulation. Analysis of trace contaminants using a colorimetric method revealed the presence in the atmosphere formed by the quail of more than 20 components, 14 of which were identified: carbon monoxide, aldehydes, hydrocarbons C 1-7, ethanol, acetones, and butanol. The total concentration of contaminants reached 1.0-1.3 mg/m³/day. Since trace contaminants can have a harmful effect, an air-purifying filter made of activated charcoal, Petryanov fabric and "Bion" fabric, was added. The ventilation block was designed for cleaning the interior of the animal maintenance chamber and the air passing through it.

Analysis of volatile atmospheric components showed that concentrations of hydrocarbons in the atmosphere decreased by 80%, acetaldehydes by 90%, ethanol by 59%, acetic acid by 12%, total of unidentified substances decreased by 89% and of organics by 36%. Alcohols (ethanol, butanol, propanol) and aromatic hydrocarbons (benzol, toluene, and xylene) were completely absent. Concentrations of trace contaminants of the atmosphere formed by the quail in a pressurized environment did not exceed the maximum acceptable level for humans.

Thus, the apparatus developed makes it possible to maintain birds for long periods in a closed environments, with an acceptable level of gas emission in the atmosphere of the pressurized chamber.

P1425(31/91) Zakharov SB.

Water supply of soil-replacing substrates for future spacecraft greenhouses (ground studies).

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 437-439.

Soil Replacing Substrates, Water Supply
Botany, Plants
Life Support Systems, Space Greenhouses

Abstract: Introduction: Water supply to plants depends not only on the qualities of substrate water, but on its energy status. Ranges of water mobility and its accessibility for the plants are determined by the magnitude of forces retaining and moving water within the substrate. The sum of these ranges is called the main hydrophysical curve, which describes water pressure in the substrate as a function of its level.

Objective and goals: The authors evaluated the availability of water in soil-replacement media Gravilen and Gravilen-3S (based on artificial fibers with addition of organic mineral components) during ground tests of these substrates, with a view toward their subsequent use in space greenhouses. The goals of these investigations included: evaluation of the energy status of the water in the substrates (major hydrophysical curve); identification of the ranges of water as a function of their mobility and accessibility to the plants; and derivation of general recommendations for developing a water-air regime favorable to these plants using these substrates. The investigations were conducted in ground-based mock-ups of space greenhouses.

Methodology: Levels of water were measured using a thermostat-weight method. Evaluation of energy state of the water in the substrates used a special method (with a capillarimeter). This method is based on the principle of moisture transfer of the water from the substrate through a fine porous membrane into a chamber with free water at a set negative pressure and establishment of equality of water pressure in the substrate and in the free water chamber at the moment moisture transfer ceases. Similar instruments and methods are described in the specialized literature.

Results: The authors derived the major hydrophysical curves for the substrates studied. Their analysis showed very high values of capillary moisture capacity: 1000-1100% for Gravilen-3S, 550-560% for Gravilen. However, despite changes in total water concentration of almost a factor of 2, the nature of changes in its mobility for the substrates studied was the same. The range of very easily moved water predominated, followed by a sharp transformation of the water into a state not accessible to the plants. For the Gravilen-3S substrate, when pressure changed from 0 to -3 kPa, the level of water decreased from 1100 to 220%, after which its mobility sharply decreased. For Gravilen there was somewhat greater water retaining capacity, but when pressure decreased from 0 to -7 kPa, water concentration also changed a great deal, from 560 to 20-25%, after which there was a sharp decrease in capacity of water to move through it. The remaining water did not move in the substrates even at pressures up to -70 kPa.

An approximate computation of the amount of air in the Gravilen-3S substrate showed that in the humidity range for plant cultivation (60-70% of full capillary moisture capacity), the amount of air was 52-45[sic.]% with total porosity (sponginess?) of 94%.

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Conclusions: The amounts of water, 200-220% for Gravilen-3S and 20-25% for Gravilen, corresponding to the boundary of sharp decrease in the ability of water to move through it, may be taken as the lower critical boundaries of substrate moisture level. The substrates studied provided mobile and easily accessible water in a very large range: for Gravilen-3S it was approximately 80% of total water level, for Gravilen from 90 to 95%. Satisfactory water-air conditions for the growth of plants in these substrates may be created in a moisture range of 60-70-% of total moisture capacity and with some deviation in moisture level in the ranges of smaller values, if the water is evenly distributed throughout the substrates.

P1426(31/91) Lebedeva TYe, Nazarov NM, Yakimova IV, Sinyak YuYe.

Potential use of immobilized cells or enzymes for final purification of water and air in a pressurized environment.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 452-453.

Life Support Systems, Pressurized Environment
Water and Air Purification
Immobilized Cells, Enzymes

Abstract: Long-term inhabitation of a pressurized environment requires the constant functioning of a water supply system based on regeneration of water from moisture-containing human wastes. The physical-chemical systems for regenerating water that exist today generally do an efficient job of purifying moisture-containing wastes of a whole series of chemical compounds. However, a group of highly volatile compounds remain in the regenerated water, which virtually cannot be removed using the technology employed. Similar difficulties occur with the air purification system.

These limits on the capacities of the sorption method make it necessary to seek other ways to solve this problem. It would seem appropriate to consider the possible use of new biotechnological methods for these goals. These methods are based on selective, and at the same time adapted, functioning of enzyme systems of microorganisms to assimilate organic components of the environment at very small concentrations. When they are carried or included in the make-up of a carrier, bacterial cells, enzymes, or polyenzyme complexes may be used as an autonomous component for final cleaning of water and air in a pressurized environment. Inclusion of this component in existing regenerative systems significantly improves the quality of the water and air. The water and air produced in this way meet the requirements of biological completeness, since these properties form as a result of the activities of living things, as occurs in natural biocenoses.

Biocatalytic technology for final cleaning of water and air based on immobilized cells, enzymes, or polyenzyme complexes may be used successfully in biological life support systems.

Results of experimental studies have shown that regenerated water contaminated with urea is difficult to purify using methods of physical chemistry. Use of immobilized urease combined with the methods of physical chemistry make it possible to completely remove the urea from the water. The possibility of obtaining ecologically pure water and air is especially important in connection with the future increase in the duration of flights, including flights to Mars.

P1427(31/91) Levinskikh MA, Meleshko GI.

Experimental study of the ecological niches of algae serving as components of the photoautotrophic link of a man-rated bioregenerative life support system.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 454-455.

Life Support System, CELSS

Microbiology, Algae, *Chlorella*, *Chlamydomonas*, *Closteriopsis*, *Spirulina*, *Euglena*

Ecological Niches

Abstract: One of the ways to optimize the autotrophic component of a bioregenerative life support system, based on algal photosynthesis is to increase the variety of species, expanding the functions of the component and balancing its linkages in the system. Formation of a multispecies algocenosis with certain properties and control of its culture are possible only after comprehensive analysis of individual ecological niches of individual components.

A comparative analysis was conducted of the ecological niches of five forms of algae — *Chlorella*, *Chlamydomonas*, *Closteriopsis*, *Spirulina*, and *Euglena* — differing in taxonomic position, morphological, biochemical and physiological/ecological characteristics. This analysis was based on modern ideas of the niche as a set of resources used by the organisms, including the factors influencing this process. All these parameters may be represented as axes of a multidimensional space. The major environmental factors that can be used to distinguish among the ecological niches for algae in the algocenosis are the composition and pH of the nutritive solution (chemical aspect), illumination intensity, temperature, concentrations of CO₂ and O₂ (physical aspect) and interspecies interactions (biological aspect).

One of the major issues of mineral nutrition is the relationship of the organism to the nitrogen source. All the forms of algae selected, except *Euglena*, may use both oxidized and reduced sources of nitrogen. *Euglena* uses only ammonium nitrate. *Closteriopsis* prefers uric nitrate. The forms of algae studied can grow within a rather wide range of pH. The optimal value of pH for growth is the same for *Chlorella*, *Chlamydomonas* and *Closteriopsis* and ranges from 6.0-8.0. The range is 4.0-6.0 for *Euglena* and 8.0-10.0 for *Spirulina*.

The effects of illumination on growth and photosynthesis of dense monocultures of algae were measured under conditions of light intensities varying from 19 to 280 W/m² PAR. The algae can be divided into two groups on the basis of position of ecological niches with regard to the coordinates of this resource (light): 1) light saturation of a dense suspension occurs at illumination intensity above 200 W/m² PAR (*Chlorella*, *Chlamydomonas*, *Closteriopsis*); 2) light saturation occurs at 100-180 W/m² (*Spirulina*, *Euglena*). The rate of photosynthesis of the algae as a function of CO₂ concentration in the gas mixture was studied in the interval between 0.2 and 5%. The saturating concentration of CO₂ for *Chlorella*, *Chlamydomonas*, and *Closteriopsis* is 3-3.5%; for *Euglena* it is 2.3% and for *Spirulina* it is 1.5% in the presence of bicarbonates as the source of inorganic carbon.

Comparison of the ecological niches of the algae with respect to temperature gradient showed that *Euglena* is a mesophil and requires a temperature of 28°C for development, while the other species of algae have maximal productivity with respect to development and cell division at 35-

39°C. The rate of photosynthesis of *Chlorella*, *Chlamidomonas*, and *Euglena* are a direct function of concentration of O₂ in the atmosphere in the range of 5 to 50%. *Closteriopsis* is tolerant of increased concentrations of O₂ in the atmosphere in a range from 20 to 50%. The rate of photosynthesis in *Spirulina* decreases at O₂ levels above 15 and below 12%.

All the species of algae studied (with the exception of *Euglena*) have a weak algostatic effect (tend to keep down populations of other algae?) and may be cultured together in a single medium. *Euglena* has a strong algostatic effect, which to a significant extent compensates for the narrowness of its ecological niche with regard to the gradient of physical and chemical conditions of the environment and increases its competitiveness in the community. Comparison of the niches showed that *Chlorella*'s niche occupies the broadest area in ecological space.

Based on study of three aspects of ecological niches the algae can be divided into three groups: those with similar ecological niches, those with partially overlapping, and those with different niches. The third group would not be suitable for joint cultivation (*Euglena* and *Spirulina*). For the two other groups of algae the authors have experimentally developed a rationale for various combinations of species, conditions of cultivation and means of regulating the number of species in a polyculture.

P1428(31/91) Meleshko GI, Anton'yan AA, Sychev VN, Solontsova IP (USSR), Shetlik I, Doukha Y. (Czechoslovakia)

The effect of space flight factors on the pigment system of one-celled algae.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 462-463.

Life Support Systems, CELSS, Photosynthesis, Pigmentation
Botany, Microbiology, Algae, *Chlorella*
Space Flight, Salyut, Mir, COSMOS-1887, -2044, Adaptation

Abstract: The functioning of the photosynthesis system is closely associated with the structure and function of chloroplasts, especially their pigments. Because photoautotrophic organisms (higher plants and one-celled algae) are critical to the development of closed ecological life support systems, this characteristic of plants must be studied in weightlessness.

The pigment system of *Chlorella vulgaris* line LARG-1 was studied under space flight conditions on various spacecraft (space stations Salyut and Mir, and biosatellites COSMOS-1887 and -2044). Two series of experiments were performed with heterotrophic nutrition (4 experiments, 9-18 days long) in the IFS-2 device without illumination, and with autotrophic nutrition in the Akvarium device (3 experiments, 7-13 days long), where the algae, grown in light in a community with fish and concomitant microflora, provided regeneration of the atmosphere.

In weightlessness, the rate of *Chlorella* growth corresponded to that in the control conditions. There were no changes in the major population characteristics of algae as compared to the results of control experiments and multiyear experiments on *Chlorella* in laboratory conditions. All this attested to maintenance of normal interrelationships among the individuals in the population, as well as among the various species of organisms in the community and also in the "organism-environment" system.

In all flight cultures, regardless of type of nutrition and design of the experiments, there were significant decreases in levels of pigments in the cells. In the four flight experiments with heterotrophic nutrition, the algae's pigment levels averaged $0.84 \pm 0.14\%$ dry weight, with coefficient of variation of 17%; in the ground control conditions, pigment levels averaged 1.47 ± 0.24 with coefficient of variation 16%. Thus, the level of pigments in flight was only 57.1% that of the ground control. In flight experiments in the Akvarium device, the total level of pigments in *Chlorella* cells was in good agreement from experiment to experiment (2.02 - 2.06% in dry weight), was not a function of experiment duration, and amounted to 54 to 63% of control. These fluctuations were due to changes in the level of pigments in the ground control conditions (3.4 - 3.7% in dry weight).

Decrease in total pigments was attributable to chlorophyll "a" and "b" in approximately equal amounts, since the ratio between them was unchanged and equalled 4.1 and 4.2 for the experimental and control conditions, respectively. The sum of carotenoids in cells of the flight cultures equalled on the average approximately 66% of control and was attributable to each one of the component pigments (carotene, lutein, violaxanthin) in approximately equal amounts. The same effect was found in an experiment using higher plants (A.I. Merkis, et al.).

Thus, decrease in the total pigments in the flight conditions compared to the controls was attributable to all components of this total in approximately equal measures, so that the structure of the pigment system of the cell was not disrupted, while the total quantity of pigment decreased. In subsequent laboratory cultivation of algae grown in space, the levels of pigments in cells were found to recover in less than a day. All this attests to the fact that the changes noted in the total concentration of pigments in cells of algae exposed to space flight do not go beyond physiological adaptation of cells, and are reversible in the same generation of individuals. There is only one major issue — determination of which space flight factor the pigment system of cells is adapting to.

PAPERS:

P1401(31/91) Morukov BV, Orlov OI, Arzamazov GS, Rustam'yan LA.
Mineral metabolism in humans undergoing a 370-day period of hypokinesia with head-down tilt.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 136-138.

Metabolism, Mineral, Musculoskeletal System

Humans, Males

Hypokinesia With Head-Down Tilt, 370-Day, Prophylactic Countermeasures, Physical Exercise, Drugs

Abstract: Introduction. Decreased gravitational loading in weightlessness and hypokinesia lead to dominance of catabolic processes in tissues of the musculoskeletal system, which, in particular, manifests itself in development of negative mineral balance. Losses of calcium, phosphorus, magnesium, and potassium, increasing with duration of exposure to these conditions, increase the risk of diseases associated with disruption of mineral metabolism.

Methodology. Nine apparently healthy males were studied. Subjects spent 370 days in strict bedrest in a head-down tilt position (-5°). Subjects in group A utilized a set of prophylactic countermeasures, including physical exercise and pharmacological correction of metabolism, throughout the treatment period. Group B subjects were deprived of these measures for the first 120 days of treatment and then began to exercise. Studies of mineral balance were performed for 20 days during the baseline period and for 360 days of bedrest.

Results. Exposure to a 370-day period of hypokinesia with head-down tilt led to development of negative calcium balance. Up to 120 days, losses of calcium were homogeneous within each group, but were twice as great in group B, amounting to 658.9 ± 53.0 mmoles. At this time, blood calcium increased in both groups, however in group B concentrations of the ionized fraction of this element increased by 0.16 mmole/l more than in group A ($p < 0.05$). Use of physical exercise by group B after day 120 did not significantly effect calcium metabolism. The difference between groups continued to increase and by the end of the experiment, calcium loss in group B reached 1807.2 ± 124.0 mmole. Use of specific drugs for correcting calcium metabolism and bone tissue status, combined with exercise significantly decreased the magnitude of negative calcium balance during the bedrest period. Unlike subjects in group B, those in group A did not demonstrate reliable increases in level of total calcium or ionized calcium in blood; calcium loss was 866.0 ± 214.4 mmole in group A.

Potassium balance was negative in group A for the first half of the bedrest period, despite use of prophylactic measures. These subjects displayed a reliable decrease in concentration of this element in blood on day 50. Increased intake of potassium, combined with physical exercise, stabilized this balance, then led to a partial recovery of the potassium deficit in group A. Changes in potassium balance in group B were more homogeneous than in group A. Development of negative balance during the first 120 days of hypokinesia as well as subsequent stabilization after introduction of exercise were more rapid than in group A. The dynamics of negative phosphorus and magnesium balance were a function of motor activity during bedrest. On the whole there were no significant intergroup differences in levels of these minerals in blood. It

should be noted that throughout the first 4 months, excretion of these mineral substances was just as great in group A as in group B. This may be explained by inadequate effectiveness of exercise in group A, or by characteristics of the course of adaptation to bedrest, during which the body inevitably rids itself of some quantity of "unnecessary" mineral substances. The second half of the bedrest period, especially in group B, was marked by stabilization of balance of minerals contained in muscle tissue, attesting to the favorable effects of physical exercise during this period.

Conclusions. Prevention of negative mineral balance in tissues of the musculoskeletal system is possible if a drug having a specific effect on mineral metabolism is combined with exercise providing loading and rational use of dietary supplements containing calcium, potassium, and magnesium.

P1402(31/91) Mosyakina LI.

Transport forms of blood lipids under conditions of long-term hypokinesia with head-down tilt.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 138-139.

Metabolism, Blood Lipids

Humans, Males

Hypokinesia With Head-Down Tilt, 370-Day, Prophylactic Countermeasures, Exercise, Drugs

Abstract: It has been established that long-term restriction of motor activity induces significant changes in lipid metabolism, expressed in increases of classes such as cholesterol and triglycerides in blood. The ratios between lipoprotein fractions, which are the transport forms of lipid fractions, is of particular interest, since they are the most important indicators of the atherogenicity of the given factor.

The fractional composition of lipoproteins was studied in the blood of nine healthy men, exposed to a 370-day period of hypokinesia with head-down tilt. Subjects were divided into two groups. In group A (N=4) a set of prophylactic countermeasures was used during the entire bedrest period, including physical exercise and pharmacological correction of metabolism. Group B (N=5) did not begin to use the set of prophylactic countermeasures until day 120 of treatment. Blood levels of very low density lipoproteins (VLDL), low density lipoproteins (LDL), and high density lipoproteins (HDL) were measured using electrophoresis on an modified Vladipor acetate cellulose membrane.

The data obtained show that on day 50 of bedrest the concentration of the main transport form of triglycerides -- VLDL increased significantly in both groups (by more than a factor of two $p < 0.01$). Levels of HDL and LDL were virtually unchanged; on day 110 there was also a high level of VLDL, especially in group B. On day 179 of treatment, there was a slight increase over baseline of VLDL in group B, but this parameter was lower than during the preceding period. Behavior of LDL and HDL was rather stable. The relatively favorable status of the lipoprotein spectrum in blood serum during this period was most likely due to the use of the set of prophylactic countermeasures in both groups. The most extreme changes in these parameters were recorded on day 200 of bedrest, especially in subjects of group B. Levels of VLDL reliably exceeded accepted physiological norms ($p < 0.001$).

To correct the lipid spectrum of blood serum, between days 200 and 230 of hypokinesia, subjects of both groups used the "Essentiale"* complex. On day 230 of bedrest, there was a significant decrease in VLDL in groups A and B; HDL and LDL were at baseline levels. However on day 290 of hypokinesia, there was another significant increase in VLDL, leading to prescription of another course of "Essentiale," at a higher dose. The period after this

* Essentiale; a drug containing all the essential phospholipids diglyceride esters of phosphatidylcholine (literally, choline phosphoric acid) and unsaturated fatty acid (linolic, and linoleic) (70%) and pyridoxine (B₆), cyanobalomin (B₁₂), nicotinamide, and pantothenic acid. Used for liver disorders. Manufactured abroad (Italy?).

preparation was taken (day 350) was marked by normalization of serum lipoprotein fractions in both groups. Ratios among VLDL, LDL, and HDL, in percentages, corresponded to baseline.

Thus, the results cited demonstrate that it is possible to successfully correct lipid metabolism during long-term hypokinesia with head-down tilt.

P1434(31/91)* Ryzhkova VYe, Mikos KN, Savina VP.

The effect of long-term hypokinesia with head-down tilt on the composition of volatile metabolites in exhaled air in humans.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 27-29; 1990.

[14 references; none in English]

Metabolism, Metabolites, Exhaled Air

Humans, Males

Hypokinesia With Head-Down Tilt, Prophylactic Countermeasures, Exercise, Drugs

Abstract: Subjects in this experiment were 10 apparently healthy male volunteers aged 27 to 42. Subjects underwent a 370-day period of strict bedrest with a head-down tilt of -5° . The subjects were divided into two groups. Group A performed a series of physical exercises and received drugs throughout the experiment. Group B received no prophylactic countermeasures for the first 120 days of bedrest, after which subjects were treated with experimental methods of exercise and new drugs for maintaining functioning of the cardiovascular and musculoskeletal systems. Parameters of gaseous products of metabolism were studied in exhaled air as a method of investigating metabolic status. Exhaled air was sampled once every 10-14 days until day 200 of the experiment and subsequently every 30 days. Air samples were collected in flexible teflon[®] containers holding approximately 5 liters 1 hour after breakfast. Samples of exhaled air were analyzed in the laboratory using a chromatograph equipped with a flame ionization detector. Separation of the microcontaminants into components occurred in a stream of gas-helium carrier in a column 1.35 meters in height filled with the sorbent "Prapak Q" at a temperature of 150° C. Quantitative analysis of the substances separated in the column was based on the magnitude of a signal from the flame-ionization detector. The substance released from the column was identified through indirect calibration of the column with reference substances. The volume of the sample input into the gas chromatographic column for analysis was 1 ml.

Figures 1 and 2 depict the patterns of change in levels of the following chemical microcontaminants in air exhaled by the subjects: methane, ethane and ethylene (together), acetaldehyde, acetone, methanol, and isopropanol and pentane (total). Onset of hypokinesia led to increased levels of volatile metabolites in exhaled air, which was most notable during the first 30 days of the experiment. As duration of the experiment increased to 120 days, certain metabolites increased further, but not as rapidly as during the initial period of the experiment. From days 1 to 120, concentration of the metabolites increased to the following extent compared with baseline: ammonia by 26%, ethane and ethylene (total) by 508%, methanol by 17%, ethanol by 7.7%, acetaldehyde by 97%, acetone by 132.7%, and isopropanol and pentane by 94.3%. Between days 1 and 120, during which only group A received prophylactic countermeasures, emission of metabolites was lower in group B. Between days 120 and 240 the following metabolites increased in exhaled air: ethane and ethylene, acetone, ethanol, and isopropanol with pentane. Despite the fact that group B began using prophylactic measures starting on day 120, between days 120 and 240, level of metabolites exhaled by this group was lower than for group A for methane, ethane and ethylene, methanol, acetaldehyde and isopropanol and pentane. During the final 120 days of treatment, concentrations of some metabolites — methanol, isopropanol with pentane, and acetaldehyde — decreased significantly. Other metabolites continued to increase: ethane and ethylene in group B and acetone in group A. Increase in ethane and ethylene was very marked in group B and exceeded that in group A by 40%. The authors conclude that study of volatile metabolites in exhaled air may be useful for assessing changes in metabolic processes during hypokinesia.

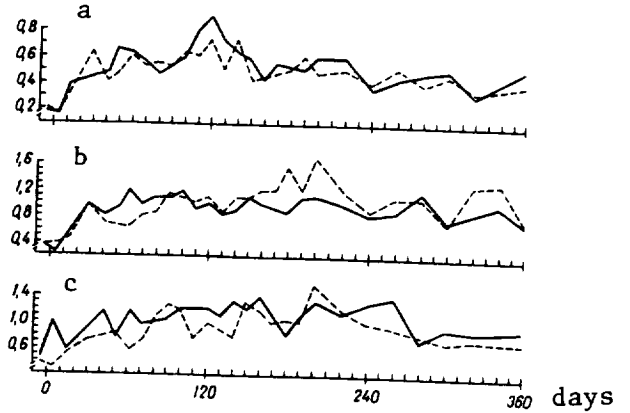
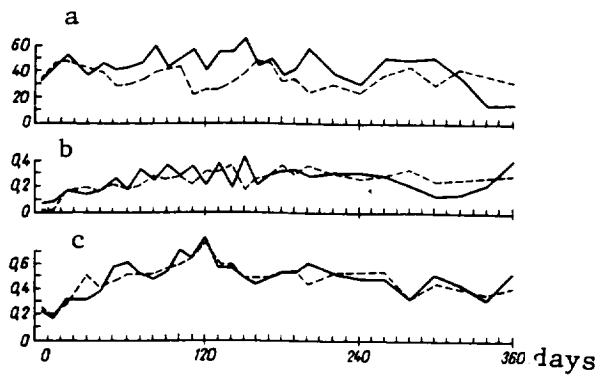


Figure 1: Dynamics of levels (in mg/m³) of methane (a), ethane and ethylene (b) and acetaldehyde (c) in exhaled air

Figure 2: Dynamics of levels (in mg/m³) of methanol (a), acetone (b), isopropanol and pentane (C) in exhaled air. Solid line - group A; dotted line group B

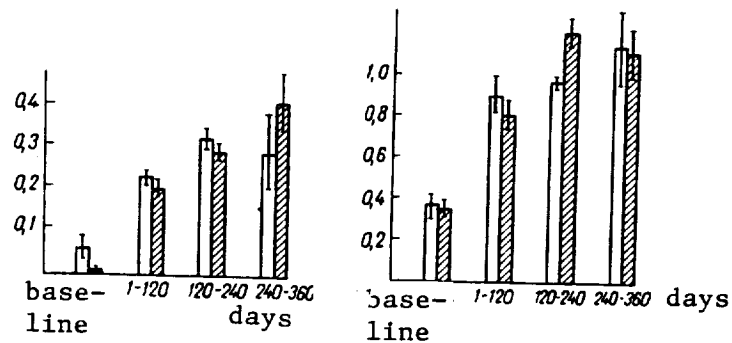


Figure 3: Mean levels (in mg/m³) of ethane and ethylene in exhaled air during different periods in the experiment

Figure 4: Means levels of acetone (in mg/m³) in exhaled air during different period of the experiment White bars - group A, hatched bars - group B.

P1438(31/91)* Gritsuk AI, Glotov NA, Danilova IG, Segal NK.

Energy metabolism in the kidneys after exposure to hypokinesia varying in duration.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 37-39; 1990.

[18 references; 6 in English]

Metabolism, Energy Metabolism, Kidneys

Rats, Males

Hypokinesia, Short-Term, Long-Term

Abstract: Experiments were performed on 120 white outbred male rats maintained in immobilization cages. Control animals were maintained in standard cages. Control and experimental animals were fed a normal vivarium diet. The animals were decapitated after 3, 10, 30, 70, or 140 days of treatment. A homogenate was prepared from the cortical layer of the kidney. Tissue respiration and oxidative phosphorylation of the kidneys were studied on a polarograph using a Clark electrode. Each duration of hypokinesia had its own control group, but these were subsequently combined into two groups — one for hypokinesia up to 30 days, and the other for the 70- and 140-day treatments. Rate of respiration was measured in endogenous substrates (homogenate of kidney tissue with no additives?), and also with addition of 2 mM succinate, 2 mM α -ketoglutarate, 2 mM pyruvate, a mixture of glutamate and malate (1mM each), in the presence of an inhibitor of the first segment of the respiratory chain (2 mM sodium amytal) and an inhibitor of succinate dehydrogenase (2 mM sodium malonate), and also with introduction of an uncoupler of oxidative phosphorylation (25 μ M dinitrophenol). Potassium salts of the metabolites were used. Rate of respiration was expressed in nanoatoms of oxygen per 1 minute per 1 mg protein of tissue studied. In addition, the stimulating effects of the additives were computed by dividing respiration rate in their presence by rate when only endogenous substrates were present.

Results showed that hypokinesia had a significant effect on oxidative metabolism in kidney tissue. After 3 days, when stress effects are most pronounced, there was a significant decrease in rate of respiration on the endogenous substrate. Amytal added to the substrates depressed respiration in the control group by a third, while after 3 days of hypokinesia amytal resistant respiration increased. The inhibiting effects of sodium malonate increased after 3 days of hypokinesia. During this same time period stimulating effects of α -ketoglutarate and succinate increased as well. These results suggest a decreased role of fatty acids in tissue respiration. A 10-day period of hypokinesia was associated with increase in the respiratory activity of the homogenate. The rate of endogenous respiration in the presence of inhibitors also increased. There was a proportional increase in the rate of oxidation of pyridine- and flavoprotein-dependent substrates. The rate of respiration after introduction of α -ketoglutarate, pyruvate, glutamate+malate, and succinate increased, while the ratios reflecting their stimulating effects remained stable, suggesting activation of Krebs cycle dehydrogenases. The authors attribute the effects after 10 days of treatment mainly to uncoupling of oxidative phosphorylation and decreased efficiency of energy formation (as indicated by decreased stimulating effect of dinitrophenol). After 30, 70, and 140 days of hypokinesia, respiratory activity decreased, as indicated by decreased rate of respiration on endogenous substrates. However the ratio of pyridine- and flavoprotein-dependent substrates of kidney tissue did not differ from the control. Decrease in the stimulating effect of dinitrophenol suggested uncoupling of oxidative phosphorylation.

The uncoupling of oxidative phosphorylation after all durations of hypokinesia studied leads not only to decreased efficiency of energy formation and associated changes in the energy-dependent functions of the renal cortex, but also to inefficient use of the endogenous substrate leading to exhaustion of the substrate reserves in the tissue and decrease in its respiratory activity. The

METABOLISM

authors conclude that there is every reason to believe that the disruption of energy metabolism in the kidneys in hypokinesia may lead to kidney dysfunction.

Table 1: Effect of long-term hypokinesia on parameters of tissue respiration in homogenate of rat kidney tissue (n= 8-47)

Hypokinesia duration	Respiration rate, nanoatoms O ₂ /mg protein/minute				
	Endogenous	+α-ketoglutarate	+pyruvate	+glutamate.+malate	+succinate
Control	19.80	33.94	20.63	27.69	60.07
3	16.54**	36.30	20.17	24.21	65.52
10	25.73**	44.99**	26.00**	34.04**	78.73**
30	17.33**	40.24	14.84**	19.40**	47.82**
Control	21.42	35.64	20.41	29.84	68.25
70	15.77**	42.31	14.40**	20.94**	77.61
140	17.22**	41.67	19.53	23.59	60.97

(continued)

Hypokinesia duration	α-ketoglutarate	Stimulating effect of:		Inhibiting effect of:	
		succinate	dinitrophenol	amylal resist.	malonate resist.
Control	1.66	3.66	1.19	0.68	0.69
3	2.04**	4.98**	1.18	0.83**	0.57**
10	1.79	3.54	1.07**	0.72	0.70
30	2.08**	4.33**	1.10**	0.66	0.67
Control	1.83	3.67	1.20	0.67	0.70
70	2.45**	7.54**	0.93**	0.65	0.72
140	2.46**	4.83**	0.97**	0.73	0.70

Notes: Stimulating effect is ratio of respiration rate in presence of additive to respiration rate when only endogenous substrates are present.

Inhibiting effect of dinitrophenol is ratio of respiration rate in presence of dinitrophenol to respiration rate in presence of α-ketoglutarate; amylal resistance is ratio of respiration rate in presence of amylate to that when only endogenous substrates are present; malonate resistance is ratio of respiration rate in presence of malonate to rate in presence of amylate.

** differences from control significant at p<0.01-0.05

MONOGRAPH:

M173(31/91) Tigranyan RA.

Gormonal'no-Metabolicheskiy Status Organisma Pri Ekstremal'nykh Vozdeystviyakh Гормонально-Метаболический Статус Организма При Экстремальных Воздействиях [*Hormonal-Metabolic Status of the Body Under Exposure to Extreme Effects*].

Moscow: Nauka; 1990.

[288 pages; 38 tables; 19 graphics; 651 references; ca. 350 in English]

KEY WORDS: Metabolism, Mineral, Protein, Carbohydrate, Lipid, Endocrinology, Hypokinesia, Immersion, Hypoxia, Exercise, Psychology, Stress, Acceleration, Cardiovascular and Respiratory Systems, Neurophysiology, High Altitudes, Prophylactic Countermeasures, Drugs, LBNP, Far North

Annotation: This monograph presents the results of research on levels of hormonal, mediator, and bioactive compounds, a wide range of enzymes and their isoenzymes, as well as the major parameters of protein, carbohydrate, lipid, and mineral metabolism in blood and urine of humans exposed to a variety of extreme factors (limited motor activity, hypoxia, graded physical exercise, stress, cerebral ischemia, etc.). The results of measurement of metabolic parameters were compared with data from clinical physiological examinations. The use of drugs to prevent and correct the changes noted in metabolic processes is discussed. This book is intended for clinical practitioners, biochemists, endocrinologists, pathophysiologists, and other specialists interested in problems of extreme states.

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P1423(31/91)Goncharova GI, Lyannaya AM.

Characteristics of bifidoflora of operators exposed to space flights.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 423-424.

Microbiology, *Bifidoflora*, Gastrointestinal System
Humans, Cosmonauts
Space Flight

Abstract: Space flight conditions, such as human inhabitation of a small, airtight environment, hypokinesia, characteristics of diet, and neuroemotional stress have negative effects on intestinal microecology. Disruption of the microbiocenosis may have an adverse effect on cosmonauts' health status and performance capacity. During space flight, human immune resistance is weakened and the body's susceptibility to pathogens, including opportunistic representatives of endogenous human microflora, is increased. Generally, dysbiotic disorders of intestinal microflora occurring in humans under extreme conditions take the form of a drastic decrease or disappearance of *Bifidobacteria*, and *Lactobacilli* and an increase in intestinal bacilli and other opportunistic microorganisms. *Bifidobacteria* are among the first to respond to adverse conditions and they may be considered an indicator of overall physiological status. To improve the health of cosmonauts and increase their resistance, we must correct their intestinal microflora by administering eubiotic preparations consisting of *Bifidobacteria*. Thus it is important to identify strains of *Bifidobacteria* promising for development of new biological preparations for individualized correction of microflora in cosmonauts.

A comparative study of *Bifidoflora* was performed in cosmonauts during the preflight period and after landing. Initial cultures for maintaining *Bifidobacteria* in 1 g feces used a dense nutrient medium with sodium azide. The strains were purified, lyophilized and stored at a temperature of 4-6°C. Over a period of 15 years, more than 300 strains of *Bifidobacteria* were isolated and their biological properties and species composition studied.

No significant differences were noted in the morphology of strains isolated pre- and postflight in cosmonauts. All strains were active acid-formers and by 72-96 hours had accumulated up to 90-120° Turner??. However, the strains isolated from the cosmonauts after long-term flights showed a tendency for decreased acid-forming activity, while culture development was drastically retarded. It was established that *Bifidoflora* were represented by three species — *B. longum*, *B. adolescentis*, and *B. bifidum*, with the third species least common. Stability of the species composition of the *Bifidoflora* was noted in one cosmonaut observed for 1.5 years.

The results obtained are of great significance for identifying the most promising individual strains of *Bifidobacteria* for creation of special purpose eubiotic preparations.

P1446(31/91)* Shikina MI, Vinogradova LA, Kolesina NB, Volkova LN.

Microflora of drinking water regenerated from moisture containing wastes in a closed (pressurized) environment.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 56-58; 1990.

[6 references; none in English].

Microbiology, Drinking Water, Species

Microflora

Life Support Systems, Regenerated Water, Closed Environment

Abstract: Samples of potable water were regenerated from products of decomposition by hydrogen peroxide (evidently from condensate of wastes generated in an inhabited closed environment) in experimental facilities. After purification through sorption, the drinking water was preserved with silver ions and underwent artificial mineralization to bring it up to hygienic standards. The species composition of microflora was studied in the samples by measuring intestinal bacilli, enterococci, and enterobacteria, and also non-fermenting gram negative bacteria. Total level of microbial contamination, species composition of microorganisms, and also ratios among indicator, opportunistic, and pathogenic microorganisms were measured in accordance with USSR state standards. A total of 14 samples of condensate and 14 samples of water regenerated from it were tested. Samples were obtained and tested regularly every 2 days for a month from the water reclamation facility. Every sample was tested in a sterile test tube, with three replications. Mean levels of microbial contamination were computed using analysis of variance for small samples.

Results showed that as the water reclamation device functioned in the closed environment experiment over a period of a month, the level of contamination of the initial condensate of products of hydrogen peroxide decomposition ranged from 140 to 6400 microbial units per 1 ml. Quantity of microorganisms in regenerated drinking water generally adhered to the USSR state standard (≤ 100 per 1 ml) at concentrations of silver ion of 0.05-0.19 mg/l. Leading species of microorganisms in the initial condensate and regenerated water included: enterococci (*Streptococcus faecalis*), oxidazo-positive and gram negative bacteria (*Escherichia coli*, *Citrobacter*, *Enterobacter*, *Klebsiella*, *Pseudomonas aeruginosa*). In the 14 samples of initial concentrate, *Citrobacter* was found in 10, *Klebsiella* in 7, *Enterobacter* in 5, *Pseudomonas aeruginosa* in 6, *Streptococcus faecalis* in 4, and *E. Coli* in 1. In 14 samples of regenerated water, *Pseudomonas aeruginosa* were found in 7, *Citrobacter* in 5, *Streptococcus faecalis* in 5, and *Klebsiella* in 3. *E. coli* were virtually absent. All the microorganisms found were human autoflora. There were no major qualitative differences between water produced by the regeneration device in the laboratory and in conditions of a closed inhabited environment. When compared to the atmosphere of the closed environment, the regenerated water contained more gram-negative bacteria and fewer cocci, spores, and yeasts. The initial condensate and regenerated water also contained much fewer *E. coli*. The condensate contained virtually no nonfermenting microorganisms, while both the condensate and regenerated water contained more *Streptococci faecalis* than the condensate of atmospheric moisture.

Table: Species composition of microorganisms in drinking water regenerated from condensate of products of hydrogen peroxide decomposition

PAPERS:

P1410(31/91) Durnova GN, Popova IA, Burkovskaya TYe, Fedotova NYu, Vorotnikova YeV, Kaplanskiy AS, Loginov VI, Arustamov OV, Vekilov MM.

The repair process in the bones of rats exposed to lack of musculoskeletal (gravitational) loading.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Page 303-305.

Musculoskeletal System, Bones, Repair, Post-Traumatic Callus, Fibula
Rats
Space Flight, COSMOS-2044, Tail Suspension

Abstract: Experiments on COSMOS series biosatellites and also ground-based simulations modeling the decreased gravitational loading of the musculoskeletal system characteristic of weightlessness, have shown that lack of static and decrease in dynamic loadings on bone lead to inhibited bone growth and neoformation of bone tissue, attributable primarily to the decrease in the number and functional activity of osteoblasts. These data support a hypothesis that the course of post-traumatic repair in bones under conditions of a decreased skeletal loading may also be disrupted. To test this hypothesis the authors performed a ground-based simulation on rats, which for 14 days were "suspended" by the tail in a head-down position, completely eliminating static loading on the hind legs. Two days before the beginning of suspension the fibula bone of a hind leg was fractured surgically in each rat and the adjacent sections of the gastrocnemius and soleus muscles were severed. The rats were decapitated 17 days after the trauma to their limbs. The results of the study showed that "tail suspension" led to a significant decrease in the size of neoformation of bone callus. The weight of the traumatized fibula bone was 38% lower than in control animals, which were maintained under vivarium conditions after trauma. The strength of the bone callus in "suspended" rats was also diminished, as indicated by the disruption of the integrity of the bone callus and the separation of fragments of bone when it was cleaned of soft tissues.

As neutron-activation analysis showed, removal of loading from the hind legs was accompanied not only by inhibition of development of bone callus, but also decrease in its mineralization as shown by decreased concentrations of bromine, cobalt, manganese, iodine, calcium, phosphorus, and magnesium in bone. Concentrations of potassium and rubidium increased in the fibula bones of suspended rats, while levels of zinc, strontium, sodium, chlorine, and barium were unchanged.

Biochemical studies of the bone calluses have established that, compared to traumatized controls, in suspended rats there is increased activity of lactate dehydrogenase and alanine transferase, and decreased activity of alkaline and acid phosphatase, creatinine phosphokinase, and isocitrate dehydrogenase.

Histological analysis of bone calluses showed that the decrease in size in experimental rats was primarily due to the external bone callus, in which the amount of cartilaginous and spongy bone tissue decreased sharply. The number of functionally active osteoblasts also decreased significantly.

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An experimental study of the course of post-traumatic repair under conditions of decreased loading of the supporting skeleton was also performed on biosatellite COSMOS-2044. In nature and duration this experiment was identical to the ground-based simulation using tail suspension. The only difference was that in the flight experiment the rats had both hind legs injured. The results of the experiment showed that 2-weeks exposure to weightlessness leads to inhibition of bone callus development and disruption of the strength of consolidation of fragments of the fibular bone. Weighing and histomorphometric analysis of the bone calluses showed that exposure to weightlessness leads to decrease in the weight and size of bone calluses, and also the amount of cartilaginous, fibrous, and spongy bone tissue they contain.

Thus, deprivation of gravitational loading leads to disruption of post-traumatic repair in hind limb bones.

P1414(31/91) Oganov VS, Skuratova SA, Murashko LM (USSR), Szilagi T, Szoor A, Rapesak M, Guba F, Osvoski I, Laszlo J. (Hungary), Meunier I, Oly C (France).

Contractile properties and composition of myofibril proteins of skeletal muscles in rats after a 13-day space flight.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 327-329.

Musculoskeletal System, Muscle, Skeletal, Contractility, Myofibril Proteins, Adaptation
Rats

Space Flight, COSMOS-1887, Tail Suspension

Abstract: Biosatellite research has established that adaptive changes in physiological properties of muscles is accompanied by appropriate changes in their structure and energy metabolism, and, in certain types of muscle fibers, in reprogramming of contractile and regulatory protein synthesis. The goal of the present research was to study the mechanisms and dynamics of the functional adaptation of skeletal muscles in response to weightlessness varying in duration.

The contractile properties of bundles of glycerinized fibers of the following muscles were studied; 5-7 of muscles of the front (triceps of the brachia /TB/ and the brachial muscle/BM/) and hind legs (soleus /SM/ and long extensor of the digits /EDL/, medial and lateral head of the gastrocnemius /MHG, LHG/). The functional activity of the sarcoplasmic reticulum (caffeine contracture of individual skinned muscle fibers) was investigated. The structure of myofibril proteins was investigated using electrophoresis on an SDS polyacrylamide gel.

It was established that a 13-day space flight and 2 days of readaptation leads to decrease in absolute mass of all the muscles studied with the exception of the postural muscles (SM, TB). Analysis of weight data from the COSMOS-1887 experiment suggests that changes in muscle mass reflect not only the effect of space flight, but also differences in gravitational loading during the first 2 days postflight.

It was established that strength of contraction decreases in the slow SM and increases along with work capacity in the fast-twitch locomotor muscles (EDL and BM) of flight animals. Study of contractile characteristics of isolated muscle fibers and functions of the sarcoplasmic reticulum also revealed a selective and substantially diminished strength of contraction of SM fibers in the flight group, but less extreme than after 5-7-day flights. In a parallel laboratory experiment using unloading of the posterior muscles (tail-suspension model) muscle strength was more severely diminished; after 2 days of readaptation muscle strength returned to a level 3/4 of control.

Maximal rate of development of contraction of muscle fibers in the flight group was diminished in SM and EDL; in TB, LGM, and MGM there was an increase in maximal development rate. Directly after suspension there was an increase in maximal rate of development in SM in the animals in the laboratory; 2 days after readaptation the value of this parameter decreased. It was also found that Ca-dependent maximal rate increase of isolated SM fibers in animals exposed to flight (followed by 2 days of readaptation) changes only insignificantly, while there was a substantial increase in this parameter of isolated SM fibers 2 days after suspension. The results of the study of speed parameters of muscles in bundles of glycerinized fibers and isolated

single fibers are in good agreement. There was also agreement in the described changes in speed properties and data on the composition of isomyosins, particularly in SM muscles.

The ratio between fast-twitch and slow-twitch myosins in flight animals showed a marked tendency to increase in SM compared to the control, but was virtually unchanged in the gastrocnemius and markedly depressed in the fast-twitch locomotor EDL and BM. The authors argue that this discrepancy is associated with unequal development of the two processes determining speed properties: restructuring of the composition of isomyosins and changes in mobility of Ca in the sarcoplasmic reticulum.

Analysis of research results attests to the fact that functional adaptation to weightlessness by muscle fibers of various kinds to a great extent depends on the degree to which the muscles serve an antigravity function. Similarly, their reaction to subsequent gravitational loading (1 g) is qualitatively different, although it occurs relatively rapidly. Also considered are possible mechanisms for rapid adaptation of the functions of skeletal muscles to changes in gravitational loading and the value of the data obtained for understanding the nature of motor disturbances observed in humans during various stages of space flight.

P1435(31/91)*Durnova GN, Vorotnikova YeV, Kaplanskiy AS, Novikov Vye.

Osteoporosis in monkeys in response to hypokinesia with head-down tilt.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 29-31; 1990.

[15 references; none in English]

Musculoskeletal System, Osteoporosis, Iliac, Tibia

Monkeys, *Macaca mulatta*, Males

Hypokinesia With Head-Down Tilt

Abstract: The ilia and tibiae bones of 12 male *Macaca mulatta* monkeys served as material for this experiment. Seven of the animals were subjected to 10° head-down tilt on a special stand in a prone position for 15 days (4 subjects) and 30 days (3 subjects); the remaining 5 monkeys formed a vivarium control group. Two weeks before the beginning of the experiment a biopsy was made of the crest of the left iliac bone in both control and experimental subjects. After the experiment the animals were sacrificed, and a biopsy made of the crest of the left iliac bone. Samples of the right ilia and tibiae bones (proximal epiphysis and metaphysis, medial portion of the diaphysis) were removed during autopsy, then fixed for 24 hours at 4°C in 4% phosphate buffered paraformaldehyde, containing 2.5% sucrose and embedded in methylmetacilate and medium JB-4. Sections of nondecalcified bones, 5 mm thick, were prepared using a microtome, and used to determine acid phosphatase activity and osteoid. The former was measured using the method of simultaneous diazo reaction.

Histomorphometric analysis of spongy bone tissue used an image analyzer to measure the following parameters: volume of trabecular bone (BV/TV), number of trabeculae (Tb.N), their thickness (Tb.Th), and intertrabecular space (Tb.Sp), and the volume of calcified bone (Md. V.) Parameters of neoformation were: relative volume (OV/TV), surface (OS/BS) and thickness (O.Th.) of the osteoid. Rate of bone resorption was estimated on the basis of measurement of the active resorption surface (OS/BS). Results were tested using Student's t.

Results of histomorphometric analysis of spongy tissue of the ilia revealed virtually no differences in the volume of trabecular bone and number and thickness of trabeculae between biopsies of the experimental group before treatment and those of the control group at the end of the experiment. However, evidently due to the stimulating effects of the biopsy, osteoid in the iliac of vivarium controls after the experiment was 20% greater and active resorption surface 23% lower than in the pretreatment biopsy. Exposure to 15 days of hypokinesia gave rise to a significant decrease in the amount of spongy bone tissue in the iliac, as indicated by a 39% decrease in volume of trabecular bone, a 37% decrease in volume of mineralized bone, a 27% decrease in thickness of trabecular bone, and a 40% increase in intertrabecular space as compared to the vivarium control. Decrease in number of trabeculae was not statistically significant. Also observed was an inhibition of bone neoformation, as shown by a marked decrease in volume, surface, and thickness of the osteoid (by 33, 31, and 35%, respectively). Resorption activity increased, as indicated by a 61% increase in the active surface of absorption compared with the vivarium control. Increase of hypokinesia to 30 days induced still more severe changes in spongiosa of iliac bone tissue. Trabecular volume decreased by 62%, number of trabeculae by 49%, their thickness by 40%, while the distance between them increased by 130%, compared to the control group. Parameters of neoformation, volume, surface, and thickness of osteoid, decreased by 91.5, 88, and 80%, respectively, compared to control. Resorption activity remained elevated at the same level as after the 15-day treatment. Osteoclasts in the experimental group appeared larger than in the control and displayed high activity of phosphatases.

In the tibiae after 15-day head down-tilt, trabecular bone volume, mineralized bone volume, and thickness of trabeculae diminished by 26, 25, and 19%, respectively. Parameters of

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neof ormation showed only a tendency to diminish. After 30 days of treatment subjects volume of trabecular bone was 40 and 51% below control in two subjects, while this parameter was unaltered in the third subject, attenuating statistical significance of the results. Parameters of neof ormation were sharply diminished in all three monkeys of this group. Active resorption surface exceeded that of the control in the two monkeys with diminished trabeculae volume, while it was below that of the control in the third monkey.

Results clearly demonstrate the development of osteoporosis in monkeys after 15- and 30-day exposure to hypokinesia with head-down tilt, progressively increasing with exposure duration. Osteoporosis is due both to greater resorption surface and inhibited bone neof ormation. The progressive development of osteoporosis indicated that 30 days is insufficient for adaptation to new conditions to occur. Comparative analysis of the morphological changes in the ilia and tibiae bones shows that they are relatively pronounced and in the same direction, which justifies use of biopsies of the iliac crest for evaluating general severity of osteoporosis.

Table 1: Results of histomorphometric analysis of the secondary spongiosa of the iliac bones of monkeys

Table 2: Results of histomorphometric analysis of the secondary spongiosa of the tibiae of monkeys

P1436(31/91)* Kuznetsov SL, Talis VL.

State of skeletal muscle fibers of rats exercising during tail suspension as a simulation of weightlessness.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 31-34; 1990.

[15 references; five in English]

Musculoskeletal System, Muscle Fibers, Femur, Enzymology, Metabolism

Rats, Male

Tail Suspension, Exercise, Passive Exercise

Abstract: Subjects in this experiment were 18 white male Wistar rats. The animals were divided into three groups. The two experimental groups were suspended in a head-down position for 21 days. The control group was maintained in standard vivarium cages. Beginning on day 7 of treatment, experimental subjects were exercised daily. Group 1 animals ran a treadmill for 15 minutes at 18 m/min., while group 2 animals' hind leg muscles were passively extended for the same period in a static mode. On days 14 and 21 animals were sacrificed. A sample of muscle tissue from the femoral biceps was flash frozen in liquid nitrogen, placed in a cryostat, and serial sections 10 μm prepared. Sections were stained. Activity of Ca-dependent ATPase myosin was measured in a pH preincubated 4.3 medium to determine fiber type. Activity of NAD·H-tetrazole reductase (NAD·H-TR), succinate dehydrogenase (SDH), lactate dehydrogenase (LDH), and oxybutyrate dehydrogenase (OBDH) were measured using tetrazole methods. Level of glycogen was measured by an undescribed method, total protein (TP) by staining with amido black 10 B and RNA by staining with halocyanin-chrome quartz. Fiber cross sections were measured with a planimeter in preparations stained to reveal ATPase myosin. Activity of enzymes and concentration of glycogen, TP and RNA were estimated with a scanning micrometer from the optical density of the fibers after appropriate staining.

As Figure 1 shows, for up to 14 days of hypokinesia, exercise prevents development of atrophic processes in all type of fibers; after 21 days all fibers were decreased in size, except type IIa. Decreases in rate of regeneration processes (decreased TP and RNA) characteristic of hypokinesia occurred in all fiber types after both periods. In type I fibers RNA had normalized by day 21. Lack of changes in activity of NAD·H-TR suggests that exercise prevented changes in overall metabolism in type I and IIb fibers, while in type IIa fibers (fast-twitch oxidative) this enzyme was depressed, although recovering somewhat on day 21. No changes in activity of glycolytic or oxidative components of energy metabolism were found in type II fibers, but in type I fibers, activity of SDH (by day 21) and LDH (by day 14) was elevated, suggesting a shift to anaerobic processes. In type II fibers glycogen concentration increased somewhat on day 14. In all fibers there was a sharp decrease in level of β -oxidation of fatty acids, as indicated by activity of OBDH.

Passive exercise prevented atrophy in types I and IIb fibers at 14 days and types IIa and IIb at 21 days. Total protein was depressed in all fibers at 14 days, but recovered in types IIa and IIb by 21 days. RNA was normal or elevated in all fibers at 14 days and depressed in types I and II after 21 days. Parameters of energy metabolism were quite different than for the exercise group. NAD·H-TR activity was elevated in all fibers on day 14, and normal or elevated (type I) on day 21. SDH was elevated in all fibers on day 14 and elevated or normal (IIa) on day 21. LDH was depressed in IIa fibers on both days and otherwise normal. Level of β -oxidation of fatty acids, as measured by OBDH, was sharply depressed at both measurement points. Glycogen was depressed in I and IIb fibers on day 14 and elevated in type I and IIa fibers on day 21.

The authors conclude that the effects of active and passive muscle exercise on atrophy and metabolic changes in muscle fibers are different, with differences particularly pronounced in

type II fibers, in which the stabilizing effects of passive exercise were more pronounced, evidently due to greater exercise of the contractile system in the latter treatment. This hypothesis is strengthened by the slighter effects of hypokinesia on RNA and total protein in type II fibers during passive exercise. Active exercise had a stronger preventive effect on type I fibers. Both exercise modes had a beneficial effect on maintaining normal energy metabolism. For passive exercise, elevation of NAD·H-TR and SDH with normal or diminished LDH is typical of a training effect. Neither treatment prevented the decrease in fatty acid oxidation typical of hypokinesia. Accumulation of glycogen in the muscles, characteristic of elimination of gravity loading occurred, at day 14 in active exercise and day 21 in passive.

Figure 1. Change in activity of NAD·H-TR, SDH, LDH, OBDH, concentrations of glycogen, total protein, and RNA in different types of muscle fibers, and also fiber size at different times for group 1

Figure 2. Change in activity of NAD·H-TR, SDH, LDH, OBDH, concentrations of glycogen, total protein, and RNA in different types of muscle fibers, and also fiber size at different times for group 2

P1444 (31/91)*Davydova NG

Relationship between mineral content and mechanical properties of the bones of dogs after a single acute whole-body irradiation.

Kosmicheskaya Biologiya i Aviaksomicheskaya Meditsina.

24(6): 51-53; 1991.

[26 references; 1 in English]

Musculoskeletal System, Bones, Femur, Jaw, Mineral Content, Mechanical Properties

Dogs

Radiobiology, Whole Body Irradiation

Abstract: Experiments were performed on 125 outbred dogs, weighing 10-16 kg, aged 2-4 years. The 10 animals in the experiment group were subjected to single acute whole-body irradiation. Irradiation dose was 4.0 Gy, with dose rate of 0.2 Gy/min. The animals died of acute radiation sickness between 14 and 245 days after treatment. After their death, the femur and mandibles were isolated and fixed. Using a diamond disk, fragments of the medial portion of the diaphysis and distal epiphysis were extracted from the femur, and interalveolar septa in the area of the front and posterior teeth, interradicular septa, and cortical layer of the mandible were removed. Mineral saturation, ash content, and density of bone fragments were determined by weight and volume by weighing the fragments in air and alcohol. The mineral components of bone tissue (Ca, Mg, Na, K) were measured in a solution of ash using an atom absorption spectrophotometer, and phosphorus content was measured using a photoelectrocolorimeter. Biomechanical studies involved compression testing of fragments of the femoral diaphysis with height of 10 mm and fragments of the epiphysis in a cube with perimeter 10 mm, and also dentoalveolar blocks embedded in fast-hardening plastic. Correlation analyses were performed on a computer.

Results showed greatest changes in mineral components and biomechanical properties in the spongy structures of the distal epiphysis of the femur and interalveolar septa of the lower front teeth. In the epiphysis, mineral density decreased by 19.8%, density by 6.9%, and ash content by 7.1% compared to the control. In the ash residue, levels of sodium increased, potassium decreased and there were no changes in the other elements. Ultimate compression strength of the epiphysis decreased by 24.1% and modulus of elasticity by 10.1%. Correlation analysis revealed a positive correlation ($r=0.59-0.94$) between parameters of mineral saturation, ash content, and density after irradiation. Mineral saturation was highly ($r=0.75-0.89$) correlated with ultimate strength and modulus of elasticity. Such correlations were not found in the control group. Mineral saturation was negatively correlated with deformability. Sodium and potassium levels were negatively correlated.

Changes were not found in the cortical area of bone tissue of the diaphysis. In the diaphysis of both control and experimental groups, there was a high correlation between parameters of the mineral component ($r=0.67-0.73$) and between calcium levels on the one hand, and magnesium and sodium on the other. There was no correlation between mineral component and strength, possibly due to low variability in these parameters.

In the mandible, irradiation was associated with changes in the mineral component and biomechanical properties of the anterior and posterior interalveolar septa. For the front teeth, mineral saturation decreased by 11.4%, ash content by 6.5%, and density by 6%; magnesium and sodium were also decreased. Analogous changes occurred in the area of the posterior teeth. When blocks of bone containing both anterior and posterior areas were tested for strength, load bearing capacity was depressed by 21.6%, energy of elastic deformation by 29.5%, while the rigidity parameter was unchanged. In all areas of the mandible studied in both experimental and control animals, there were high positive correlations between mineral saturation, ash content and density. Mineral saturation and density were highly correlated with load-bearing capacity

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in the area of the interalveolar septa of the irradiated dogs. There was a positive correlation between load-bearing capacity and levels of magnesium and calcium.

Table: Change in the mineral component and biomechanical properties of bone tissue of various portions of the femur of irradiated dogs.

P1409(31/91) D'yachova LN, Sluch VN.

Ultrastructure of the cerebral cortex of white rats exposed to a 2-week space flight.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

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Neurophysiology, Brain, Cerebral Cortex, Ultrastructure, Adaptation

Rats

Space Flight, COSMOS-1887, -2044

Abstract. The problem of the study of physiological adaptation to space flight is closely linked with analysis of adaptive changes in the nervous system and its most highly developed portion — the cerebral cortex — as one of the leading components in the mechanisms supporting selection and organization of optimal forms of activity for physiological systems.

This work studied the ultrastructure of the somatosensory and visual cortex of white rats exposed to space flight for 2 weeks on biosatellites COSMOS-1887 and -2044, as well as rats maintained on the ground in synchronous conditions and in a vivarium control. A layer-by-layer study was made of ultrafine sections and a quantitative analysis of the ultrastructure was performed.

The visual cortices of rats exposed to space flight displayed changes in the ultrastructure of neurons, synaptic formations, glia, and vessels. The changes observed attest to reorganization of the system of interneuronal contacts in the cerebral cortex of flight animals. Structural characteristics of this process are degeneration (mainly of the light /chromatolytic?/ type"), increase in axonal terminals and neof ormation of synapses, and increase in density of glial and vascular components in the zone of plastic deformation. The most pronounced adaptive changes in ultrastructure occurred in the neuropil of the surface layer of the neocortex, mainly in the sensory motor region.

Data on the characteristics and sequence of changes in the ultrastructure of the cerebral cortex during space flight should be considered when developing the schedule for the space flight, prescribing physical and psychological workload under conditions of weightlessness, and also in determining whether ontogeny can proceed under conditions of weightlessness.

P1413(31/91) Krasnov IB.

Morphological manifestations of changes in vestibular impulses in the cerebellar nodulus of rats exposed to weightlessness.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 313-315.

Neurophysiology, Cerebellar Nodulus, Vestibular Impulses, Endocrinology, Hypothalamus, Pituitary, Thyroid

Rats

Space Flight, COSMOS-1514, -1667, -1887, -2044

Abstract: Electron microscopy of the cerebellar nodulus of rats exposed to space flight for 5 and 7 days on COSMOS-1514 and -1667 revealed changes in ultrastructure at locations where vestibular fibers terminated. These changes are indicative of the status of excitation of the "receptor cell of the utriculus-neuron of the vestibular ganglion" systems occurring in Earth's gravity after exposure to weightlessness and demonstrating increased sensitivity of this system (I.B. Krasnov, et al., 1986, 1987).

Electron microscopy of the ultrastructure of the cortex of the cerebellar nodulus in rats after 2-week space flights on COSMOS-1887 and -2044 revealed changes in the terminals of mossy fibers, including sharp increase in number of synaptic vesicles, significant increase in electron density of pre- and postsynaptic membranes and postsynaptic flattening, and expansion of the synaptic cleft. Also in a number of cases increase in distance was noted between synaptic vesicles and the presynaptic cleft (by 10-20 nm), suggesting a state of excitation, accompanying a block of synaptic transmissions. The majority of axosomatic synapses formed by the axonic terminals of Golgi cells on bodies of granular cells, were in a state of hyperchromatic degeneration.

Changes in the ultrastructure attest to an increase in the flow of vestibular impulses from the otolith apparatus in the Earth's gravity after weightlessness, and indicate an increase in sensitivity of the otolith apparatus in weightlessness. At the same time within the nodular cortex the mossy fiber terminals were marked by a lightened matrix, sharply decreased number of synaptic vesicles, absence or extreme scarcity of synaptic vesicles at the presynaptic membrane, appearance of neurofilaments -- that is chromatolytic degeneration due to the long-term decrease in functional activity of neurons of the vestibular ganglia, reflecting in turn a decrease in flow of vestibular impulses from the otolith apparatus in weightlessness.

The morphological data indicates that there was a decrease in the flow of vestibular and also proprioceptive impulses entering brain structures. This suggests to the authors that there is a hypoadrenergic mechanism that underlies the hypofunction of the thyroid, and decrease in synthesis and excretion of growth hormone occurring in weightlessness. The order of events is hypothesized to be as follows: 1) decrease in vestibular and proprioceptive impulses entering the vestibular nuclei along vestibular and spinovestibular fibers; 2) decrease in the functional activity of neurons of the vestibular nuclei; 3) decrease in impulses from the vestibular nuclei to the locus ceruleus; 4) decrease in activity of noradrenergic neurons of the locus ceruleus; 5) decrease in impulses from the noradrenergic neurons of the locus ceruleus to neurons releasing TRH of the periventricular portion of the paraventricular nucleus of the hypothalamus; 6) decrease in activity of the neurons releasing TRH of the paraventricular nucleus; 7) diminished

release of TRH from axosomatic synapses to neurons releasing GHRF of the arcuate nucleus of the hypothalamus; 8) decrease in the synthesis and excretion of GHRF; 9) decrease in the synthesis and excretion of growth hormone by somatotrophs and of thyrotropic hormone by the thyrotrophs of the pituitary; 10) decreased synthesis and excretion of thyroxin.

When norepinephrine triggered activation of neurons releasing TRH decreases, the significance of its antagonist — serotonin, which activates neurons releasing somatostatin — may increase. Evidently, the decrease of tone of the noradrenergic system that occurs in weightlessness can also explain inhibition of erythropoiesis (due to decrease in activating effects of the noradrenergic system on the posterior hypothalamus), vagotonia of the digestive system (due to decrease in the regulating effects of noradrenergic neurons on the nuclei of the hypothalamus), decreased area of the noradrenergic cells in the adrenal gland, and increased number of β -adrenoreceptors in the heart and spleen, all of which have been shown by a number of researchers to occur in rats after space flight, and make it possible to speak of the hyponoradrenergic syndrome of weightlessness.

P1414 (31/91) Moshkov DA, Savel'yeva LN, Oygenblik EA.

Ultrastructure of Mauthner's cells in fish after return from orbital flight.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 325-327.

Neurophysiology, Mauthner's Cells, Ultrastructure
Fish, Guppies
Space Flight, COSMOS-2044, Mir

Abstract: The problems of adaptation to conditions of weightlessness and subsequent readaptation of animals and humans to conditions on Earth are interrelated. It is evident that the longer the exposure to weightlessness, the more painful and acute will be the reaction to return to normal gravity. This will be manifest most strongly in the central nervous system (CNS), especially in portions of it that receive and process vestibular information and regulate the functioning of other portions of the CNS and somatic organs (including motor organs) on the basis of this information. Due to the exceptional complexity of designing experiments to study the CNS, it has not been given a great deal of attention in space biology. In our opinion, experiments on lower vertebrates, whose CNS are less complex, are promising.

One of the appropriate subjects is the CNS of fish and amphibians, especially Mauthner's cells (MC), which receive vestibular innervation and control motoneurons, which regulate contraction of muscles of the tail and thus control the motion of the animals.

The "Akvarium" program studied morphofunctional aspects of reactions of the MC to return of fish (guppies) to the Earth's gravity after long-term (14 days) exposure to space on biosatellite No. 9 (COSMOS-2044) and on space station Mir. Results were compared with data obtained from untreated fish, and also from transport and synchronous controls. Study of the physiological status of the MC revealed their extreme exhaustion after return of the fish to the Earth: there was an almost fivefold decrease in the function of the neurons, which was reflected in the motor activity of the animals. Ultrastructure studies revealed a whole set of changes correlated with the data concerning depression of MC function. There were extremely severe consequences of the great functional loading on the neurons from the vestibular apparatus after a long period of relative dysfunction. Virtually all portions of the neuron sustained damage. Afferent synapses lost a significant portion of synaptic vesicles, and many became completely empty. The postsynaptic area was strongly vacuolized, and there was frequent exfoliation of the surface membrane with synapses from the matrix. The cytoplasmic mitochondria took on a horseshoe shape in the area of the nucleus, and were elongated on the periphery and in the dendroplasm. The cristae underwent filamentous transformation. Many mitochondria swelled and lost their cristae. The nucleus changed from oval to very elongated, the cytoplasm penetrated deep into the nucleus, forming fingerlike outgrowths of the nucleus. The karyoplasm contained intranuclear inclusions of crystal-like appearance. The cytoskeleton of the MC also underwent significant changes. In the norm the cytoskeleton of the MC of this type of fish is composed mainly of loosely packed neurofilaments, infrequently crossed by microtubules and isolated small bundles of fibers finer than neurofilaments. Changes in organization of the MC cytoskeleton due to functional deviations in the control experiments were insignificant. In the MC of experimental fish after long exposure to weightlessness and return to Earth, almost the entire cytoskeleton was transformed. Bundles of densely backed osmophilic filaments were numerous and completely filled the cytoplasm. Such bundles were homogeneous, of elongated

shape and contained condensed ribosomes and polysomes. Between these bundles were mitochondria and vacuoles, but the remaining space was virtually empty. Such destructive changes in organization of the cytoskeleton and other elements of the neuron were previously noted in the MC of other species of fish after long-term natural (vestibular) stimulation, suggesting extreme exhaustion of neurons, which persists for a long period and frequently ends in death.

Thus, return to Earth and the initial period of readaptation to normal gravity after long-term exposure to weightlessness accompanied by dysfunction of the vestibular apparatus, is marked by pernicious disruption of the morphofunctional state of the central neurons responsible for regular movement and under the control of the vestibular apparatus.

P1418(31/91) Yakushin SB, Beloozerova IN, Sirota MG, Kozlovskaya IB.

Neuronal activity of vestibular structures of the brain stem and cerebellum in monkeys during a space flight.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая

Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

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Neurophysiology, Vestibular Structures, Brain Stem, Cerebellum

Monkeys, *Macaca mulatta*

Space Flight, COSMOS-2044

Abstract: During the 14-day space flight of COSMOS-2044, multicell activity of the medial vestibular nucleus and the flocculus of the cerebellum was recorded extracellularly in two *Macaca mulatta* monkeys. Head movements, and horizontal and vertical electrooculograms during gaze fixation on point light targets were also recorded. All signals were recorded on magnetic tape in low and high frequency bands. In a number of cases it was possible to isolate the activity of individual cells from the total activity of neurons of the medial vestibular nucleus.

Data were obtained concerning changes in neuronal activity of the medial vestibular nucleus and flocculus of the cerebellum during transition to weightlessness and subsequent adaptation. Changes in activity of these structures during adaptation to weightlessness were well correlated with each other.

P1433(31/91)*Ilyina YeA, Yarullin KhKh, Alekseyev DA, Fotina LA, Sokolov VI.

Functioning of the nervous system in middle-aged men under conditions of hypokinesia with head-down tilt.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 23-27; 1990.

[11 references; 3 in English]

Neurophysiology, Nervous System Functioning, Adaptation
Humans, Males, Middle-Aged, Atherosclerosis, Hypertension
Hypokinesia With Head-Down Tilt

Abstract: The goal of this experiment was to study the effects of 30 days of hypokinesia with head-down tilt (-8°) on the nervous systems of male volunteers ($n=24$) aged 25-52. Fifteen subjects were 40-52 years old, and nine of these showed initial symptoms of cerebral atherosclerosis (group 1), and six initial signs of cerebral atherosclerosis with high blood pressure (group 2). The control group contained nine apparently healthy volunteers aged 25-39 (group 3). Nervous system functioning was investigated with traditional clinical methods, including an EEG and impedance plethysmogram of the head. Emphasis was placed on functioning of the autonomic nervous system. Autonomic tonus was studied using a special table. Autonomic reactivity used methods of local dermatographism, the "white spot" test, oculocardiac reflex, clinostatic (decrease in pulse upon assumption of a horizontal position), and orthostatic reflex (increase in pulse upon assumption of vertical position). Autonomic support of activity was estimated from data on endurance of tilt ($+75^\circ$) and submaximal bicycle ergometry. Examinations were performed during a baseline period, on days 1, 7, 14, 21, and 28 of hypokinesia, and on days 1, 3, 10, 14, and 20 of readaptation.

During the baseline period, group 1 subjects complained of increased fatigue and decreased performance; similar complaints and headaches were noted in group 2, and no such complaints in group 3. Baseline autonomic tonus was judged to be in equilibrium in control subjects. While parameters were within normal limits for subjects in the experimental group, ratios between them suggested disruption of autonomic regulation. During hypokinesia, the nature and direction of response of autonomic reactivity parameters were similar, but were less pronounced in the older subjects especially in group 1. In response to tilt, group 1 subjects displayed increased heart rate and pulse pressure during the first minutes of tilt, rapid blood pressure normalization and delayed heart rate normalization after return to horizontal. In group 2 subjects, heart rate response to tilt was in the form of a diffuse autonomic response, suggesting disruption of mechanisms for adjusting to change of position. In control subjects, heart rate response to exercise occurred before blood pressure response, while in group 2 subjects the reverse was true. Examination of hemo- and neurodynamics of the brain in the older subjects revealed moderate decrease in pulsed blood filling of the vertebrobasilar system. Generally, low amplitude, desynchronic and polymorphic types of EEG could also be observed.

During the late hypokinesia period most subjects in all groups showed disruption of autonomic support activity, including excessive response to tilt and exercise tests, especially in group 2. After return to normal activity, all subjects showed a gradual recovery of the nervous system. Readaptation was complete in younger subjects by day 9, and required 20 days in older subjects. The authors conclude that a 30-day period of hypokinesia with head-down tilt leads to more severe decreases in adaptive capacities of the nervous system in older individuals. However, the majority of subjects displayed deviations of a moderate and reversible nature. This indicates that despite age-related atherosclerotic changes in the nervous system, middleaged individuals retain a relatively high level of functional capacity in extreme conditions simulating space flight.

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Table 1: Mean values of physiological autonomic parameters in middle-aged individuals under conditions of a 30-day period of hypokinesia with head-down tilt

Table 2: Mean values of physiological autonomic parameters in middle-aged individuals in study of autonomic reactivity under conditions of a 30-day period of hypokinesia with head-down tilt

Table 3: Mean values of physiological autonomic parameters in middle-aged individuals under conditions of a 30-day period of hypokinesia with head-down tilt in response to a tilt test

Table 4: Mean values of physiological autonomic parameters in middle-aged individuals under conditions of a 30-day period of hypokinesia with head-down tilt in response to an exercise test

P1455 (31/91)Lychakov DV.

Motion sickness: A resonance hypothesis.

Uspekhi Fiziologicheskikh Nauk

21(3): 125-128.

[7 references; 5 in English]

Neurophysiology, Motion Sickness, Symptoms, Nausea, Vomiting

Theoretical Article

Brain Potential, Zeta Waves, Poisoning

Abstract: This theoretical paper considers the role of the vestibular apparatus in the genesis of motion sickness (MS), and the reason for the particular symptoms that occur (nausea, vomiting). The author considers the extent of structural-functional polarization of receptor organs of the vestibular apparatus to be important. If direction of vestibular stimulation coincides with the predominant direction of structural-functional polarization, then the stimulation induces the greatest excitation of the receptor organ as a whole and intensifies spike activity in the nerve; if the direction of stimulation is in the opposite direction, then the reverse occurs. With alternating acceleration, a prerequisite for the occurrence of MS, the nerve impulses that are transmitted to the vestibular center from the receptor organs are modulated to alternate between excitation and inhibition. It follows that the greater the correspondence between the direction of the stimulus and the direction of polarization, and the more predominant the structural-functional polarization of the receptor organ, the more strongly will the frequency of nerve impulses be modulated, and the more severe will be the MS. This is consistent with the observation that when MS is induced through rocking motion, changes in the position of the head, and thus of the vestibular receptor organs with respect to the direction of the acceleration, may decrease sensitivity to MS.

The fact that MS occurs in response to exposure to alternating acceleration oscillating in only a certain range of frequencies is of critical significance for the study of MS. The value of the most effective frequency for inducing MS, according to data of various authors is 0.167, 0.25, or 0.33 Hz for humans, and 0.28 Hz for cats. A shift in frequency of oscillation in either direction, even when the amplitude of acceleration increases, leads to a decrease in MS. It should be noted that exposure to oscillation at between 0.15-0.33 Hz does not exceed the capacity of the human vestibular apparatus, since the receptor organs can modulate themselves to accord with oscillations with a frequency of an order of magnitude greater. Why should alternating acceleration with frequency of approximately 0.2 Hz be the most effective for inducing MS?

In searching for an answer to this question the authors discovered a correspondence of frequencies of MS inducing acceleration and frequencies of zeta rhythms (0.17-0.25 Hz), which are one of the components of super slow electrical activity of the brain. They hypothesize that all three components -- waves of vestibular afferentation with frequency of approximately 0.2 Hz, zeta rhythms, and autonomic disorders -- are associated in a single chain of cause and effect relationships.

M. Traysman attempted to understand why vestibular afferentation occurring in response to rocking motion is closely associated with a series of autonomic disturbances, such as perspiration, pallor, and vomiting, which at the same time are symptoms of poisoning. He has proposed that the vestibular apparatus, as a continuously operating sensory system, is part of the system that protects the body from toxins entering the body with food. He proposes that the vestibular apparatus may have a tonic influence on the system protecting the body from poisoning or may be one of the sensors for poisoning and disrupted homeostasis. It is biologically expedient for the vestibular apparatus to be included in the system protecting the body from toxins because, first the vestibular apparatus is a highly sensitive, constantly

operating sensory system, and second, because the vestibular apparatus is constantly attuned to a stable, external factor — the acceleration of gravity. Thus, deviation from the norm, a discontinuity in perception, and the appearance of vertigo are evidently among the most unpleasant, unusual, memorable subjective sensations, and can induce long-term aversion to the food responsible for the symptoms.

Zeta rhythms are super slow oscillations of brain potential. It is believed that dynamic changes in zeta rhythms reflect various functional states of the brain and are a sign of activity of its slow control system. This system is characterized by "absence of reactions to short-term and random environmental factors and at the same time by the development of changes in response to systematic (or extreme) factors; long latencies (minutes and tens of minutes) of response to stimulation; and the potential to maintain a given mode for several hours."

Existing data support a hypothesis that the slow control system of the brain regulates, among others, the system protecting the body from toxins and that one of the manifestations of the operation of this mechanism is the appearance and intensification of zeta rhythms. Making this assumption, one can further hypothesize that when the body is subjected to rocking motion, the vestibular apparatus — registering the oscillations of acceleration and transmitting information to the vestibular centers — has a modulating effect on them. If the frequency of these modulations, i.e., waves of excitation and inhibition, coincide with the rhythm of zeta rhythms, then the structure of the brain associated with the system protecting the body from toxins, reacts to these oscillations as if they were a signal indicating poisoning. This triggers an avalanche of reactions, which lead ultimately to stimulation of the emetic center and vomiting. Thus, it can be hypothesized that MS is the result of a kind of resonance between the frequency of rocking motion and the frequency of zeta rhythms, associated with the system for protecting the body from toxins. The vestibular apparatus serves here not only as a transmitter, but also as a generator or pacemaker for zeta rhythms.

These assumptions clarify why the frequency of rocking motion that induces MS is limited to a very small range: precisely that of zeta rhythms. From a biological point of view, this correspondence, of course, was completely unexpected for the body, since evolutionarily significant frequencies to which the head is exposed during running, walking, and jumping are in the range of 0.5-1.0 Hz.

To summarize, a resonance hypothesis of the genesis of MS may be advanced in the following form:

1. The system protecting the body from toxins is controlled by the slow control system of the brain. One of the manifestations of the functioning of the toxin protection system is the development or intensification of zeta rhythms with frequency 0.17-0.25 Hz.
2. The vestibular apparatus as a highly sensitive, constantly operating sensory system, with a stable point of reference, is included in the system protecting the body from poisoning. The vestibular centers, and possibly the vestibular apparatus itself, are sensors of disruption of homeostasis and generators or pacemakers of zeta rhythms.
3. When the vestibular apparatus is stimulated by rather long-term and intense alternating acceleration with frequency of approximately 0.2 Hz, the activity of the vestibular centers is modulated to correspond to the zeta rhythm, which ultimately triggers autonomic reactions and vomiting.
4. Sensitivity to MS and its symptoms may vary in animals of various species, in an individual within a species over its lifetime, and between various individuals of a given species.

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5. Motion sickness should be less common in species with highly specialized or limited diets or in animals resistant to toxins that may be encountered in nature, since in these animals central mechanisms of the system for protection against toxins must be weakly developed.

6. When diet is changed during the course of a lifetime, changes in susceptibility to MS will occur. Thus, MS is rarely encountered in infants younger than 2 years old, when children consume a diet of milk and only a limited number of foods. Subsequently, sensitivity to MS increases sharply and reaches a maximum at ages 3-12, i.e., during the period when children begin to independently learn about what is edible and what is not. With age, sensitivity to MS decreases. Variation of sensitivity to MS in children is evidently associated with restructuring of the nerve centers, since it is well known that in mammals and humans the vestibular apparatus forms during early stages of ontogenesis and has stable characteristics. Decrease in sensitivity with age evidently is associated with degenerative changes in the vestibular apparatus, which begin in humans, for example, relatively early.

7. In animals subject to MS, sensitivity may differ not only because of differences in the CNS, but also due to differences in structural-functional organization of the receptor organs of the vestibular apparatus. Sensitivity to MS should be greater the better the capacity of the receptor organs to be modulated to correspond to alternating acceleration, the fewer defects of various kinds present in its structure, and the greater the predominance of polarization of receptor cells in the receptor epithelium.

Figure 1: Diagram of a portion of the endolymph surface of the receptor epithelium of the otolith organ of the vestibular apparatus. The structure of hair bundles of receptor cells is shown. The longest hair (kinocilia) are on one side and the shorter one (stereocilia) on the other. The arrow indicates the direction of polarization of receptor cells.

Figure 2. A diagram of polarization of receptor cells in the receptor epithelium of the sacculus of a guinea pig (A) and human (B). Explanation in the text.

P1439(31/91)* Nekhorosheva AS, Glinchikov VV.

Mechanisms underlying the effects of infrasound on the receptors of the auricular labyrinth.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 39-42; 1990.

[15 references; 1 in English]

Neurophysiology, Auricular Labyrinth, Receptors
Guinea Pigs
Infrasound

Abstract: In this experiment 18 guinea pigs were exposed to infrasound at 8 and 16 Hz with a level of acoustic pressure of 90-120 decibels in an acoustic isolation chamber. Duration of exposure was 1, 5, 10, 15, and 25 days, with daily exposure sessions lasting 3 hours each. Hearing in guinea pigs is very similar to that in humans, especially at frequencies of 1 kHz; their cochlea is accessible to manipulation, and they have been extensively studied in sound experiments. The animals were decapitated, the bulla tympanica opened, and the bone capsule of the cochlea sliced near the tip. Further manipulation took place with the aid of a stereoptic microscope. The entire labyrinth membrane, including its vestibular and cochlear sections, was removed at the same time. Nucleic acids were identified in the isolated cochlea to investigate processes of "rhythmic functional pulsation" of nuclei and concentration of nucleic acids in the outer and inner hair cells. Ampullae of the three semicircular canals were taken for electron microscopy and processed using standard methods.

After a single 3-hour exposure to infrasound, changes were inconsistent and included sharp increases or decreases in size of nuclei, including shriveled nuclei. There was swelling of cytoplasm, with increase in basophilic material, and formation of vacuoles. RNA in nuclei of type I receptor cells of the utricle, but not in type II cells, decreased. Electron microscopy revealed that changes in receptor cells of the semicircular canal were less pronounced than those in the vestibular area. The cytoplasm of the latter showed decreased number of ribosomes, widening of Golgi apparatus membranes, and a marked swelling of mitochondria. The most extreme changes occurred in the hair cells of the spiral organ displaying "functional pulsation" of the nuclei, as evidenced by redistribution of chromatin, decreased levels of diffuse RNA in the karyoplasm and cytoplasm, and increased size of nuclei. At the same time some cells were very intensely colored.

After 5 days of exposure, receptor cells of all three canals displayed marked polymorphism of nuclei, including very large, normal and shriveled nuclei. This was accompanied by lightening of cytoplasm and diminished diffuse RNA in karyoplasm and cytoplasm. Swelling and shriveling of nuclei is associated with "rhythmic functional pulsation" in response to infrasound. Electron microscopy revealed decreased ribosomes, severely swollen mitochondria, and deformation and tears in the membrane of the endoplasmic reticulum. These changes are associated not only with direct effects of infrasound, but with disrupted circulation.

On day 10, virtually all receptor cells of all canals were in a state of "functional shriveling." The outer hair cells were most changed while inner ones responded relatively weakly. After 25 days of exposure, all outer hair cells in all canals displayed shriveled nuclei with increased levels of RNA and strong displacement of DNA to the periphery, where clumps of chromatin formed highly stained areas. All the changes described were reversible and gradually normalized. Foot cells were virtually unaffected.

The authors conclude that they have demonstrated that changes occurring in receptor cells of the labyrinth and their severity are associated more with level of acoustic pressure and duration of the exposure than with frequency. Since effects of infrasound at frequencies of 8 and 16 Hz,

with acoustic pressure of 90-120 dB, led to reversible "functional shriveling" of the nuclei of receptor cells of the labyrinth, it is hypothesized that this shriveling is a result of cell fatigue.

Figure 1. Histological sections of the utriculus after 3 hours of exposure to infrasound

Figure 2. Flat preparation of the spiral organ

P1445(31/91)* Kostyuchenkov VN, Farashchuk NF, Bondarev DP.
Pharmacological correction of stress response to hyperthermia.
 Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.
 24(6): 53-55; 1990.
 [13 references; none in English].

Neurophysiology, Stress Response, Sympathetic Nervous System, Adaptation
 Rats, Males, Females
 Hyperthermia, Drugs, Neuroleptics, Adrenergic Blockers

Abstract: The goal of this experiment was to study the potential increase in adaptive capacities of the body to heat through use of neurotropic drugs. Experiments were performed on 260 white rats of both sexes. Animals were heated in a thermal chamber to 50°C with relative humidity of 26%. Heat stroke was judged to have occurred on the basis of prostrate position and absence of pain reflexes. Rectal temperature was measured before injection of drugs, before placing animals in the thermal chamber, and during heat stroke. One hour before heating, animals were injected subcutaneously with the following drugs: amobarbitol sodium, chlorpromazine hydrochloride, haloperidol, diazepam, benactyzine hydrochloride, adiphenine hydrochloride, nialamide, amitriptyline, sapilent (equivalent unknown), adrenalin, serotonin, L-DOPA, amphetamine sulfate, phentolamine hydrochloride, propranolol HCl, methyldopa, guanethidine sulfate, EGIT-739 (equivalent unknown), and hemidine (equivalent unknown). The state of the animals was assessed on the basis of time elapsed before development of excitement, and heat stroke. survival over the course of the day, weight of the adrenal and thymus glands, amount of bleeding in the stomach and biochemical parameters of blood. Blood levels of lactic acid, urea, nonesterified fatty acids, and ATP were measured. Ascorbic acid and cholesterol were measured in the adrenals and thymus. Acid-base balance of blood was also studied. After heat stroke the animals were decapitated and blood and organs removed for study. Analysis of variance was used.

Rats receiving no drugs began to display motor excitation after 18.8 minutes and heat stroke after 44.0 minutes. All animals died within 79.3 minutes. These animals displayed elevated blood lactic acid, urea, nonesterified fatty acids, and decreased ATP. Metabolic acidosis developed. There was bleeding of the stomach lining, and increased adrenal and decreased thymus weight. Adrenal glands displayed decreased levels of ascorbic acid and cholesterol attesting to disrupted glycolytic and energy-forming processes, and endocrine reactions. The neuroleptic chlorpromazine hydrochloride prevented occurrence of excitation, postponed heat stroke, and prevented death in 85% of the cases. It also decreased bleeding in the stomach and prevented changes in gland weight and blood lactic acid, urea and ATP. The stimulant amphetamine sulfate accelerated excitation, heat stroke, and death, and worsened biochemical parameters. However, the effects of the neuroleptic haloperidol were slight, while the tranquilizer diazepam and the soporific amobarbitol sodium had no effect. Thus, it would seem that the effects of chlorpromazine hydrochloride in hyperthermia were not due to its tranquilization of the CNS. However, this drug also affects the adrenal system. Other drugs with similar actions were tested. The β -blocker propranolol HCl had no effect, but the α -blocker phentolamine hydrochloride prevented death in 50% of the cases and improved biochemical parameters, suggesting that the antihyperthermic effect of chlorpromazine HCL is associated with effects on the α -adrenergic system. However, the adrenomimetics epinephrine and L-DOPA did not prevent death from hypothermia, while the antidepressants nialimide, sapilent, and amitriptyline with similar physiological action did so in 73% of the cases. Of drugs with a combined sympathetic and adrenergic action, methyldopa had a strong protective effect, and guanethidine sulfate, EGIT-739, and hemidine weaker ones. The central cholinolytics benactyzine hydrochloride and adiphenine HCl had a slight protective effect in hyperthermia.

The authors conclude that a number of neurotropic substances (chlorpromazine HCL, phentolamine HCL, nialamide, sapilent, amitriptyline, and methyldopa) can to some extent

improve the status of animals exposed to high temperature and prevent their death. At the same time these substances decrease shifts in glycolytic and energy formation processes and attenuate changes in endocrine glands. The results suggest that the sympathetic nervous system plays a role in development of heat stroke, and that drugs with a sympathotropic action should be used into prevent adverse effects of high temperatures.

Table 1: Effects of drugs on morphological parameters in hyperthermia

Table 2: Effects of drugs on biochemical parameters in hyperthermia

P1432(31/91)* Chernyakov IN, Sishov OA, Vorob'yev OA, Nekrasov VI, Popov NV, Razinkin SM, Semyonov AV.

The efficacy of hyperbaric oxygenation as a means to increase human tolerance of space flight factors.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 21-23; 1990.

[10 references; none in English]

Neurophysiology, Motion Sickness, Fatigue, Human Performance, Tolerance. Altitude, Motion Sickness

Humans, Males, Individual Differences

Space Flight Factors, Hypoxia, Acceleration, Coriolis, Hyperbaric Oxygenation, Nutrition

Abstract: This study investigated the efficacy of hyperbaric oxygenation as a means to increase human tolerance to acute hypoxia and Coriolis acceleration, as well as to eliminate fatigue and motion sickness during flight task performance. Experiments utilized a compression barochamber and devices simulating flight factors such as a high altitude barochamber, and a unit to produce optokinetic stimulation, as well as a tracking apparatus and a flight simulator. A total of 30 men, aged 19-48, whose health status had first been examined, served as subjects. Some subjects were selected for depressed high altitude and statokinetic tolerance. Hyperbaric oxygenation was produced either in a series of 5, 7, or 10 sessions or a single exposure. Duration of sessions was 1 hour and O₂ pressure attained was 2 atmospheres.

Four experiments were performed. In experiments 1 and 2, the efficacy of a course of hyperbaric oxygenation for increasing tolerance to high altitude hypoxia and rocking motion was investigated. In some conditions hyperbaric oxygenation was combined with a diet including a supplement (Novinka) designed to increase nonspecific resistance. In experiments 3 and 4 the efficacy of single hyperbaric oxygenation sessions to accelerate arrest of motion sickness symptoms was studied. A total of 407 sessions were completed.

In experiment 1 high altitude tolerance was estimated from duration of maintenance of mental performance (or time of occurrence of marked altitude sickness symptoms) during stepwise increase in altitude to an equivalent of 8 km, with 5 minute "plateaus" at altitude equivalents of 5, 6, 7, and 8 km. Evaluation of tolerance was based on altitude ceiling (highest altitude attained and total time at altitudes of 5, 6, 7, and 8 km). At each altitude plateau, the subject took a test of written arithmetic, while during the remainder of the time he responded orally to questions on the multiplication of numbers. A number of sessions were used to determine baseline high altitude tolerance and effects of repeated ascents before and after either a control condition or a session of hyperbaric oxygenation. Baseline tolerance varied from 6.8 to 7.3 km, and endurance time at 5-8 km from 14 to 16.5 minutes. In the control condition, repeated (2-4 times) ascents during a period of 2-4 months failed to show a pronounced training effect: tolerance increased by 0-0.3 km and endurance time by 1.5-0.8 minutes. The experiments using hyperbaric oxygenation were performed on subjects with low initial tolerance: initial tolerance ceiling was 6-6.4 km and endurance time from 10.6-11.5 minutes. The series of hyperbaric oxygenation sessions significantly increased tolerance. Ceiling increased by a mean of 0.8 to 1 km, and endurance time at 5-7 km increased by a mean of 3-4 minutes. The effect persisted for 2 months in 7 subjects, and 3 months in 4. Before hyperbaric treatment, subjects could only perform the written arithmetic task at 5-6 km, with diminished success; after treatment the same subjects were able to perform the task at 7 km. Cardiovascular parameters that responded to the treatment included heart rate (increased from 78 to 98-104 beats/minute at 5-6 km before treatment, and from 56-71 to 82-86 after it). Blood pressure also changed less on ascent after oxygenation. Cardiac output before oxygenation increased at 5-6 km by 1.5-3.5 l/minute due solely to increased heart rate. After treatment this parameter

increased by the same amount but was also attributable to increased systolic volume. Provocative tests revealed that the hyperbaric oxygenation treatment increased static endurance and voluntary breath holding.

Hyperbaric oxygenation had a smaller effect on individuals with moderate initial high altitude tolerance. When the nutritional supplement was administered alone without oxygenation, high altitude intolerance increased (does not specify for which groups of subjects, but appears to be those with moderate tolerance), but the effect was unstable and did not persist for long. Combination of the two treatments led to a marked increase in tolerance (ceiling increased by 1 km, and endurance time at 5-8 km by 5-8 minutes. These effects persisted after 1-2 months.

Effects of hyperbaric oxygenation on resistance to motion sickness was studied in subjects with low (0.5-1.5 minutes) and moderate (3-6 minutes) endurance of a vestibulometric test. Endurance (called statokinetic tolerance) was measured before and 1-2 days and 1 month after a series (7 over the course of 10 days) of hyperbaric oxygenation sessions. This treatment increased tolerance significantly (by a factor of approximately 2-2.5) only for subjects with moderate initial tolerance. This effect persisted in a weakened form for 1 month.

In a separate experiment the use of hyperbaric oxygenation to arrest symptoms of motion sickness was investigated. Subjects were exposed to motion sickness inducing stimulation until symptoms rated 8-10 on Galle's scale developed. A control group received no further treatment, the experimental group underwent a one hour hyperbaric oxygenation session 20-30 minutes after motion sickness induction. Subsequently both groups were observed until all symptoms disappeared as indicated by psychophysiological parameters. For the control group, recovery occurred after 4.2 hours, and for the experimental group after 3.2 hours; however the difference was not statistically significant. A preliminary (pre-motion sickness) course of hyperbaric oxygenation appeared to intensify the effect of the treatment applied after motion sickness.

The effect of hyperbaric oxygenation on fatigue was studied in subjects performing a 24-hour session on a flight simulator and those working at a tracking task under exposure to high noise and heat until exhaustion. Twenty-four hours after the marathon performance on the simulators subjects who had not undergone hyperbaric oxygenation had not fully recovered, those who had been exposed to a single treatment session had done so. After the tracking task, hyperbaric oxygenation treatment curtailed the time until full recovery from 36-72 hours to 24-48 hours.

P1452(31/91) Matsnev EI, Yakovleva IYa, Serebrennikov MI, Gavrilin LN, Zakharova LN, Nichiporuk IA, Isupov VG, Markin AS.

The course of motion sickness in long-term otolith stimulation in a head-down tilt position.

Vestnik Otolaringologii

1990(1): 8-14,

[37 references; 24 in English]

Authors Affiliation: Institute of Biomedical Problems, USSR Ministry of Health.

Neurophysiology, Motion Sickness, Tolerance, Body Fluids, Fluid Redistribution
Humans, Males, Individual Differences
Head-Down Tilt

Abstract: To investigate the hypothesis that space motion sickness may be a symptom of a more general space adaptation syndrome, the authors tested induction of motion sickness on the parallel swing in a position of head-down tilt (-8°), simulating fluid redistribution to the upper body typical of the early period of adaptation to weightlessness. In this study the subject lay on his back in a special parallel swing so that the long axis of his body coincided with the axis of rocking of the swing. During motion sickness induction, hemodynamic shifts were recorded visually and through data of an impedance plethysmogram of the head, medical monitoring was performed and symptoms of motion sickness were rated. Before, during and after the treatment physiological parameters recorded included: EKG in 11 standard leads, respiration frequency, compensatory eye movements oculographically recorded synchronously with swing movements, skin temperatures, blood pressure, and ocular counterrolling. Blood and urine were analyzed for various hormones by radioimmune assay, as well as electrolytes. Exposure was terminated after 4 hours, or sooner if severe motion sickness or vestibulohemodynamic symptoms occurred. Subjects were 30 healthy male volunteers, aged 24-37, divided into two groups on the basis of resistance to motion sickness. The first group (n=17) included individuals with average vestibuloautonomic tolerance as indicated by performance with a preliminary procedure consisting of 10 minutes of cumulative Coriolis and precessional acceleration. The second group included 13 individuals with low levels of tolerance.

The two groups showed significant differences in the expected direction in the time to develop motion sickness and in its severity. The majority of subjects experienced vestibulohemodynamic discomfort including signs of fluid redistribution in the cranial direction and symptoms of motion sickness. These symptoms included puffiness, and pallor or hyperemia of the face, difficulty breathing through the nose, symptoms of the ears being stopped up and rush of blood to the head, heaviness of the head, and hoarseness, spatial illusions (feeling of falling or tumbling), sleepiness, perspiration, heat or cold, nausea, hypersalivation, and in some cases vomiting. Impedance plethysmography of the head revealed that subjects prone to motion sickness displayed decreased pulsed blood filling, significant changes in tone of the major peripheral arteries and capillaries, and in venous resistance. Such symptoms were much less pronounced in those resistant to motion sickness. There was a tendency for those resistant to motion sickness to display greater otolith symmetry. Motion sickness induction eliminated compensatory eye movements in 7 subjects. The ocular counter-rolling reflex was altered in all subjects after treatment. The amplitude decreased, and as a rule the asymmetry increased. Group 1 subjects generally displayed reliable decreases in activity of plasma renin activity, concentration of aldosterone and sodium with unaltered angiotensin I, antidiuretic hormone (ADH), ACTH, thyrotropin, hydrocortisone, and prolactin, with a tendency of plasma osmolarity to decrease and level of growth hormone (GH) to increase. Urine showed a tendency for osmolarity to decrease with virtually unaltered excretion of fluid and electrolytes. Group 2 subjects displayed reliable increases in plasma ACTH, ADH, GH, prolactin, hydrocortisone, aldosterone, potassium, and renin activity, compared both to their own baseline and data from

group 1. Blood sodium decreased and osmolarity increased. Excretion of fluid, sodium, potassium and chlorine increased significantly and osmolarity decreased. Changes in this group were evidently associated with the high levels of glucocorticoids in blood and altered response of the renin-angiotensin system to the head-down position.

Table 1: Endurance of rocking motion on the modified parallel swing in group 1 and 2 subjects

Table 2: Changes in hormonal status after motion sickness induction on the modified parallel swing (in % of baseline)

Parameter	Group 1 (n=8)	Group 2 (n=14)
Growth hormone	410±130*	986±203*,**
Prolactin	96±17	292±45*,**
ADH	96±7	151±14*,**
ACTH	159±32	327±74*,**
Aldosterone	74±12+	111±11**
Hydrocortisone	105±13	151±12*,**
Plasma renin activity	36±10+	120±15**
Angiotensin I	86±20	96±14
cAMP	43±4*	95±11

* Difference significant compared to baseline (p<0.05)

+ Difference described as significant in text, but not so marked in table.

** Difference between groups significant (p<0.05), not marked in table reconstructed from text.

PAPER:

P1429 (31/91) Katuntsev VP, Nikolayev VP, Anisimov OI, Sherbakova MA.

Evaluation of the possibility of arresting decompression sickness in cosmonauts by raising space suit pressure.

In: Biomedical Problems of Decompression: Papers from the First All-Union Conference.

Moscow: 1991: 16-17.

[No references]

Authors' Affiliation: Institute of Biomedical Problems, USSR Ministry of Health

Operational Medicine, Decompression Sickness, Pain

Humans

Space Suit Pressure, Compression

Abstract: Many experiments studying the effects of high-altitude decompression on humans have shown that symptoms of decompression sickness in the form of muscle and joint pains typically disappear when pressure is increased to a level that is still below that on Earth. For this reason the most natural means to arrest decompression pains that may occur in cosmonauts during EVAs, is provision of the capacity to increase pressure in the EVA suit above the standard level. To determine the minimal level of pressure that arrests high altitude decompression pains, a series of 24 barochamber sessions with 7 volunteers were conducted.

A subject breathing oxygen through a mask ascended at a rate of 25 m/sec. to an altitude equivalent of 7000 m, where every 20 minutes he performed 5 minutes of physical exercise, which tends to provoke decompression sickness. If symptoms did not occur after 1 hour, then he was raised to an altitude of 8100 m, and if necessary to 9000 or 10000 m, where he also performed physical exercise on the schedule indicated above. When high-altitude decompression pains occurred, a subject underwent compression by means of decrease of the altitude in the barochamber at a rate of 5 m/sec. Compression was stopped when the pain symptoms disappeared and the altitude attained at that moment in the barochamber was held constant for 20 minutes. Then pressure in the barochamber was lowered to the previous level and if pain did not reoccur, the subject began to exercise. If pain occurred again, it was arrested by the same method. In each experiment the total duration of the subject's exposure in the barochamber at low pressure did not exceed 5 hours.

In the 24 experimental sessions there were 38 instances of arrest of decompression pain occurring at altitude equivalents of 7000-10000 m. The largest number of instances of pain arrest (15 of 38) occurred with pain developing at 8100 m, i.e. during decompression from normal pressure to 260 mm Hg (0.356 atm.). In all these instances, 20 minutes of compression produced pronounced arrest of the decompression pains.

Due to the relatively small amount of experimental data, the difference between pressure levels arresting the first, second and third occurrence of pain in the same subject were not statistically significant. However, these data suggest that the requisite pressure depends strongly on the time of the pain occurrence, counting from the moment of ascent to the first test altitude. When pain occurred between 40 to 100 minutes it was arrested by increasing barochamber pressure by a mean of 41 mm Hg; when it occurred between 100 and 150 minutes, pressure had to be increased by 67 mm Hg, and when it occurred later pressure had to be increased by 74 mm Hg. On the whole, arrest of decompression pain occurring at an altitude of 8100 m required compression be increased by a mean of 61 mm Hg, with a range from 24 to 121 mm Hg.

Thus, the research showed that pain symptoms of high-altitude decompression sickness, can be arrested effectively by relatively slight compression suggesting that this technique could be

used in cosmonautics. Judging by the greatest values for the requisite compression identified in the experiment, the practical implementation of this technique would require the potential for increasing space suit pressure with regard to standard of 0.35-0.4 atm by 0.2 atm (i.e., to 0.6 atm).

P1430 (31/91) Barer AS, Filipenkov SN.

Decompression safety of work in EVA suits.

In: Biomedical Problems of Decompression: Papers from the First All-Union Conference.

Moscow: 1991: 16-17.

[4 references; 4 in English]

Authors' Affiliation: Zvezda Machine-building Plant

Operational Medicine, Decompression Safety
Theoretical Article, Humans, Cosmonauts
Space Suit, EVA

Abstract: The risk of decompression sickness (DS) and the duration of desaturation procedures are determined by the ratio of partial nitrogen pressure in tissues and pressure in the space suit, the so-called coefficient of supersaturation (CS). In theory, to provide absolute decompression safety one must assume that decompression may occur with some determined probability at any level of nitrogen supersaturation. The Americans make this assumption and, for example, set the risk of decompression sickness during EVA at CS of 1.1. The authors consider this assumption too conservative, arguing that it overestimates the probability of decompression sickness. They state that it has been demonstrated experimentally that given moderate supersaturation of tissue with CS range of 1.3-1.8, decompression sickness is improbable given conditions of physical activity characteristic of EVA. Use of this range provides statistically reliable decompression safety during work in an EVA suit. The original pressure schedule in the suit was based on work by Haldane indicating that pressure decrease from a normal atmosphere by a factor of 2.25 and thus a CS of 1.8 is the threshold for development of decompression sickness. Later it was found that DS occurs at lower CS of up to 1.4. Thus, breathing of oxygen for no less than 30 minutes is required before EVA. To accelerate desaturation moderate exercise is performed during the decompression period. The authors believe that during nitrogen desaturation, it is essential to differentiate CS for various tissues. Thus, the blood and lungs have a half-desaturation period in oxygen breathing of 2 minutes, internal organs of 1.5-10 minutes, and muscle and blood of 12-30 minutes. After 30 minutes of oxygen breathing, CS approaches 1 for these tissue for decompression of 38-42 kPa. Only bone, connective, and fat tissues, which require a long period of oxygen desaturation, have CS of 1.6-1.8 in the conditions described.

The theoretical range of pressures in a spacecraft cabin and suit may fall between normal pressure (101.3 kPa) and partial oxygen pressure in air (21 kPa). When a pure oxygen atmosphere is used, the lower limit of pressure in the suit is determined by danger of hypoxia and must be 20 kPa, while the upper limit (50 kPa) is determined by hyperoxia. It is believed that when oxygen exceeds the latter limit it becomes toxic for the lungs when EVAs are repeated a number of times. Given space suit pressure of 30-40 kPa, oxygen breathing is accompanied by moderate hyperoxia, and functional changes, which rapidly normalize after the procedure or during exercise.

If lowered pressure of 20-30 kPa is used, metabolic rate and physical effort needed to maneuver in the space suit decreases. Such pressure can only be used after a long desaturation period or in emergencies for short term exposure with vital signs monitored. High pressure, on the order of 55-70 kPa leads to inflation and stiffening of the space suit shell. Thus the effort needed by the cosmonauts to maneuver increases and the flexibility of the suit decreases. At the same time gas leakage, particularly through the pressurized bearings, increases and bearings become more difficult to design. Thus from an engineering standard a low pressure schedule is preferable, although inconsistent with the physiological preference for high space suit pressure to avoid desaturation. Thus compromise is required. Compromise solutions are presented in Table 2.

OPERATIONAL MEDICINE

The procedure of shifting from a normal atmosphere with pressure of 101.3 kPa through intermediate pressure in the spacecraft cabin of approximately 70 kPa to a final pressure of 34 kPa was studied and validated in the "Apollo-Soyuz" program.

The Soviet concept of DS prevention is based on the need to support a high level of safety for cosmonauts on EVAs. It provides both minimal risk and capacity to perform therapeutic measures if DS does occur. These measures include recompression, breathing pure oxygen, hyperbaric oxygenation in the suit at a pressure on the order of 140 kPa, and relative rest for 12-24 hours. All these measures have been developed to be as cost effective as possible. The safety of the decompression schedule used by the Soviets is backed by data from a large number of barochamber tests of high-altitude gear, over a period of 30 years summarized in Table 3.

Available data confirm that the reliability of DS protection for the 95% confidence interval is no lower than .995, with probability of DS at 0.5%. In addition, there have been no instances of DS on actual EVAs (65 instances, by 26 cosmonauts, for duration of 0.2-7 hours, at pressure of 38-42 kPa with three shifts to pressure of 27-30 kPa for 1-3 minutes) Analysis of this material has suggested a hypothesis linking decrease in DS probability with nature of motor activity of cosmonauts and with the constraining effects of the space suit shell on amplitude and angular velocity of joint motions. The authors hypothesize that with motion limited, cavitation and thus gas bubble formation is diminished. This is confirmed by the positive effect of wearing space suits on preventing DS. Stringent medical selection of cosmonauts is also important. The Soviets believe that individuals with defects in the cardiac septum should not be permitted to perform EVAs.

Reports of cosmonauts themselves is currently the main procedure for diagnosing DS during EVAs. In the future, ultrasound Doppler instruments built into the suits may also be used. In addition analysis of signals concerning gas formation must be automated.

Table 1:

O ₂ breathing 4-6 hrs at pressure:	Partial pressure, mm Hg				Acid-base equilibrium	
	in alveoli		in capillaries		pH units	BE mequiv/l
	PAO ₂	PACO ₂	PAO ₂	PACO ₂		
101.3 kPa	660	39.5	348.3	39.5	7.39	-0.93
42 kPa	212	36.4	110.8	38.4	7.40	-1.8
40 kPa	192	37.2	113.5	39.3	7.38	-1.9
30 kPa	132	38.7	93	38.3	7.39	-1.22

OPERATIONAL MEDICINE

Table 2:

Space program	Desaturation, hrs	Pressure, kPa		O ₂ level, %	
		cabin	suit	cabin	suit
Gemini Apollo	breathing of O ₂ before launch (3 hr) and exposure to oxygen atmosphere of the cabin before EVA	34	25.2	100	100
Skylab	breathing of O ₂ before launch (3 hrs) and exposure to oxygen atmosphere in spacecraft and oxygen-nitrogen atmosphere in station before EVA	34	25.6	70	100
Shuttle	1) 3.5 hrs. O ₂ breathing in suit before EVA;	101.3	29.3	22	>95
	2) 1 hr. O ₂ breathing before drop in cabin pressure, no less than 12 hrs. exposure to hypobaric atmosphere and 0.67 hr. breathing of O ₂ in suit before EVA	69.3	29.3	26.5	>95
USSR	0.5 hr. O ₂ breathing in suit before EVA	101.3	40 and 30	22	>95

Table 3:

Condition	Pressure, kPA	Energy expended, W	Time min	sessions	Number of	
					subjects	Cases of DS
without suit	38-42	230-350	120-360	1162	--	110
with suit	37-40	230-350	120-360	624	207	0
with suit	27-30	230-350	15-40	198	100	10
						(in 8 subjs)

P1448(31/91)* Perkovskiy AV.

Hardware system for maintaining certain sanitary and hygienic parameters for the medical module of spacecraft.

Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

24(6): 62-63; 1990.

[18 references; 3 in English].

Operational Medicine, Medical Module
Sanitary and Hygienic Parameters
Equipment and Instrumentation, Hardware System

Abstract: This paper describes in general terms a system for maintaining environmental parameters in the medical module on future long-term spacecraft. Studies are said to indicate that general space station environmental parameters are not fully adequate for use as a medical treatment facility. For example, it would be desirable to have the life support system for the module contain a system for bacterial protection creating an area with a bacteria-free atmosphere. Auxiliary areas of the module could maintain the same environmental parameters as the station as a whole; however, the author argues that the environment should be designed for the therapeutic quarters on the basis of additional special considerations, e.g., decreased resistance of an ill individual. A table of recommended parameters for such areas as the operating area, and infectious diseases isolation is provided.

Table: Major sanitary-hygienic parameters of specialized areas

Figure 1: Composition and major functions of the life support system for a spacecraft medical module

Figure 2: Flow chart of the bacterial protection system for a spacecraft medical module LSS

Figure 3: Classification of the peripheral components of the bacterial protection system

PAPERS:

P1404(31/91) Polyakova NZ.

Psychophysiological characteristics of operators and their effects on performance parameters as a function of gender.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences; Institute of Biomedical Problems, USSR Ministry of Health

Pages: 265-266.

Human Performance

Humans, Males, Females, Gender Differences

Psychology, Psychophysiological Characteristics

Abstract: The problem of sexual dimorphism (differences in structural and productive parameters) and dipsychism (differences in psychological characteristics), posed in the works of B.G. Ananyeva and N.A. Tikha have important theoretical and applied significance for human space flight. Professionally significant traits, especially personality traits were examined as a function of gender.

The study involved 99 apparently healthy subjects (of whom 44 were female). Subjects were studied while they were undergoing flight certification examinations. Measurements included: personality traits (i.e., MMPI, Cattell 16 factor test); level of anxiety (i.e., Silber-Hannan method); and need for recognition (i.e., Raven methodology); and also included features of operator performance on the "Palestra-02" device. Autonomic responses (i.e., heart rate and blood pressure) revealed very clear dimorphism in the subjects.

Findings:

- Within-individual variability of motor and intellectual functions (in performance of the Raven test and operator tasks on the Palestra-02 device) were higher for females, and within group variability for males. This is evidently associated with characteristics of females (high emotionalism, anxiety, etc.). This would explain their lower achievement in activities involving emotional stress. In males, the high variability of mean values within the group may be explained by their high level of motivation to reach their goal;
- The process of acquiring sensorimotor skills was more successful in females than in males. The former are better at retaining associations formed in previous series and thus have a greater ability to maintain their job performance at an optimal level;
- While males display a high level of reactivity in parameters of systolic and diastolic pressure, females show more reactivity in pulse pressure under conditions of frustration during their flight certification examinations;
- Speed of response at the beginning and end of the task performance period are different in males and females. Females show more intense autonomic response at the beginning of a frustrating situation, but recover more rapidly to the initial level after it is over. Males react more slowly and recover more slowly after termination of the frustrating factor.

These characteristics suggest that females are more flexible with respect to exposure to stress factors than are males.

Experimental research has shown that the problem of sexual dysphoria (as one of the most important problems in applied psychophysiology) is of major significance for medical support of space flight at the stages of selection, training, and operational medical monitoring of cosmonauts.

P1431(31/91)* Myasnikov VI, Gushchin YuR, Ivanovskiy YuR, Kholin SF.
Medilab and problems of psychophysiological support of manned space flights.
 Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.
 24(6): 11-18; 1990.
 [26 references; 8 in English]

Psychology, Psychophysiological Support, Human Performance, Group Dynamics, Space Flight,
 Equipment and Instrumentation, Computer Complex
 Theoretical Article, Humans, Cosmonauts
 Operational Medicine, Medilab

Abstract: The problems of providing psychological support for the increasingly large and heterogeneous crews of long-term space flights will be addressed through the use of a multipurpose computer-based "psychophysiological complex" on board the MEDILAB orbital biomedical laboratory which will be docked with space stations. The complex will be included in the actual "human-machine" system of the station, thus allowing diagnostic work to be performed through quantitative evaluation of "symptoms." At the same time, these symptoms are parameters of the functional capacity and professional reliability of the crew (e.g., sleep, performance, group interactions, psychophysiological stress, job skills, etc.). The complex will also solve problems of psychological prophylaxis and optimization of crewmember job performance and will monitor status of professionally significant traits. These traits will be treated as a hierarchically organized system. Mission performance during flight will be determined by the following factors:

- task properties (rate, number and variety of elements, degree of uncertainty);
- motivation to perform assignments, level of achievement motivation;
- performance capacity: general (status of higher psychological functions - attention, memory, thinking) and special (job-related skills);
- state of perceptual and cognitive functions;
- psychoemotional state;
- personality traits;
- nature of intragroup interactions and cooperative activity.

A measure of performance efficiency will be derived from the ratio of relevant parameters of speed, reliability, and accuracy, and the psychophysiological "cost" of the result obtained. Only dynamic evaluation of the entire set of parameters will allow the specialists to use MEDILAB for the following objectives:

- diagnosis of changes in professionally significant traits during the flight;
- prediction of successful mission performance and changes in the psychological health of cosmonauts;
- prevention of adverse effects of space flight factors on the psychophysiological state and performance capacity of the crew;
- correction of possible deviations from optimal levels for the given individual under the given conditions.

Important diagnostic information is provided through "by-products" of task performance, such as speech and work style. Speech parameters used for these purposes include acoustic characteristics, amount of verbal activity, and verbal initiative. Quantitative measures (unspecified) have also been devised for assessing style. The major source of diagnostic information is the performance of the crew. The same system is used for evaluating performance during testing, training, and actual flight.

Computers may be used not only to gather, process, and store information, but to present test situations to the operator. In the system being developed, plans call for diagnostic research to be performed during the course of training on a computer based simulator. In addition, a multipurpose operator test will be developed in the form of a computer game, incorporating a number of methods of evaluation. The game will be of modular format so that different aspects of performance can be tested separately or in combination with specified others, as required. As a game the test can also be considered part of the relaxation facilities.

Plans call for ensuring motivation of crewmembers to cooperate with psychodiagnostic procedures by:

- presentation in the form of a computer game, avoiding monotony and fatigue;
- integration of diagnostic testing into work on the training simulator which is associated with high levels of motivation;
- provision of on-line performance feedback and participation of crewmember in immediate use of results to select specific prophylactic and corrective measures (e.g., work schedule, psychological regulation system).

When diagnostic techniques are selected, plans call for use of concealed tests, decrease in the number of direct methods (e.g., questionnaires) in order to avoid conscious manipulation of results by cosmonauts. Analysis of speech and work style, and study of movements of crewmembers relative to each other within the inhabited modules will be important, since they are not subject to the conscious manipulation of the operator.

Selection, sequence, and other aspects of use of diagnostic, prophylactic, and corrective psychological measures will be individualized. Plans call for the use of adaptive tests, which will allow each individual to take fewer tests, without compromising reliability and validity of the results.

The concept of this system involves a number of specifications on how information will be presented to the physician and subject:

- the examination will be performed in interactive mode, creating the illusion of human conversation, by individualizing the dialogue through rephrasing and utilizing in further communication information previously obtained from the subject;
- the rate at which information is presented to the operator must accord with his perceptual speed, without waiting periods;
- data collection must be confidential;
- test information and results of the research should be presented primarily in graphic form, for better intelligibility.

Specifications for the collection, processing and analysis of information include:

- complex automation of all phases of the operation;
- the capacity to control all software and hardware;
- the capacity for processing psychological information in real time (during the test);
- concomitant recording and preliminary processing of physiological parameters (EKG, GSR, HR, EEG, EMG, etc.);
- the capacity to create a base of data, knowledge, models and methods, and use it actively;
- the capacity to create dynamic models of psychophysiological state and performance capacity based on a constantly augmented "psychophysiological passport" for each operator.

Development of this system will have two phases. During the first on the ground, the most appropriate psychophysiological methods and models of work schedules will be selected. During the second stage, in space flight, the final selection of methods will occur on the basis of comparative evaluation of their diagnostic effectiveness and prognostic significance. Subsequently, the selected methods will be placed in a data base and used in orbit.

The systems for psychological diagnosis, prophylaxis and correction will use a common set of software and will have very similar structures.

Hardware required will include:

- a computer or computer net with standard I/O devices;
- additional I/O devices (special keyboard, mouse, joystick, etc.);
- devices for recording the operator's physiological parameters (sensors of BP, EKG, EMG, EEG, EOG, temperature, GSR, HR, microphones, accelerometers, etc.);
- devices for preliminary processing of electrophysiological and biophysical signals (amplifiers, transformers, filters, etc.);
- devices for storing digital and analog information (magnetic and optical media);
- devices for generating graded biophysical stimulation (stimulators of biologically active points and reflexogenic zones, generators of sound, background light, smells, etc.)

All these devices will form an automated work station for the operators. The physician will also have an automated work station consisting of an intelligent terminal of a distributed net of information processing and computer hardware. The station will allow the physician access to all the capacities of the complex.

Data structures will include data and model banks, documentation programs, access protection programs, and programs for the storage, generation, and individualization of the mathematical models of physiological system and behavioral responses. Algorithms will include formalized methods (procedures and algorithms) for examinations and experiment, procedures of on-line and delayed analysis of information obtained to correct the formalized knowledge base, programs for simulation modelling of operator tasks, and for processing and selecting scientifically justified principles, methods and procedures for solving problems, including means for formalizing and presenting knowledge (hypothesis, models, theories). Software developed for the system will be divided into systems and applications. The systems software will organize the operating system for running the applications programs which will implement the algorithms and data structures described above. The software will offer the user a menu, hints, interactive graphics, sound signals and other properties of a friendly interface. When algorithms for standard psychophysiological studies are in operation, the default regime is used to free the operator to concentrate on the tasks at hand. The applications programs will have a modular expandable structure so that they can be modified and replaced to solve new problems.

Plans also include a special isolated psychophysiological module on MEDILAB for performance of the tasks described above. The use of several independent work stations will make possible training exercises involving joint work by two or more operators. It will be possible to translate psychophysiological information during performance of actual operator tasks from operator station to the psychophysiological complex. The psychological software of the system will be integrated in the system for MEDILAB as a whole.

The ground-based portion of the system will provide:

- methodological, hardware and software flexibility in support of experimental activity;
- the capacity to perform research while simultaneously modeling physiological effects of space flight factors on humans;
- simulation of job performance using mock-ups of real consoles and cabins;
- two way information exchanges with analogous on-board devices.

Figure 1: Parameters affecting performance efficiency of a human operator

Figure 2. Information technology for psychological diagnosis, evaluation, and optimization of the level of professional skills, and psychological prophylaxis and correction of a human operator

Figure 3. Flow chart of the psychophysiological complex

P1442 (31/91)*Mikhaylichenko PP, Tikhonchuk VS, Ushakov IB.

Neuropharmacological reactivity in response to the effects of extreme factors: The effects of irradiation.

Kosmicheskaya Biologiya i Aviaksomicheskaya Meditsina.

24(6): 47-49; 1991.

[26 references; 1 in English]

Neurophysiology, Central Nervous System, Physical Endurance

Mice, Males

Radiobiology, Irradiation, Drugs

Abstract: Experiments were performed on white male mice irradiated with γ -quanta from ^{137}Cs in a dose of 100 Gy with dose rate of 1.9 Gy/min. Effects of radiation on the functioning of the central nervous system were studied by administering drugs with a selective effect on specific receptor formation: galantamin [an alkaline isolated from snowdrop berries that inhibits choline esterases and increases sensitivity to acetylcholine] (30 mg/kg); benactyzine hydrochloride (30 and 60 mg/kg); arpenal [γ -Diethylaminopropyl ester of diphenylacetic hydrochloric acid, which blocks n-choline receptors of the autonomic ganglia and central nervous system] (30 mg/kg); amphetamine sulfate (3, 6, and 10 mg/kg); phentolamine hydrochloride and propranolol hydrochloride (1 mg/kg); haloperidol (0.5 and 1 mg/kg); apomorphine hydrochloride (2mg.kg); phenazepam [7-Bromine-5(ortho-chlorophenyl)-dihydro-1H-1,4-benzodiazepin-2-on, a tranquilizer] (0.05 and 2 mg/kg); phenibut [γ -Amino- β -phenyl butyric acid hydrochloride, a phenyl derivative of GABA] (200 mg/kg); and strychnine (0.1 and 0.2 mg/kg). These drugs were injected intraperitoneally 1.5 and 5.5 hours after irradiation (30 minutes before a forced swimming test). Pharmacological efficacy was evaluated on the basis of physical muscle endurance 2 and 6 hours after irradiation. The pool for the forced swimming test used for this evaluation was filled with water at 35° C. To make the test more taxing, a weight 5% of body weight was attached to the animals' tails. Duration of swimming was measured at the point of drowning. Each experiment had its own control.

Previously it had been established that irradiation in the dose used here decreases physical endurance soon after treatment with a maximum effect after 2 hours and recovery 6 hours after treatment to 70-80% of the norm. Results showed that the reversible inhibitor of choline esterase galantamin increased duration of swimming in nonirradiated rats by more than a factor of 1.5. However, neither 2 nor 6 hours after irradiation did it improve endurance in treated subjects. Benactyzine hydrochloride, a blocker of central M-cholinergic structures, slightly improved performance of nonirradiated mice at the lower dose and sharply decreased it at the higher dose. Arpenal, a antagonist of n-choline receptors, had a similar effect. Two hours after irradiation these substance lost their effect on endurance, but 6 hours after irradiation arpenal's effect was identical to that for the control group. These results suggest that the sensitivity of the affected CNS receptors is impaired 2 hours after irradiation, while that of n-cholinergic receptors recovers after 6 hours.

Amphetamine, which indirectly mimics the effects of norepinephrine and dopamine, had no effect on endurance of irradiated animals, while increasing endurance at the lower dose of nonirradiated animals. The higher dose impaired performance nonirradiated subjects, but did not affect irradiated ones. In all subjects this drug increased stereotyped movements and aggression. It is hypothesized that the post-irradiation decrease in sensitivity of catecholaminergic systems to this powerful psychostimulator is associated with disruption of the functional activity of specific postsynaptic receptors particularly α - and β -adrenergic synapses.

The agonist of benzodiazepine receptors, phenazepam, which in a dose of 0.05 mg/kg stimulated endurance of nonirradiated animals, had no effect on endurance 2 hours after irradiation, and depressed it 6 hours after treatment. At a dose of 2 mg/kg, this drug completely depressed endurance of nonirradiated mice, but increased it both periods after irradiation. The agonist of GABAergic receptors, phenabut, did not affect endurance 2 hours after irradiation, but had a similar effect to that on the control group 6 hours after irradiation. The stimulating effect of the concurrent antagonist of glycinergic receptors, strychnine, was not in evidence 2 hours after irradiation, even when the dose was doubled.

The results obtained suggest that partial recovery of physical endurance of irradiated animals is accompanied by activation of certain mediator systems, specifically, the n-cholin- and GABAergic and benzodiazepine receptors. Evidently these neurochemical structures have a pronounced compensatory effect on the relationship between processes of excitation and inhibition in the CNS, which are accompanied by a recovery of the disrupted physical performance of irradiated animals. It is likely that the drugs tested lose their effectiveness on endurance due to disruption of sensitivity of neurochemical structures to their agonists and antagonists.

Figure 1: Effects of neurotropic drugs on duration of swimming of mice at various periods after irradiation in a dose of 100 Gy

Figure 2: Effects of neurotropic substance on duration of swimming of irradiated mice

P1443 (31/91)* Belousov VV.

Changes in the amplitude of the B-wave of electroretinograms of rabbits after irradiation of the eye with ultraviolet light.

Kosmicheskaya Biologiya i Aviaksomicheskaya Meditsina.

24(6): 49-51; 1991.

[8 references; 7 in English]

Neurophysiology, Electroretinogram, B-wave

Rabbits

Radiobiology, UV-Irradiation

Abstract: Subjects in this experiment were 9 chinchilla rabbits whose eyes were irradiated with ultraviolet light with spectral maximum at 302 nm and biologically effective doses of 10,000, 5,000, 3,000, and 1,000 J/m². To record electroretinograms, rabbits were wrapped in cloth and placed in a special stand. The ERG recorded was the sum of response to 10 flashes of identical intensity. Frequency of stimulation was 1 Hz, duration of the flash was 3.1 msec. The intensity of the stimulus decreased radially in a range of approximately 6 logarithmic units. Stimuli of 10-12 different intensities were used in the experiments. Each animal was tested three times to obtain control values for the ERG. The amplitudes of B-waves were tested using the nonparametric Kolmogorov-Smirnov and Wilcoxon statistics.

Amplitude of the B-wave decreased during early post-irradiation stages. By the end of the observation period (days 20-30) values had recovered somewhat but had not returned to baseline, even though overt signs of photokeratoconjunctivitis had disappeared. Even a slight decrease in B-wave amplitude may correspond to a large decrease in light perception. Changes in B-wave amplitude may be attributed to a cumulative result of decreased transparency of structures in the eye as well as changes in the retina associated with UV-radiation.

Table: Decrease in amplitude of B-wave of the ERG in rabbits at various times after irradiation of the eye with UV-radiation.

PAPER:

P1412(31/91) Ilyin YeA, Korolkov VI, Kaplanskiy AS, Alpatov AM.

Some results of research on biosatellites COSMOS-1887 and -2044.

In: Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina.

Tezisy Dokladov IX Vsesoyuznoy Konferentsii. Космическая Биология и Авиакосмическая Медицина. Тезисы Докладов IX Всесоюзной Конференции. [Space Biology and Aerospace Medicine: IXth All-Union Conference]

Kaluga: 19-21 June 1990.

Affiliation: Scientific Council on Space Biology and Physiology, USSR Academy of Sciences;

Institute of Biomedical Problems, USSR Ministry of Health

Page 311-313.

Space Biology and Medicine, Adaptation, Neurophysiology, Musculoskeletal System, Cardiovascular System, Body Fluids, Metabolism, Gastrointestinal System, Hematology, Microbiology, Genetics, Developmental Biology, Biological Rhythms
Monkeys, Rats, Bacteria, Fish, Amphibians, Botany, Higher Plants, Insects, Worms
Space Flight, COSMOS-1887, -2044

Abstract: On 2-week flights of biological satellites COSMOS-1887 and -2044, experiments were performed to study the mechanisms of the physiological reactions of animals during the initial and transitional period of adaptation to weightlessness. In experiments on monkeys of the species *Macaca mulatta* a comprehensive study was performed on mechanisms underlying the functioning of the vestibular and motor systems, and a large number of studies were conducted of the cardiovascular system, fluid electrolyte metabolism, and bone and muscle systems.

Study of the mechanisms of adaptation of the vestibular and motor systems showed that in weightlessness the level of static and dynamic excitability of the canal of the vestibular apparatus, vestibular nuclei, and integrative areas of the medulla increase. The studies conducted identified the temporal dynamics of the motor function in flight from days 1 to 7 and later up to day 14 and made it possible to hypothesize the processes on which adaptation of motor function is based.

Study of the monkeys' behavior, and conditioned reflex performance, and sleep of the monkeys did not reveal significant changes in the functions of the higher nervous system. On day 1 postflight, there were changes in hydration status, including decreased total, interstitial, and intravascular fluid, shift of fluid from extracellular to the intracellular space, and increased excretion of K, Ca, Na, and P. Postflight there were changes in erythron function as manifested by shifts in lipid and phospholipid spectra, decrease in electrophoretic mobility, and increased metabolic processes in erythrocytes.

Experiments on Wistar line rats showed that a 2-week exposure to weightlessness leads to significant adaptive shifts in a number of functional systems. Thus, study of the CNS revealed increase in sensitivity of the otolith apparatus and the system of "receptor cells of the utricle -- neurons of the vestibular ganglion," a decrease in the functional activity of motoneurons of the spinal cord, and a decrease in the flow of afferent impulses to the sensorimotor cortex. The rats' muscles diminished in strength and rate of contraction, and there was a decrease in level of actomyosin, atrophy of muscle fibers, and changes in neuromotor synapses. The gastrointestinal tract displayed development of hypersecretory stomach syndrome and a decrease in the functional activity of the pancreas. The hemopoietic organs, as in the preceding experiments, displayed inhibition of erythroid hemopoiesis.

The "Trauma" experiment (on biosatellite COSMOS-2044) represented a first attempt to study the effects of weightlessness on the course of repair of skin, muscle, and bones of rats. At the

present time it can be concluded that the process of healing injured muscles and bones is significantly inhibited in weightlessness.

Experiments in gravitational biology during the flight of the biosatellites utilized a variety of different subjects: bacteria (*Escherichia coli*); protozoa (*Tetrahymena pyriformis*, *Chlamydomonas reinhardtii*, *Chlorella pyrenoidosa*); higher plants (*Daucus carota*, *Brassica napus*, *Impatiens balsamina*); insects (*Trigonoscelis gigas*, *Drosophila melanogaster*, *Carausisus morosus*); fish (*Poecilia poecilia*); and amphibians (*Pleurodeles wallii*). For the first time it was demonstrated that the genetic apparatus of the cell could participate in the response to space flight factors. Experiments on cellular biology were the starting point for development of a concept of the existence of several interrelated paths through which the gravitational stimulus is realized at the level of the cell. One insect experiment revealed for the first time a displacement of a fundamental biological constant -- spontaneous (endogenous) period of circadian rhythm, indicating the possibility of changes in optimal duration of a day in weightlessness. Another insect experiment revealed an especially vulnerable stage in embryonal development, at which the effects of weightlessness are adverse. A series of experiments on various levels of organisms -- plants, worms, and amphibia -- showed that space flight factors do not impede the process of post-traumatic regeneration, but in some cases actually accelerate it.

This paper considers future directions for research on the mechanisms of homeostasis at various stages of adaptation to weightlessness under conditions of space flight.

MONOGRAPH:

M174(31/91) Trudy XXIV Chtennii Posvyashchennykh Razrabotke Nauchnogo Naslediya i Razvitiyy Idey K.E. Tsiolkovskiogo; Труды XXIV Чтеннии Посвященных Разработке Научного Наследия и Развития Идей К.Э. Циолковского [*Proceedings of the XXIVth Lecture Series Devoted to Development of the Scientific Heritage of K.E. Tsiolkovskiy*]. Kaluga 12-15 September, 1989.

Section on: Problems of Space Medicine and Biology
Moscow: USSR Academy of Sciences; 1990 (79 pages)

KEY WORDS: Space Biology and Medicine, Immunology, Origin of Life, Perception, Neurophysiology, Decompression Sickness, Cardiovascular and Respiratory System, Botany, Plant Growth

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Report Documentation Page

1. Report No. NASA CR-3922(37)		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle USSR Space Life Sciences Digest - Issue 31				5. Report Date September 1991	
				6. Performing Organization Code	
7. Author(s) Lydia Razran Stone, Ronald Teeter, and Joseph Rowe, Editors				8. Performing Organization Report No.	
				10. Work Unit No.	
9. Performing Organization Name and Address Lockheed Engineering and Sciences Company 600 Maryland Avenue, SW, Suite 600 Washington, D.C. 20546-0001				11. Contract or Grant No. NASW-4292	
				13. Type of Report and Period Covered Contractor Report	
12. Sponsoring Agency Name and Address Office of Space Sciences and Applications National Aeronautics and Space Administration Washington, DC 20546-0001				14. Sponsoring Agency Code	
				15. Supplementary Notes Lydia Razran Stone and Ronald Teeter: Lockheed Engineering & Sciences Company, Washington, D.C. Joseph Rowe: Library of Congress, Washington, D.C.	
16. Abstract <p>This is the thirty first of NASA's USSR Space Life Sciences Digest. It contains abstracts of 55 journal or conference papers (including all papers in Issue 6 , 1990 of the journal "Kosmicheskaya Biologiya i Aviakosmicheskaya Meditsina")published in Russian and of five Soviet monographs. Selected abstracts are illustrated with figures and tables from the original. The materials in this issue have been identified as relevant to 18 areas of space biology and medicine. These areas are: adaptation, biological rhythms, cardiovascular and respiratory systems, endocrinology, enzymology, genetics, group dynamics, habitability and environment effects, hematology, life support systems, metabolism, microbiology, musculoskeletal system, neurophysiology, operational medicine, psychology, radiobiology, and space biology and medicine.</p>					
17. Key Words (Suggested by Author(s)) space biology, aerospace medicine, flight experiments, flight simulation, microgravity, USSR			18. Distribution Statement Unclassified - Unlimited Subject Category 51		
19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of pages 116	22. Price A06		



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