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DEVELOPMENT OF GUIDELINES FOR SETTING PHYSIOLOGICAL AND HYGIENIC STANDARDS FOR NOISE LEVELS IN AEROSPACE MEDICINE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 28 Mar 83) pp 4-7

[Article by Yu. V. Krylov]

[English abstract from source] The development of the physiologic and hygienic principles of noise standardization in aerospace medicine is described. The contribution of aerospace medicine to the theory of noise standardization is emphasized. Also discussed are principles of standardization with respect to noise equivalent levels, dose-based standardization, as well as noise tolerance related to the work load. Further studies are needed to assess the applicability of the above principles for the evaluation of noise effects onboard flying vehicles.

[Text] The work of pilots, cosmonauts and engineering-technical personnel who service flying vehicles is constantly asssociated with the noise factor. For this reason, it is a tradition in aerospace medicine to investigate the adverse effect of noise on health status and work capacity of the above-mentioned specialists [2-5, 9-11, 17, 20-22, 24, 25, 28, 31, 33, 36, 37, 44-46, 52-60, 62, 64, 65].

The studies of Soviet and foreign authors have observed the distinctions of effects of noise on the acoustic analyzer of pilots, as related to its intensity, duration, distinctions in using aircraft and helicopters. Works dealing with the effect of noise on hearing under the specific conditions of spaceflights are of independent significance [3, 20, 25, 31, 37, 45, 54, 57, 58, 64, 65].

Among the set of measures to prevent the adverse effect of noise on man, an important place is referable to working on questions related to its physiological and hygienic standardization, which was first done in the USSR [38, 39]. Standard-setting was based on evaluation of intensity of noise, with consideration of its effect on the auditory analyzer. Subsequent modification of the standards retained this pricniple. Subsequently, allowable noise levels for residential buildings and transport vehicles were also defined [8, 15, 16, 32, 34]. Introduction of sanitary standards for noise was an important phase in elaboration of measures to improve working and recreational conditions for workers. However, use of the developed standards involved difficulties, since in practice one encounters more often intermittent noise, which fluctuates in time and level. The variability of these parameters is often so great that it is impossible to use regulations to assess the adverse effect of noise. For this reason, aviation methods proposed that noise be standardized on the basis of its duration. For example, I. Ya. Borshchevskiy, E. V. Lapayev and V. S. Kuznetsov, who studied the performance of aviation specialists, concluded that in the case of daily exposure, a noise of 100 dB for 6 h, 110 dB for 1 h and 115 dB for no more than 30 min could be allowable. Of basic importance is the conclusion that, if earmuffs are used, the allowable noise levels could be increased by 10 dB [6]. Subsequently, aviation medical specialists, who studied the effect of acoustic energy in excess of 125 dB, arrived at the conclusion that it is necessary to develop means of "total protection" of man against noise [19]. The principle of "noise intensity--class of antinoise gear," "noise intensity--time of continuous exposure" was experimentally validated in aviation and cosmonautics [21]. These studies essentially reflected already the "energetic principle of effects of noise on the body," which was used for elaboration of new guidelines for setting standards, more adequate to practice [14, 40, 51]. Experimental validation of the energy principle of noise effects made it possible to turn to estimation of its equivalent level.

The equivalent (in energy) level of sound, L_{eq} (in decibels A) of a given non-constant noise corresponds to a sound that has the same root-mean-square sound pressure as a constant noise for a specific period of time.

Calculation of equivalent level is made using the formula:

$$L_{A\,eq} = 10\lg\frac{1}{100}\left(\sum_{i=1}^{n} f_i\cdot 10^{0.1 L_i}\right) = 30 + 10\lg\left[\sum_{i=1}^{n}\frac{1}{100} f_i\cdot 10^{0.1(L_i - 30)}\right] = 30 + \Delta L_A,$$

where f_i is the share of number of sound level readings within a given interval in relation to total number of readings (%), L_i is mean level in a given interval (in dBA) and $i = 1, 2, \ldots, n$.

Noise levels are broken down into 17 intervals, from 38 to 122 dBA, in 5 dBA steps; the number of readings in each interval is counted. The share of readings, specific [or partial] indexes and values of ΔL_A (in decibels A) are determined from special tables [16, 41, 42, 63, 67].

Further development of the scientific concept of equivalent levels consists of validating the principle of "noise dose" (ND), i.e., energy of noise accumulated over a specific time of its presence.

In essence, ND is the product of multiplying L_{Aeq} by exposure time. Determination of noise energy is an intermediate step for calculation of ND. It is proportionate to the square of sound pressure. The dose of noise energy can be described, in somewhat simplified form, by the following function:

$$D = E/r = p^2 t,$$

where E is transmitted noise energy (in J), r is wave drag of the air atmosphere for two eardrums each 9 mm in diameter, while p is mean sound pressure in time t. The following formula provides a more complete expression of dose in the case of nonconstant noise, with consideration of transition in relative values (%):

$$ND = \frac{\sum^{n} p_i^2 t_i}{ND_{all}} \cdot 100\ \%,$$

where p is sound pressure corresponding to noise levels, L_i and t_i is time of exposure to noise of the following level:

$$L_1 \left(\sum_{i=1}^{n} t_i = 8\ h \right),$$

where n is total number of periods of noise, ND_{all} is allowable noise dose, taken as 100, and corresponding L_{eq} = 85 dBA for an 8-h work day [7, 12, 13, 26, 41, 48, 61, 66, 68].

The next direction of development in setting standards, which is important to aerospace medicine, is the conception of "daily noise dose" (ND_{day}) with consideration of nature of work, recreation and sleep of subjects ($ND_{day} = ND_w + ND_{rec} + ND_{slp}$) [7]. This conception expands significantly the annual safe ND developed in the United States [11]. Use of the conception of daily ND with consideration of its levels at work, during leisure hours and sleep (ND_w, ND_{rec} and ND_{slp}) is extremely attractive for the most adequate standardization of the acoustic factor during long-term spaceflights. This approach is also quite convenient for setting noise dose standards for flight and engineering-technical personnel. At the same time, it should be noted that, according to the description, the dosage increases substantially when noise level is raised. Thus, when noise level is raised from 90 dBA by 10 dBA, the dosage increases by more than 10 times. For this reason, in recent years work has been in progress to validate the range of applicability of the dose estimates for nonconstant noises. Thus, G. A. Suvorov and V. G. Shinev showed that, with a noise in excess of 95 dBA, dosage as an integral evaluation of nonconstant noise is an inadequate indicator of its deleterious effect [47]. The data we have submitted make it necessary to proceed with caution in interpreting the results of investigations under conditions where a worker is exposed to high-intensity noise, even if it is for a short time. This applies primarily to the distinctions of the work of ground-based aviation specialists.

In recent years, data have been obtained indicative of the marked general adverse effect of noise on man [1, 23, 41]. The accumulated experimental data indicate that it is possible to assess the effect of noise on a worker only with quantitative consideration of degree of fatigue that develops under the influence of the work process itself [41]. To date, the basic quantitative functions have been determined referable to characteristics of industrial noise and intensity of labor [27, 49, 50], as well as for the combined effect of noise, marked muscular and nerve loads characterizing both the difficulty and intensity of labor [18].

Use of the obtained data, with consideration of the possible modifying effect of the distinctions of work of pilots, cosmonauts and engineering-technical personnel for the purpose of setting differentiated standards for noise in aviation and cosmonautics, is a rather pressing task.

It is also important to consider the combined and associated effect on aerospace specialists of noise, vibration and other physical and chemical factors [29, 30, 35, 43]. However, in view of the extreme complexity of this problem, it should be submitted to special scrutiny and analysis.

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EXPERIMENTAL AND GENERAL THEORETICAL RESEARCH

UDC: 629.78:612.13/.17.014.47

COSMONAUTS' POSTURAL REACTIONS AFTER LONG-TERM MISSIONS ABOARD SALYUT-6 ORBITAL STATION

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 21 Jun 83) pp 7-10

[Article by V. V. Kalinichenko and A. F. Zhernavkov]

[English abstract from source] Tilt tests were used to study changes in cardiovascular responses to ortho- and antiorthostasis of four cosmonauts after their 96- and 140-day flights onboard Salyut-6. Preflight the cosmonauts were exposed to head-up and head-down tests in order to facilitate their readaptation to weightlessness. Postflight all cosmonauts exhibited a better cardiovascular capability to counteract cranial blood redistribution during antiorthostatic tilt tests. This can be considered as a result of their adaptation to weightlessness. After flight every crewmember showed a significant decrease of orthostatic tolerance. One of the factors responsible for the lower orthostatic tolerance is assumed to be inactivity of the vascular tone mechanisms. It is suggested that their better stimulation before reentry may improve the efficacy of countermeasures against postflight orthostatic disorders.

[Text] Investigation of mechanisms of alteration of circulatory system control during spaceflights is a mandatory prerequisite for improving methods of maintaining good work capacity of cosmonauts during missions and restoration of their functional state after them. For this purpose, studies were pursued of circulatory system reactions to orthostatic and antiorthostatic loads in the commander (CDR-1) and flight engineer (FLE-1) after a 96-day mission, as well as in the commander (CDR-2) and flight engineer (FLE-2) following 140-day flight aboard Salyut-6 orbital station.

Methods

Evaluation of circulatory system function in earth's gravity was made by means of a passive postural test, which consisted of having the subject in the following successive positions: horizontal, orthostatic (70°) for 10 min, horizontal and antiorthostatic [head-down tilt] of -15° and -30° for 6 min each. The Savitskiy mechanocardiograph was used to record parameters of systemic hemodynamics, and a rheograph was used to record delivery of blood to the head in the bitemporal lead; both tests were done in each even-numbered minute in the above positions. From the mean values of primary parameters and their dynamics over the period of the test, we calculated integral parameters of orthostatic (IPO) and antiorthostatic (IPA) tolerance of systemic hemodynamics, as well as the parameter of antiorthostatic tolerance of blood flow in the head (PATBFH).

Results and Discussion

Antiorthostatic reactions. The similarity of hemodynamic changes in antiorthostatic position and in weightlessness [1-3, 7] make it possible to assess, to some extent, adaptation to weightlessness according to nature of postflight antiorthostatic reactions. The capacity of the circulatory system to counteract blood redistribution in a cranial direction with an antiorthostatic load was used as the gage of adaptation. This capacity is called antiorthostatic tolerance (ANOT).

Initial antiorthostatic tolerance of the crew of Salyut-6 did not exceed the satisfactory level, which is normal for healthy males in the usual occupations, but not adequate for rapid adaptation to weightlessness. For this reason, in order to enhance the adaptation capabilities of the circulatory system, accelerate and facilitate its adaptation to flight conditions, it was suggested that adaptation be started in the preflight period. For this purpose, the cosmonauts undergo special conditioning with use of gravitational loads of variable sign [6]. We monitored progress of the conditioning process by determining the parameter of antiorthostatic tolerance of blood flow in the head during each training session. The conditioning process involves, in most cases, temporary worsening of adjustment of antiorthostatic tolerance. Since only the first stage of the training process had been performed, for several reasons, before lift-off, ANOT diminished in 3 cosmonauts and remained close to the base level only in CDR-2. We observed the plastic type of conditioning in CDR-1 and FLE-2, which enabled us to predict good adaptation to weightlessness, whereas in the FLE-1 and CDR-2 it was conservative, implying some difficulties in adaptation.

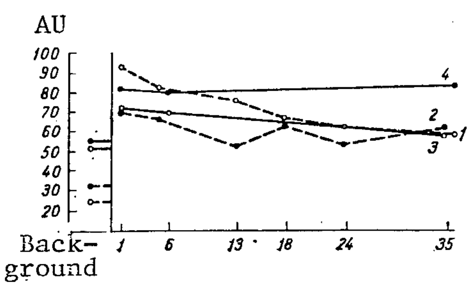

Figure 1.
Integral parameters of antiorthostatic tolerance (in AU--arbitrary units) of systemic circulation of cosmonauts before and after flights. Here and in Figures 2 and 3:
1) CDR-1 3) CDR-2
2) FLE-1 4) FLE-2
X-axis, postflight days

One day after landing, the reactions to an antiorthostatic load became more conservative in all of the cosmonauts than preflight, and we interpret this as the consequence of adaptation to weightlessness. Increased antiorthostatic resistance of the circulatory system was manifested by the following changes in parameters in antiorthostatic position, as compared to preflight data: shorter expulsion period, decreased cardiac output and ratio of lateral systolic pressure of arm to leg, increased tonus of major arteries and peripheral resistance. The integral parameter of antiorthostatic tolerance increased by 69 points in CDR-1, 38 in FLE-1, 19 in CDR-2 and 28 in FLE-2 (Figure 1).

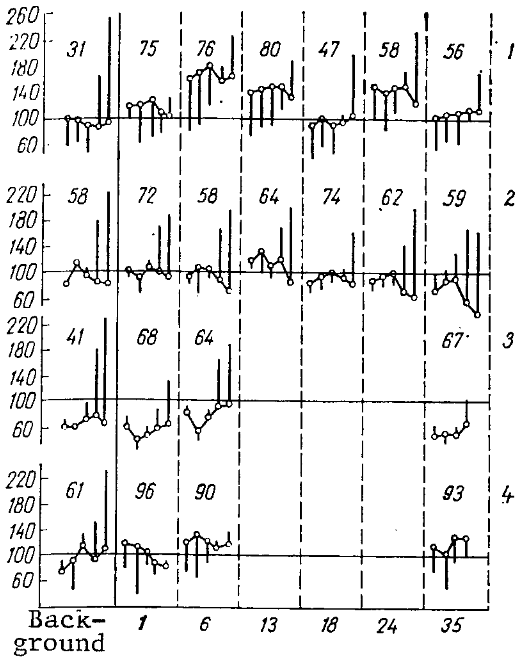

Figure 2.
Dynamics of rheoencephalographic parameters during passive postural tests
Circles on curves--amplitude of early peak of systolic wave as average for successive test positions, horizontal, orthostatic, horizontal, -15° and -30° antiorthostatic; vertical lines--difference between amplitude of early and late systolic waves (in mΩ); the numerals on the graphs refer to antiorthostatic stability of head circulation

There was very typical change in control of circulation in the head. All cosmonauts presented a decreas in pulsed delivery of blood to the head in head-down position (Figure 2). This change was the most marked in CDR-1 and FLE-2, who also presented high antiorthostatic tolerance and parameters of systemic circulation. It was significant that, when they were in a -15° position, pulsed delivery of blood to the head even diminished somewhat, as compared to horizontal position, whereas it had increased before the flight. Even in -30° position, delivery of blood to the head remained virtually stable, which was indicative of adequate adaptation of circulation in the head to weightlessness and confirmed the prediction made from results of preflight conditioning.

Reversal of the above changes was slow, and antiorthostatic tolerance was substantially greater in all cosmonauts 5 days after the flight than before it. The persistence of adaptive changes in regulation of the circulatory system is apparently determined chiefly by duration of exposure to weightlessness. Thus, signs of adaptation to weightlessness were demonstrable for about 1 week after missions lasting up to 8 days, 2-3 weeks after 30-63 day flights, 3-4 weeks after 96-day flight and 5 weeks after the 140-day one.

Orthostatic reactions. Orthostatic tolerance was good before flights in all cosmonauts. On the day they landed, it was diminished in all cases, according to medical monitoring. Thus, tolerance of orthostatic position by CDR-1 and CDR-2 did not exceed a few minutes, and for the CDR-2 orthostatic intolerance was aggravated by vestibular disturbances.

Cosmonauts tolerated the 10-min orthostatic load with greater tension 1 day after landing than preflight. Poorer orthostatic tolerance was manifested by greater increase in heart rate, reduction of expulsion period and cardiac output. In addition, great-artery tonus was diminished in CDR-1 and CDR-2. At the time, the integral parameter of orthostatic tolerance was lower than preflight by: 26 points for CDR-1, 15 for FLE-1, 30 for CDR-2 and 23 points for FLE-2, i.e., their orthostatic tolerance was about one-fourth lower than the preflight level, although it did increase significantly within one day back on earth. The decline of orthostatic tolerance was more persistent in the cosmonauts after the 140-day mission than after the 96-day flight (Figure 3). The course of restoration of orthostatic tolerance reflected the proper choice of the motor readaptation program, along with the depth of deconditioning of control mechanisms. It was noted that both too active and too passive

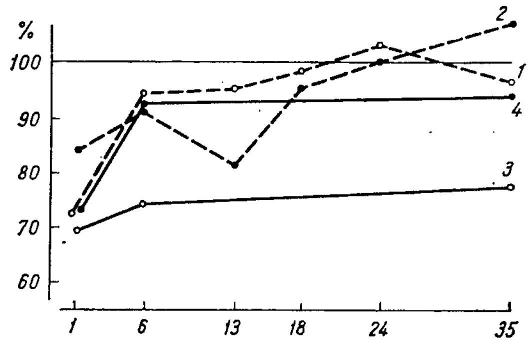

Figure 3.
Integral parameter of orthostatic tolerance after the missions (% of preflight value)

conditions lead to a second decrease in orthostatic tolerance. Such a second decrease was observed in FLE-1, apparently due to inadequate motor activity at the early stage of readaptation.

It is known that, with increase in flight duration, one observes a tendency toward increase in orthostatic deconditioning. However, most cosmonauts who participated in missions lasting 1 month or more can be put in the same group according to orthostatic tolerance. The basic differences in extent of decrease in orthostatic tolerance were attributable to the nature of individual resistance to the adverse effect of weightlessness which, in our opinion, is indicative of the desirability of special screening for long-term missions.

The fact that orthostatic tolerance increases quite rapidly upon returning to earth's gravity and that one observes retention of capacity for increasing vascular tonus with an orthostatic load enables us to consider the inactive state of mechanisms of controlling vascular tonus, particularly the pressor reaction, as the main cause of low orthostatic tolerance. Their activation by the time of landing could apparently be considered as a means of prevention of postflight disorders that is still not being used to a full extent.

Thus, as a result of testing postural reactions following long-term spaceflights, we found that it was possible to both facilitate adaptation to weightlessness by means of preflight conditioning and to improve the efficacy of preventing postflight orthostatic disorders.

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DIET OF FIRST SOVIET EXPEDITION ON MOUNT EVEREST

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 8 Apr 83) pp 10-14

[Article by M. S. Belakovskiy, V. A. Voskoboynikov, V. N. Gulyayev, T. S. Zakharenko, Yu. A. Senkevich, V. A. Ivanov and N. G. Bogdanov]

[English abstract from source] Biomedical requirements for the diets to be used by the Soviet mountaineers during their Everest expedition have been determined, employing the experience of Soviet mountaineers who have ascended the highest summits in this country, dietary data accumulated by the mountaineers who have conquered the Himalaya Mountains and the Karakoram Range, as well as current concepts of human physiology and biochemistry in highlands. This paper presents the major nutritional parameters of the diets and the arrangement of meals. The Soviet mountaineers were on the whole happy with the diets and showed no disorders in the health state, gastrointestinal system or digestive function that can be of nutritional origin.

[Text] When working on questions of organizing optimum nutrition for participants of the first Soviet expedition up the world's highest peak, Mount Everest (8848 m above sea level) and formulating diets, current conceptions were used concerning physiological and biochemical distinctions of human vital functions at high altitudes, the abundant Soviet experience in conquering the highest mountains in our country (Communism, Lenin peaks and others); a comprehensive analysis was made of available data on organizing nutrition of participants in expeditions to the Himalayas and Karakoram Range, to altitudes of around 8000 m [1-18]. Foods and diets as a whole were tested under model conditions (pressure chamber) and in the Tyan-Shan and Pamir mountains. The results of these studies made it possible to define the main biomedical criteria for forming the food allowances:

The diet should cover the energy and plastic requirements of the body, and it must be differentiated, depending on altitude and intensity of work done.

While the diet should be of maximum nutritional value, the foods should have minimal volume and weight.

As altitude increases, the proportion of main nutrients in the diet should change in the direction of lowering the quota of fats and raising the quota of carbohydrates, primarily those that are readily assimilated (monomers, oligomers, in particular fructose).

Protein content in the diet should follow the same pattern, depending on altitude--reduction of protein with increase in altitude, but it should constitute at least 12% of total calories.

Proteins in the diet must be primarily of animal origin, with optimum amino acid proportion.

Fats should be primarily of plant origin, with a large share of unsaturated fatty acids.

Vitamin (water- and lipid-soluble) intake should be increased to 200%, starting at the base camp, as compared to the physiological norm. Special attention should be given to adequate intake of antioxidant vitamins.

The food items in the diet should be selected in accordance with the individual preferences of expedition members, taking into consideration the decrease and change in appetite at high altitudes, and they should be as diversified as possible.

The assortment of foods, according to data on change in appetite and experience of high-altitude climbs, should include some with sharp flavor and odor.

Most of the dishes should be prepared in such a way that they could be consumed in liquid and hot form.

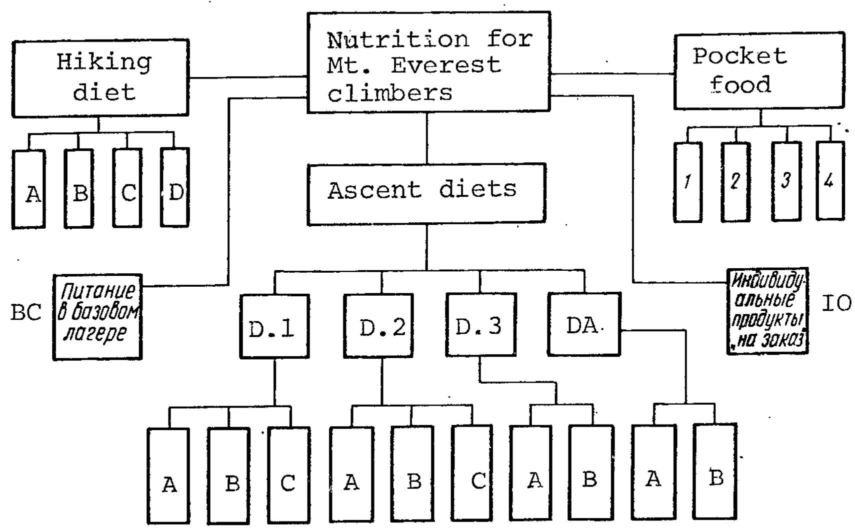
Use of "pocket" food consisting mainly of carbohydrate monomers is recommended while advancing on the itinerary, setting up mountain camps and assaulting the peak.

Intake of at least 3 liters of water per day per expedition member is recommended during approach to base camp and while remaining there, and at least 4 liters at high altitudes.

Artificial mineralization by means of salt supplements is recommended to improve the organoleptic properties and physiological value of melt recovered from snow or ice and intended for drinking purposes.

Several versions of diets for use at different stages of ascent (see Diagram) were developed in accordance with the above recommendations. The food kits provide 1 day's nutrition for participants in the expedition at different stages of the ascent: when approaching the base camp and returning to it, at different altitudes and when assaulting the peak (Table 1). The ration kits consisted of an assortment of canned meat, fish, vegetables, dairy and fruit products, concentrates, confections, dry fruit, sugar, tea and coffee. There was wide representation of foods preserved by the heat sterilization method, with heat and sublimation drying for dehydration, which made it possible to reduce the total weight of the rations considerably.

Chart of mountain climbers nutrition



Key: D) diet
DA) diet during assault
IO) individual "ordered" foods
BC) base camp diet

Table 1. Main indicators of nutritional value of expedition diets (M±m)

Places where diets were used	Caloric value, kcal	Protein, g	Fat, g	Carbo-hydrates, g	Total weight of food, g	Total wt. without pocket food
Hiking (Katmandu--base camp--Katmandu)	4648±127,3	194,0±7,1	209,1±16,7	537,5±3,1	1600,4±99,8	—
Base camp	5203,1±135,6	199,5±6,3	246,8±11,5	576,1±17,6	1741,4±61,7	—
At 5300-6500 m	337,5±174,8	120,0±11,4	153,9±7,5	394,4±26,2	933,0±19,5	803,0±19,5
At 6500-7800 m	2588,8±106,4	85,1±12,0	92,9±11,1	334,8±47,9	714,2±26,3	584,2±26,3
At 7800-8500 m	2434,9±129,1	66,1±8,8	77,2±17,5	360,6±114,2	638,5±92,9	508,5±92,9

To make up the rations, the foods used were prepared at a time that assured their preservation for the duration of the preparatory period and expedition, but for at least 6 months. Colored fabric sacks were used to identify the different rations. All of the foods had labels indicating the name of the product, net weight, and they were put up in portions for two people.

During passage to the base camp and return to Katmandu, a 4-day (see diagram, A, B, C, D) hiking diet was used, which provided for 3 meals per day. In this case, in addition to canned foods, extensive use was made of fresh products (meat, green vegetables, etc.). Moreover, so-called pocket food was provided for this period (see Diagram, 1, 2, 3, 4). Average nutritional value of the hiking diet was 4650 kcal, with 194.0±7.1 g protein, 209.1±16.7 g fat and 537.5±31.1 g carbohydrates.

It was important to organize wise nutrition at the base camp, which was a sort of recovery center. The distinction of the diet there was that it was necessary to recover the weight lost after the ascent, as well as to form physiological supplies of protein, carbohydrates and minerals. The ration was planned for 7 days, with 4 meals per day. The rather diversified menu included a wide assortment of fresh foods: potatoes, meat, vegetables and fruit that were purchased from the indigenous inhabitants. Many dishes were prepared to order for the climbers: stuffed meat, pancakes, dumplings, meat-pies, etc. Total nutritional value was about 5300 kcal/day. On the eve of the expedition, each climber ordered a lunch of his choice and was given a "gift" assortment, which included honey, candies, fruit, fruit pudding, roasted meat, etc. The rations for the climb were differentiated, depending on the altitude and intensity of work: from 5300 to 6500 m, 6500 to 7800 m and 7800-8500 m (see Diagram, D.1, D.2, D.3). The first two rations were for 3 days (A, B, C) and provided for 3 meals. The last ration was of the 2-day type (A, B), also with 3 meals per day. With increase in altitude, there was substantial decrease in overall weight of rations, which constituted 803.0±19.5, 584.2±26.3 and 508.5±92.9 g, respectively. For this reason, the caloric value of the daily rations decreased from 3372.5±174.9 to 2434.9±129.1 kcal. The share of carbohydrates increased substantially, to 71%, with decrease in protein to 13.4% and fats to 15.6% (in relation to total basic nutrients). For obvious reasons, special attention was given to planning an assault diet (DA) (Table 2), which was consumed at the final and most difficult stage of the ascent. The diet was used in two versions (A, B): weight 411.0 and 445.0 g, caloric value 1775.5 and 1574.2 kcal, respectively. The rations included cottage cheese with pureed black currants, beef tongue in aspec, tea, sugar, plum jam, prunes with nuts, cake, wheat bread, dehydrated juices, dry milk, salt, dehydrated garlic sauce. The assault diet had less than 14% fat content, 14.5% protein and 71.5% carbohydrates.

Pocket food, consisting chiefly of carbohydrates was consumed while "processing" the itinerary, setting up mountain camps and during assault of the peak.

On the whole, the climbers considered the food rations satisfactory. They retained a relatively good appetite. The flavor of the food remained normal. The amount of food was sufficient. Results of analysis of questionnaire responses revealed that freeze-dried cottage cheese, dessert based on cream of wheat, sauces and different gravies were particularly popular with the mountain climbers. Many stated that there was not enough sugar in the rations and that they had a negative attitude toward the sterilized bread in small packages.

Table 2. Basic indicators of nutritional value of assault rations (8500-8848 m)

Indicators of nutritional value of rations	First version: without pocket food	First version: with pocket food	Second version: without pocket food	Second version: with pocket food	Mean (including pocket food)
Caloric value, kcal	1775,5	2192,2	1574,2	2229,2	2210,67
Protein, g	43,75	69,85	52,8	63,5	66,7
Fat, g	48,8	61,1	46,6	67,5	64,3
Carbohydrates, g	239,1	299,2	247,8	358,8	329,0
Overall weight (without packaging), g	411,0	541,0	445,0	575,0	428,0 558,0

No disturbances referable to wellbeing, condition of the gastrointestinal tract and digestion related to the diet were observed during the ascent.

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PSYCHOPHYSIOLOGICAL NATURE OF 'AIRCRAFT FEEL'

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 5 Aug 83) pp 14-18

[Article by A. V. Vorona, S. V. Aleshin and A. M. Safronov]

[English abstract from source] On the basis of reported data and questionnaires filled in by 26 pilots and 60 cadets an attempt was made to give a psychophysiological characterization to the "aircraft perception." It was compared with the characteristics of motor skills and thus the "aircraft perception" was interpreted as an objective property of flying skills, i.e., a specific expression of automatic actions the pilot performs when flying a plane. At a certain stage of the development of the flying skills some movements are controlled via direct sensations and perceptions of noninstrumented signals. The "aircraft sensation" unloads the pilot's attention allowing him to concentrate on other problems.

[Text] From the time aviation emerged and to this day, there have been such expressions as "sense for aircraft," "flying feel," "bird feel," "instinct," etc. in flying practice. In the contemporary literature, the concept of "aircraft feel" or "flying feel" is used more often [5, 7, 9, 10]. This expression is invested in an aura of mystery, and it is related to experiencing the feeling of "fusion" of the pilot with the aircraft, aircraft obedience, feeling of joy and elation about the flight. The attitude of pilots and aviation physicians toward the "aircraft feel" is dual.

Thus, V. S. Tkachev, the first recipient of the Order of St. George in Russian aviation, in his manuscript, "The Wings of Russia," believed that such a sense is very important to flying an aircraft, and he noted its relation to flight experience: "I personally started to comprehend the entire significance of so-called feeling in flight and reflex many years later...." [8]. One of the first Russian pilot-instructors, P. A. Kuznetsov wrote about the same thing: "After lengthy practice, you will be able to sense somehow, internally, whether the airplane is moving in horizontal position, whether it is climbing or descending, or ascending too steeply, or making a very sharp curve. You acquire, so to speak, the necessary feeling of equilibrium in the air, the instinct and feel of a bird...." [2].

On the other hand, P. N. Nesterov, who is not only a pioneer in aerobatics, but a founder of the principle of awareness in flight training, indicated: "The construction of a craft requires of us, as a mandatory property, 'instinctive' piloting. It is this instinctive control that has been the cause of death of many aviation comrades and colleagues" [3].

Among specialists in aviation medicine, various opinions have existed and still do concerning the role of "aircraft feel" in flying practice. Thus, Patient, Hazelton, Porter, Mashborn, Grote, Metz, Ruff and Shtrughold observed that a feel for flying is very important to piloting an aircraft. Grote called attention to its special role in controlling an aircraft when the ground is visible.

V. A. Ponomarenko and N. D. Zavalova stressed the benefit of "aircraft feel" construed by them as the sense of connection with the craft while flying it [5, 9]. In their conception of the image of a flight, "aircraft feel" is contained in the structure of image of flight as an independent element.

On the other hand, Geratevol', who authored a survey [10] dealing specially with this matter, concluded that the significance of "flying feel" to piloting is debatable and requires further investigation. A. P. Popov wrote on this score: "True, a good pilot 'feels the machine and studies its quirks,' but this is not what pilots previously mean under the term of 'flight feel.' In modern times, the content of the concept of 'flight feel' that was imparted at the early stages of development of aviation cannot, of course, be taken into consideration. On the contrary, at the present time, aviation physicians instill in modern pilots a distrust in the 'flight feel' and trust in instruments, with which flights are made today, particularly when meteorological conditions are difficult and at night" [6].

Thus, in spite of the long-term existence of the concept of "aircraft feel" in aviation practice, there is still no scientifically validated interpretation for it. In our opinion, this hinders, to some extent, development of psychophysiological recommendations for formation of the proper mechanism of psychological control of pilot actions during flight training.

Analysis was made of opinions voiced in the literature on this score, on the one hand, and those of pilots and cadets from one of the flying schools, on the other hand, in order to obtain a reasonable interpretation of the psychophysiological nature of "aircraft feel" and determination of its significance to flying.

Geratevol' believed that Grote provided the best definition for "flying feel"; he viewed it as "man's capacity for proper and fine perception and subconscious selection of all sensory stimuli important to controlling an aircraft, and the capacity to react to them with well-coordinated reflex movements of the limbs." In turn, Geratevol' himself mentioned the close relationship of "flight feel" to sensorimotor coordination, which he construed as man's "capacity" to transform reactions of the body or limbs, evoked by sensory stimuli, into purposeful, desirable and coordinated movements." Metz related the "aircraft feel" to the fact that the aircraft, as a distinctive prosthesis, becomes part of the tactile and sensory system of man in such a way that all tactile and sensory perceptions from different parts of tactile receptors are related to the corresponding parts of the aircraft, and the aircraft controls are included entirely in the tactile and motor system of the pilot.

V. A. Ponomarenko and N. D. Zavalova, who stress the relationship of "flying feel" to perception of noninstrument flight signals, attribute the leading role in its formation of a poorly perceived muscular feeling. They mention the two-level nature of processes of controlling sensorimotor actions when flying an aircraft and make a distinction between the level of verbal-thinking processes based on processing of instrument readings and the level of perception of noninstrument signals, of which one is often not aware [5, 9].

M. Radchenko and V. Savel'yev relate the "aircraft feel" to motor sensations of the pilot that are instrumental in development of flying skills [7].

In addition, in the opinion of Grote, Geratevol' and Walter, "aircraft feel" is determined by emotional factors, in particular, harmony and rhythm of the motor process, the beauty of performing aerobatic stunts [10]. Let us mention here that the very concept of "feel" is dual--cognitive and emotional [4].

Methods

In order to learn the opinions of pilots and cadets as to the content of the conept of "aircraft feel" and its relation to flying experience, we surveyed 26 pilot instructors, 22 4th-year cadets who were completing their training and 28 3d-year cadets, who had just started training in a qualifying aircraft. The survey involved written answers to the qeustion, "What is 'aircraft feel'?"

Results and Discussion

Semantic analysis of the answers is given in the Table. As an addition to this table, let us mention that, in some of the answers, "aircraft feel" was associated with feelings of easiness, soaring, happiness and delight with flying, and self-confidence.

Generalization of the opinions about "aircraft feel" in the literature and the answers from pilot instructors and cadets listed in the Table makes it possible to distinguish the following basic guidelines as to meaning in the psychophysiological characterization of the concept in question: 1) capacity, unconscious factors, choice of signals important to flying, direct perception of position and movement of aircraft, direct control of movements during piloting, motor coordination, anticipation of aircraft behavior; 2) emotionality of "aircraft feel."

The submitted psychophysiological characteristics of "aircraft feel" are close to the classical characteristics of a motor skill. Indeed, skill is characterized by the following factors: formation of motor structures; detection of signals relevant to a given motor task; change in correlation between levels of control, in particular, increase in role of the sensory-perceptual level of control which is mostly subconscious, which is what the automatization phenomenon comprises.

In favor of the skill-related nature of "aircraft feel" is, in particular, that there was less said about "aircraft feel" as a capacity (see Table, Item 1) and role of direct aircraft control (Item 6), and more about the importance of union with the aircraft (Item 9) by 3d-year cadets, as compared to 4-th year cadets and pilots. We interpreted this as meaning that, because of inadequate development of flying skills, the 3d-year cadets had not yet developed sufficiently the capacity for direct aircraft control, which is what evoked in their consciousness actualization of the significance of being united with the aircraft, which did not apply to them but which they had to achieve. Pilots and 4th-year cadets had this capacity, and it was construed by them as something taken for granted, and it was not actualized in their consciousness. In addition, we were impressed by the facts that cadets, as compared to pilots, spoke much less about the possibility of anticipating the behavior of an aircraft (see Table, Item 7), which definitely depends on experience in flying, i.e., level of development of flying skill. Answers mentioning the relationship between "flight feel" and hours logged in the air (see Table, Item 8) and, in addition, the fact that 4 3d-year cadets could say nothing at all about "aircraft feel" are also indicative of the significance of flying experience to development of "aircraft feel." One of these four cadets mentioned the fact that he had not flown for almost 1 year.

Distribution of cadet and pilot-instructor answers about the content of the concept of "aircraft feel" (% of total answers in group)

Item No	Semantic association of "aircraft feel"	Cadets, %		Pilot-instructors
		3d year	4th year	
1	With capacity	15.8	30.8	30.8
2	With direct perception of noninstrument flight signals (visual perception of aircraft in relation to the ground, audio perception of engine operation, acceleration perception, perception of position of body)	68.4	68.2	53.8
3	With instrument readings	15.7	15.4	8.6
4	Unrelated to instrument readings	10.5	22.7	11.6
5	With conceptions of flying and theoretical knowledge	23.6	31.8	15.4
6	Direct reaction to changes in flight parameters in form of integral movements of aircraft controls (required graded exertion, knowledge of rudder response, etc.)	39.4	45.4	57.8
7	With anticipation of aircraft behavior	21.1	22.7	46.1
8	With flying time logged in general and for a specific type of aircraft in particular	10.5	13.6	15.4
9	With sense of wholeness, of being fused with aircraft	23.6	9.0	7.6

Thus, our analysis of the psychophysiological nature of "aircraft feel" and its comparison to the psychophysiological characterization of a motor skill enables us to view "aircraft feel" as an inseparable property of flying skill, a specific expression of automation of actions to control the aircraft, which is manifested at a certain stage of flight work and is consistently related to unconscious elements of pilot performance, passage into the subconscious of technical, background details of executing and controlling movements [1].

Consequently, "aircraft feel" is the capacity for immediate, sensory-perceptual reflection of the aircraft's position and movement, direct (i.e., according to sensations and perceptions) control of movements to fly the aircraft.

It is expressly the immediacy of reflection of aircraft movement in the form of its rate and rhythm, which are manifested in kinesthetic melodies repeating the sound of the engine, flashing of visual images, dynamics of acceleration sensations that merge into a single symphony of flight, that determine, along with the sense of risk, the emotional nature of "aircraft feel," which is expressed by a feeling of joy, "flying holiday," on the one hand, and self-confidence, on the other.

Thus, the relevance of "aircraft feel" to flying, which ensues directly from the nature of motor skills (in spite of possible different opinions), is unquestionable. "Aircraft feel" makes it possible to relieve, to some extent, the pilot's attention during visual flight so that he can take care of other tasks. At the same time, there is a danger of a pilot's excessive confidence in "aircraft feel," about which P. N. Nesterov gave warning. From the psychophysiological point of view, this danger is related to separation of sensory-perceptual control of piloting movements from verbal-thinking control, which is effected on the basis of processing instrument readings. It is expressly as a result of such separation that pilot errors occur, whereas under difficult meteorological conditions and during instrument flights illusions occur. Evidently, this circumstance was the cause of negative attitude of some pilots and aviation physicians toward "flying feel" and, as a consequence, of appearance of the categorical thesis, "Do not trust feelings, trust only instruments!"

This analysis of psychophysiological nature of "aircraft feel" enables us to draw some practical conclusions. Pilot instructors and aviation physicians should not instill distrust in "flight feel" among flight personnel, which leads, from the psychophysiological point of view, to rejection of sensory-perceptual components from the overall system of psychological control of aircraft piloting actions and is in contradiction to objective logic of formation of a motor skill. In the course of ground-based training, it is necessary to explain to pilots the nature of "aircraft feel" as a logically appearing capacity, at a certain stage of development of flying skills, to make use of one's immediate sensations and perceptions in flight, along with instrument readings, to control actions pertaining to flying the aircraft. It should be stressed that they are used to control only part of the controlling movements (mainly during visual flights), whereas integral actions in flying an aircraft, particularly under difficult meteorological conditions, are performed on the verbal-thinking level and are related to processing of instrument readings.

The optimum combination of instrument information and visual perception of the situation outside the cabin during a visual flight, auditory perceptions of engine operation, vestibular, proprioceptive and tactile sensations while flying the aircraft will result in emotional satisfaction with the flight and, consequently, prevention of fatigue and increasing professional longevity of flight personnel.

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+Gz ACCELERATIONS TOLERANCE OF INDIVIDUALS 41 TO 58 YEARS OF AGE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 10 Jan 84) pp 18-23

[Article by V. Yu. Luk'yanyuk]

[English abstract from source] Forty-five men (non-pilots) aged 41-58 were used in 186 experimental runs to study their tolerance to +Gz acceleration. The test subjects were either healthy people or showed atherosclerotic symptoms (the number of which varied from 1-2 to 5 and more). During centrifugation the test subjects had no anti-G suits on. Healthy test subjects exhibited high tolerance to +Gz acceleration of up to 5 g in most centrifugal runs (90.3%). The test subjects with early atherosclerotic changes showed a significantly lower tolerance as compared to the matched controls. It was found that in the atherosclerotic subjects tolerance to +Gz acceleration decreased as its value increased and as the number of atherosclerotic symptoms grew. The major symptoms that limited tolerance to +Gz acceleration in all the test subjects were cardiac arrhythmias and in the atherosclerotic subjects they were also eye disorders and autonomic-vascular reactions during recovery. The data obtained show that it is important to measure individual tolerance to acceleration in people aged 41-58 years old.

[Text] The advances of cosmonautics have made it possible to include older research cosmonauts (41-55 years of age) among crew members, i.e., individuals at the flower of their professional and creative maturity [2].

However, the results of numerous Soviet and foreign investigations [3, 4, 9, 10] indicate that, after the age of 45 years, many essentially healthy people begin to show signs of atherosclerosis in discrete or mild clinical form. At the same age, one observes considerable rise in incidence of essential hypertension and ischemic heart disease.

With regard to effects of accelerations, it is known that tolerance to accelerations in head-pelvis direction is lower in individuals with any deviations in health status (such as neurocirculatory dystonia of the hypertensive and cardiac types, stage I essential hypertension, vegetovascular dystonia) than in healthy people of the same age [6-8].

There are no data in the literature concerning tolerance to accelerations of individuals over 40 years of age with early signs of atherosclerosis.

Our objective here was to test tolerance and physiological reactions to accelerations in head to pelvis direction (+Gz) in healthy subjects and those with signs of atherosclerosis differing in severity 41-58 years of age.

Methods

We made a total of 186 tests on a centrifuge with 7.25 m arm on 45 male volunteers ranging in age from 41 to 58 years.

There were two series of studies. In the first series (control), we tested 23 healthy men and in the second, 22 with early signs of atherosclerosis.

Before starting the tests, all of the subjects underwent a clinical examination to determine their health status and, in particular, number of direct signs of atherosclerosis (clinical manifestations--accented second sound on the aorta and systolic murmur upon auscultation, roentgenological signs of atherosclerosis of the aorta, vascular changes in the fundus of the eye, disturbances in lipid metabolism, rheoencephalographic changes of the atherosclerotic and hypertensive types).

The second series of sbujects were divided into 3 groups according to severity of atherosclerosis: 1st group--4 subjects with 1-2 signs of atherosclerosis, 2d--12 subjects with 3-4 signs and 3d--5 subjects with 5 or more signs of atherosclerosis.

The healthy subjects had an average age of 44.9 years (41-55), those with 1-2 signs of atherosclerosis 45.8 (43-48) years, with 3-4 signs 45.6 (43-53) years and those with 5 or more signs 52 (45-58) years.

We used longitudinal, head-pelvis (+Gz) accelerations by the method of P. M. Suvorov [8]; they are used in expert medical certification of flight personnel as a functional load test. Accelerations of 3, 4 and 5 G were used for 30 s ("plateau") with a build-up and deceleration gradient of 0.2 G/s. There were intervals of at least 10-15 min between rotations.

In order to enhance tolerance to accelerations, the subjects created static tension of muscles of the prelum abdominale and lower limbs. No anti-G devices were used during the tests.

In all of the studies, we recorded the following parameters: ECG in the 3 "Neba" leads and monopolar V_1 and V_5 leads for subsequent calculation of heart rate (HR) and detection of disturbances referable to cardiac rhythm; pneumogram for calculation of respiration rate (RR); systolic arterial pressure (BP) in vessels of the earlobe using a photoplethysmographic sensor; systolic and diastolic BP in arm vessels according to Korotkov sounds; motor response time to photic signals. In addition, the subjects were monitored by [closed-circuit] television, and there was two-way communication.

The centrifuge tests were stopped if the subjects' wellbeing worsened or syncope appeared, or visual disturbances in the form of "gray" or "black" film and their precursors with decrease in amplitude of earlobe vascular pulse to 25% of the base value or with drop of systolic BP in earlobe vessels to less than 40 mm Hg [5], marked disturbances of cardiac rhythm in the form of multiple, polytopic and/or group extrasystoles and other cardiac functional disturbances.

All of the material was processed by Student's method of variational statistics. Differences were considered reliable at $P<0.05$.

Results and Discussion

During exposure to accelerations the general condition of most healthy subjects 41-55 years of age was good. We failed to observe any visual disturbances or pain.

In the vast majority of cases, acceleration tolerance was good (Figure 1). Satisfactory tolerance to +4 Gz accelerations was observed in 4.9% of the cases and to +5 Gz in 7.3%. Tolerance to 3-5 G accelerations was poor in 2.4% of the cases.

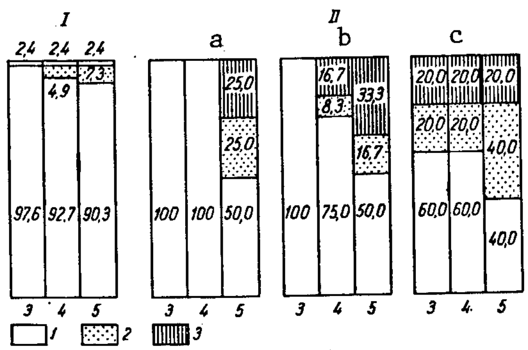

Figure 1.
Tolerance to +Gz accelerations of healthy subjects (I) and those with atherosclerosis of different severity (II) at 41 to 58 years of age.
Here and in Figure 2:
a, b, c) 1st, 2d and 3d groups of subjects
1, 2, 3) good, satisfactory and poor tolerance to accelerations, respectively.
The numbers in the bars refer to percentage of subjects with indicated tolerance. Those under the bars refer to magnitude of accelerations (G)

Acceleration tolerance was limited by disturbances in cardiac rhythm in the form of group, polytopic and/or multiple extrasystoles (Figure 2). In addition, mild disturbances of cardiac rhythm in the form of isolated nomotopic extrasystole were observed in older healthy subjects during exposure and in the aftereffect period (see Table).

With accelerations of +3 Gz, +4 Gz and +5 +5 Gz, we observed sinus tachycardiac of 117±4, 137±4 and 150±4/min, respectively. Systolic BP in earlobe vessels constituted 113±4, 115±4 and 112±4 mm Hg. We never observed critical BP drop or decline of amplitude of pulsed oscillations in earlobe vessels. Systolic BP in the brachial artery rose to 176±4, 199±4 and 211±5 mm Hg; diastolic BP rose to 110±3, 126±4 and 136±4 mm Hg, respectively.

We failed to demonstrate a noticeable difference in HR and BP between subjects with good, satisfactory and poor tolerance.

Postrotation examination revealed that the healthy subjects were in good condition. In a few cases there were isolated petechial effusions of blood in the ankle region.

Older subjects with early signs of atherosclerosis generally tolerated +Gz accelerations appreciably worse than healthy subjects of the same age.

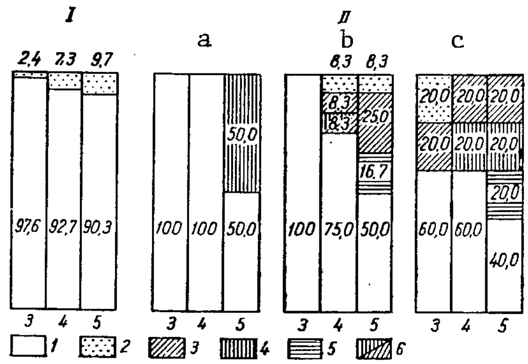

Figure 2.
Criteria of diminished tolerance to +Gz accelerations in healthy subjects (I) and individuals with varying severity of atherosclerosis (II) 41 to 58 years of age

1) no signs of diminished tolerance to accelerations
2) marked disturbances of cardiac rhythm
3) visual disorders or their precursors
4) marked autonomic reactions in aftereffect period
5) medical contraindications for +5 Gz acceleration
6) combination of disturbances

The numbers in the bars refer to percentage of subjects with indicated physiological functional disturbances. Those under the bars show magnitude of accelerations (G)

The general condition of atherosclerotic subjects ranged from good to poor during centrifuge rotation. Almost half of them (47.6%) reported visual disorders or vertigo, weakness and nausea. Examination of these subjects after stopping the centrifuge often revealed noticeable facial pallor and hyperhidrosis of the integument. There was not a single instance of pain or loss of consciousness.

Acceleration tolerance (see Figure 1) was good in most of the subjects in the first group, and it did not differ appreciably from that of healthy individuals of the same age. A decrease in tolerance to +5 Gz accelerations (see Figure 2) was observed in 50% of the cases, and it was due to appearance of marked autonomic reactions in the aftereffect period (hyperhidrosis and pallor of integument of the face, as well as weakness, vertigo and nausea).

In the 2d group, tolerance to +Gz was noticeably poorer than in healthy subjects and those in the 1st group (see Figure 1). Thus, according to tolerance to +3 Gz these groups of subjects did not differ, whereas with +4 Gz a decline of tolerance was observed in subjects of the 2d group in 25% of the cases and with +5 Gz in 50%.

The causes of diminished tolerance in this group of subjects were more diverse (see Figure 2) but, at the same time, they all pertained to the cardiovascular system (visual disorders, BP drop in earlobe vessels, marked and persistent impairment of cardiac rhythm, combination of visual disorders and marked autonomic reactions). In addition, 2 subjects (16.7%) could not be submitted to accelerations of +5 Gz due to poor tolerance to +4 Gz.

In the 3d group of subjects, noticeable decline of tolerance was already observed at +3 Gz (see Figure 1). With accelerations of +4 Gz and 5 Gz, the number of individuals with satisfactory and low tolerance also increased appreciably.

Analysis of our data revealed that physiological functional disturbances that caused a decrease in tolerance to accelerations were about the same in the 2d and 3d groups of subjects (Figure 2). However, the severity and incidence of these disturbances were greater in the 2d group.

At the same time, it must be noted that we observed mild disturbances of cardiac rhythm in the form of isolated nomotopic extrasystole (see Table) in a considerably large number of cases in this group (100% at +5 Gz).

Incidence and severity of cardiac rhythm disturbances with expsoure to +Gz accelerations among healthy subjects and individuals with varying severity of atherosclerosis 41 to 58 years of age (% of total number of subjects in each group)

Acceleration	Presence and severity of cardiac rhythm disturbances	Healthy subjects	Subjects with early signs of atherosclerosis group		
			1	2	3
+3 G_z	No disturbances	83,0	100,0	100,0	60,0
	Mild*	14,6	—	—	20,0
	Marked**	2,4	—	—	20,0
+4 G_z	None	80,5	100,0	75,1	60,0
	Mild	12,2	—	16,6	40,0
	Marked	7,3	—	8,3	—
+5 G_z	None	68,3	100,0	90,0	—
	Mild	22,0	—	—	100,0
	Marked	9,7	—	10,0	—

*Mild cardiac rhythm disturbances--isolated nomotopic extrasystole.
**Marked rhythm disturbances--multiple (5 or more extrasystoles), group, polytopic extrasystoles and other cardiac functional disorders.

With accelerations as described above, subjects presenting early signs of atherosclerosis had sinus tachycardia which was about the same in severity among 1st and 2d group individuals as in healthy subjects. In the 3d group, heart rate went up to 110±13, 120±12 and 122±6/min, and it was reliably lower at +4 Gz and +5 Gz (by 17 and 28/min, respectively) than in healthy subjects submitted to analogous accelerations.

Systolic BP in earlobe vessels at +3, +4 and +5 Gz constituted 136±2, 132±5 and 132±2 mm Hg, respectively, in subjects of the 1st group, 106±10, 111±9 and 123±7 mm Hg in the 2d group, 116±6, 120±11 and 136±4 mm Hg in the 3d group. We were impressed by the fact that this parameter was not lower among subjects with early signs of atherosclerosis, whereas in the 1st (at all magnitudes of acceleration) and 3d groups (at +5 Gz) it was even higher than in healthy subjects exposed to analogous accelerations. In addition, a reliably higher systolic BP in earlobe vessels was found in all individuals with early signs of atherosclerosis in the aftereffect period as well, particularly in the 1st min after stopping the centrifuge.

BP in vessels of the arms did not differ appreciably in all subjects with early signs of atherosclerosis from levels obtained in healthy subjects. However, those in the 2d and 3d groups showed a tendency toward development of lower diastolic BP.

Postrotation examination of subjects revealed that the general condition of those with early signs of atherosclerosis was usually satisfactory. There was usually normalization of wellbeing of subjects who had presented marked vegetovascular reactions within 15-20 min after discontinuing rotation.

The incidence of isolated petechial hemorrhages in the ankle region was virtually the same as in healthy subjects.

Thus, older subjects with atherosclerosis showed poorer tolerance to +Gz as a whole than healthy subjects of the same age. The individuals with early signs of atherosclerosis presented two main patterns: 1) tolerance to accelerations worsens more with increase in their magnitude than in healthy subjects; 2) with increase in number of demonstrated signs of atherosclerosis there is also increase in degree of worsening of tolerance to accelerations.

In essence, tolerance to accelerations of all subjects in the older age group was limited by changes in the cardiovascular system, mainly marked disturbances of cardiac rhythm and visual disorders.

Two groups of factors probably play a part in the genesis of ectopic arrhythmias in older individuals exposed to accelerations.

Some factors are related to impaired control of heart rhythm during exposure to accelerations. They include the following: change in delivery of blood to heart chambers, excitation of autonomic centers for control of the cardiovascular system, reflex impulsation from different organs and parts of the body related to their displacement and circulatory disturbance, signs of myocardial hypoxia, depletion of energy resources of the myocardium, etc. [1, 8].

The other group of factors is attributable to age-related distinctions of the subjects and presence of an atherosclerotic process. They include such factors as diminished automatism of the sinus node and atherosclerotic involvement of coronary arteries, poorer conduction in some parts of the myocardium, formation of sites of impaired metabolism, electrolyte changes in the myocardium, etc.

Visual disorders in the form of "gray" or "black" film or their precursors were the second most frequent symptom limiting tolerance to accelerations of older subjects with early signs of atherosclerosis.

These changes were observed in 2 subjects with atherosclerosis (9.5%), in whom a decline of systolic BP in earlobe vessels below 40 mm Hg or decreased amplitude of pulse in earlobe vessels to the isoelectric line was associated with visual disorders in the form of "gray" or "black" film, respectively, already at +4 Gz. In healthy subjects of the same age, no visual disorders or their precursors were ever observed.

At the same time, we were impressed by the fact that visual disorders in the form of gray film, which were observed in 14.3% of the subjects with early signs of atherosclerosis, were not associated with decline of pulse amplitude or BP in earlobe vessels. It is important to mention that clinical examination of these subjects revealed changes in vessels of the fundus that are typical of atherosclerosis.

The lower HR and tendency toward development of lower diastolic BP in arm vessels of subjects in the 2d and 3d groups, as compared to healthy individuals, and those in the 1st group, can probably be attributed to some decline of sinus node automatism and diminished elasticity of vessels, respectively.

Rigidity of atherosclerotic arterial walls could be the cause of higher systolic BP in earlobe vessels of subjects with early signs of atherosclerosis during and after exposure to accelerations; this inhibited somewhat redistribution of blood during exposure and led to more drastic retrograde return of blood to the upper half of the body after stopping the centrifuge.

Thus, analysis of our findings revealed that, in the vast majority of cases (90.3% to +5 Gz) tolerance to the tested modes of +Gz accelerations was good in healthy subjects 41 to 58 years of age.

In individuals of the same age with early signs of atherosclerosis varying in severity, this parameter was, on the whole, poorer than in healthy subjects.

The tolerance to +3 Gz and +4 Gz accelerations was good in all cases among the 1st group of subjects, and a decrease in tolerance was noted only at +5 Gz.

With increase in number of demonstrated signs of atherosclerosis from 1-2 to 5 or more, there was noticeable decline of tolerance (in 25-40%), even with +3 Gz and +4 Gz accelerations.

At the same time, 40-50% of the subjects 41 to 58 years of age with early signs of atherosclerosis presented good tolerance to +Gz accelerations up to 5 G.

Consequently, when examining older subjects after rotating them on a centrifuge, particularly those with early signs of atherosclerosis, individual evaluation of tolerance to accelerations acquires special significance.

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EFFECT OF 120-DAY ANTIORTHOSTATIC BEDREST ON GAS EXCHANGE AND PULMONARY CIRCULATION IN MAN

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[Article by V. Ye. Vorob'yev, V. R. Abdrakhmanov, A. P. Golikov, L. L. Stazhadze, I. B. Goncharov, I. V. Kovachevich, S. G. Voronina and A. V. Vabishchevich]

[English abstract from source] Parameters of gas exchange and pulmonary circulation were measured in five healthy test subjects during 120-day head-down tilt test and early recovery. During the first half of the bed rest study CO_2 tension in arterial blood increased significantly. During the second half of the study oxygen and carbon dioxide tension decreased significantly. The mechanisms of these changes are discussed.

[Text] It is known that redistribution of blood in a cranial direction, in particular to the intrathoracic region, is of substantial significance in development of functional changes under the influence of spaceflight factors and during antiorthostatic hypokinesia (AOH). Expressly this factor under AOH conditions leads to increase in volume load on the left heart [3], and it is one of the causes of pressure elevation in the system of the pulmonary artery [1]. However, questions related to the nature of associated changes in gas exchange have still not been definitively answered.

Our objective here was to make a comparative study of exchange of gases and regional pulmonary circulation in subjects during 120-day AOH and in the early recovery period.

Methods

External respiration, gas composition and acid-base balance (ABB) of arterial blood were studied under basal metabolic conditions in 5 essentially healthy subjects during 120-day AOH with a tilt angle of -4° and in the early recovery period. Minute respiration volume (MV) was determined using a Wright electronic spirometer and META-1-25B spirograph; gas composition of exhaled air was analyzed using a capnograph and paramagnetic oxygen analyzer. Samples of arterial blood taken by puncturing the radial artery were immediately examined on an AME-1 instrument by the Astrup method. Nonelastic resistance to respiration (R) was determined by the method of forced oscillations on a

Siregnost FD-5 apparatus. The ventilation reaction to CO_2 was tested by the method of rebreathing [5]. The subjects breathed in a bag filled with 5-6 ℓ 100% oxygen for 4-5 min. The exhaled air was analyzed with a capnograph and returned to the breathing bag. Minute ventilation of the lungs ($\dot{V}_E$) was calculated every 60 s by means of spirograph recording. Partial CO_2 tension in alveolar air (p_ACO_2) was plotted on the x-axis and the corresponding $\dot{V}_E$ on the y-axis, and we then found points in the system of coordinates characterizing the relationship between them. By drawing a line through these points, we obtained a plot of minute ventilation as a function of p_ACO_2. Intersection of the continuation of this line with the x-axis corresponded to point B, which characterizes p_ACO_2 level at which ventilation equals zero. From the data thus obtained, we determined the coefficient of proportionality S characterizing the slope of the regression line. Using the regression equation $\dot{V}_E = S(p_ACO_2-B)$ [8], we calculated mean $\dot{V}_E$; physiological dead space was determined according to Bohr.

Concurrently, we recorded rheograms of the upper, middle and lower parts of the right lung, using conventional methods, with a 4RG-1A rheograph and Galileo Firm encephalograph [4]. We studied the following parameters: ratio of duration of anacrotic phase of rheogram to duration of cardiac cycle (α/T) expressed as percentage and reflecting mainly tonus and elasticity of large- and medium-caliber arteries; ratio of height of incisura to maximum amplitude of rheogram--dicrotic index (DCI) and ratio of dicrotic elevation to maximum amplitude--diastolic index (DSI) reflecting, respectively, tonus of arterioles and veins; we calculated the parameter of intensity of pulsed delivery of blood (RI) to vessels of the region examined in relative units.

All of the tests in the background and early recovery periods were performed with the subjects in horizontal position, and during AOH in antiorthostatic position. The results were submitted to statistical processing. Reliability of differences was assessed according to Student.

Results and Discussion

In the background studies, all tested parameters were within the normal range (Tables 1 and 2). On the 55th day of AOH we demonstrated a reliable ($P<0.05$) elevation of blood pCO_2 by a mean of 3.9 mm Hg, as compared to background values, as well as 25% decline of MV ($P<0.01$). The end of the first half of the hypokinetic period was characterized by reliable ($P<0.05$) increase in delivery of blood to the upper parts of the lung, whereas filling of middle and lower parts diminished somewhat.

On the 75th day of AOH we demonstrated an increase in alveolar-arterial gradient for oxygen, which constituted a mean for the group of 20.6 mm Hg ($P<0.05$), as compared to the background. All subjects showed further drop of blood pO_2 by 14.9 mm Hg as the average for the group ($P<0.05$) and, unlike the preceding stage of the study, we demonstrated a reliable drop ($P<0.05$) of CO_2, as compared to value before starting AOH.

The data obtained on the 100th day of AOH were indicative of continued decline of blood CO_2 by a mean of 7.2 mm Hg ($P<0.01$). In this period, the subjects presented reliable ($P<0.05$) increase of R by a group mean of 2.2 mbar/ℓ/s, as compared to base value (before AOH).

Table 1. Dynamics of some external respiration parameters and blood ABB during 120-day AOH and recovery period (M±m)

Parameter	Background period	AOH, days			Recovery, days	
		55	75	100	2	7
MV, ℓ/min	6,2±0,2	4,8±0,2**	5,0±0,3*	5,6±0,3*	6,8±0,2	6,0±0,6
RR/min	11,2±0,6	9,3±2,0	7,7±0,8*	9,8±1,60	12,0±0,7	8,3±1,2
R, mbar/ℓ/s	3,6±0,2	5,7±0,8	5,8±0,8	5,8±0,7*	2,8±0,2	3,4±0,3
S, ℓ/min/mm Hg	3,95±0,15	2,98±0,20*	3,60±0,34	3,08±0,16	—	—
P_AO_2, mm Hg	104,0±1,2	107,4±1,2	111,2±3,1	110,4±1,7*	110,3±0,6	111,3±2,0
P_aCO_2, mm Hg	37,7±0,8	41,6±0,6*	33,8±0,8*	30,5±1,2**	37,5±1,3	36,8±2,0
P_aO_2, mm Hg	97,2±1,2	88,3±3,5	82,3±4,1*	86,6±2,7	93,0±1,2	92,5±1,2
pH	7,42±0,01	7,41±0,01	7,42±0,01	7,44±0,01	7,41±0,01	7,43±0,01
SB, mmol/ℓ	24,7±0,2	24,8±0,8	22,7±0,5*	23,0±0,5	24,1±0,4	24,5±0,8
BE, mmol/ℓ	+0,3±0,3	+1,0±0,7	—0,2±0,5*	—1,7±0,5	—0,3±0,5	+0,1±0,9
$P_{A-a}O_2$, mm Hg	8,3±1,7	20,4±5,6	28,9±5,1*	20,2±3,7	17,3±0,7*	16,0±3,0
V_D/V_T, %	38,0±1,42	40,0±1,24	41,6±2,66	46,7±1,95*	47,2±2,83	40,8±3,18

Key: RR) respiratory rate
SB) standard bicarbonates
BE) base excess (deficit)
$P_{A-a}O_2$) alveolar-arterial gradient for O_2
*Reliability of differences from background at P<0.05
**Same at P<0.01

Table 2. Dynamics of rheographic parameters during 120-day AOH (M±m)

Part of lung	Parameter	Background	AOH, days		Recovery, days	
			58	116	1	5
Top	RI	1,28±0,25	2,34±0,14*	1,16±0,33	1,35±0,15	2,05±0,44
	α/T	22,8±2,23	21,9±1,83	17,8±1,96	25,9±2,01	25,6±1,71
Middle	RI	2,52±0,58	2,17±0,20	2,84±1,12	2,07±0,51	2,83±0,22
	α/T	25,4±1,86	25,3±1,44	25,6±3,68	28,5±3,17	30,4±3,32
Bottom	RI	1,43±0,21	1,31±0,14	2,03±0,39	1,57±0,25	1,87±0,50
	α/T	30,0±2,67	31,9±2,80	25,3±3,11	25,7±2,37	22,7±3,86

*Reliability of differences from background at P<0.05

The second half of the hypokinetic period was characterized by change in regional perfusion of the subjects' lungs. The middle and lower parts of the lung were found to receive the maximum supply of blood, while filling of upper parts was close to background levels (see Table 2).

It should be noted that the deviations in gas exchange during the first half of the 120-day period of AOH are indicative primarily of impaired ventilation-perfusion relations in the lungs. Their evaluation by means of gradients for oxygen and carbon dioxide, which revealed an increase in alveolar-arterial gradient for O_2 and a tendency toward increase of arterial-alveolar gradient for CO_2, warrants the belief that there was an increase in nonuniformity of ventilation and perfusion in the lungs.

For this reason, when examining the genesis of impairment of ventilation-perfusion relations in the subjects' lungs, we can mention the decline in efficiency of ventilation, judging by the increase in V_D/V_T ratio, as well as probable uneven distribution of blood flow. This is confirmed by rheographic data on delivery of blood to the lungs, which revealed heterogeneity of pulmonary perfusion and its predominant increase in the upper parts of the lungs.

At the same time, we cannot rule out diffusion of gases through the alveolo-capillary membrane, particularly in cases of hemostasis in the lungs. However, in view of the higher diffusion capacity of CO_2, it appears more probable to consider this a secondary mechanism.

The changes in different directions in blood pCO_2 and MV merit attention. According to our data, the subjects presented a reliable decline ($P<0.05$) of S on the 55th day of AOH. The demonstrated decline of ventilation reaction to CO_2 is apparently attributable to diminished sensitivity of the respiratory center to the stimulating action of carbon dioxide. At the same time, increase of R was demonstrable in all subjects during hypokinesia, and according to a number of authors [6, 7] this reflects total respiratory resistance, increase of which is the most informative sign for early detection of disturbances in respiratory mechanics, including those of an obstructive nature.

The results of tests on the subjects in the second half of the 120-day period of AOH are indicative of relative adaptation of gas exchange under these conditions. According to rheography of delivery of blood to the lungs, we found a decrease in the upper parts and concurrent increase in the middle and especially lower parts of the lungs. Such change in regional pulmonary circulation, as manifested by inconsistency between its distribution and direction of vector of hydrostatic pressure, enables us to assume that complex mechanisms of control of vascular tonus are put into action. The increased perfusion of lower parts of the lungs is probably related to decreased tonus of arterial vessels. Thus, signs of diminished arteriolar tonus (reduction of DCI) were demonstrated in two subjects, and decreased tonus of arterial large- and medium-caliber vessels (reduction of α/T ratio) were found in three. Triggering of mechanisms of control of tonus of regional pulmonary vessels, increased delivery of blood to middle and lower parts of the lungs could be instrumental in enlarging the zone of perfused alveoli.

We know from the literature [2] that studies of external gas exchange in hypokinetic man usually revealed some decline of basal metabolism, which was associated with some decrease in pulmonary ventilation and respiration rate. The body's demand for O_2 delivery, CO_2 and other metabolite production diminish and, in such cases, the constant decline of demand for O_2 and elimination of CO_2 affects external respiratory function. This can apparently create conditions for decline of blood pCO_2, which we demonstrated in the subjects during the second half of the AOH period.

It should be noted that maintenance of blood ABB at a relatively stable level during hypokinesia is indicative of adequate compensatory-adaptative capabilities of the body in the presence of gradually developing changes in gas exchange.

Analysis of gas composition of blood, which was made on the 2d day of the recovery period following 120-day AOH with limited motor activity, revealed a tendency toward elevation of pO_2 and pCO_2, as compared to findings on 100th day of AOH (see Table 1). Moreover, a reliable ($P<0.05$) increase persisted in alveolar-arterial gradient for oxygen by 9.0 mm Hg as the mean for the group. On the 7th day of the recovery period, the reverse dynamics were observed in blood gas composition, namely a tendency toward decline of pO_2 and pCO_2.

In our opinion, this can be explained by the results of rheographic examination of delivery of blood to the lungs. While the start of the first day of the recovery period was characterized by some decrease in delivery of blood to all parts of the lungs, as compared to the second half of the hypokinetic period, which occurred against a background of moderate increase in tonus of medium- and large-caliber arterial vessels (see Table 2), on subsequent days we observed a tendency toward increased pulmonary perfusion.

As shown by the results of our studies, during 120-day AOH there were signs of discrete respiratory insufficiency of a compensated nature, which is due to changes occurring under such conditions in regional pulmonary circulation. The dynamics of the tested parameters in the early recovery period are indicative of reversibility and functional nature of deviations of gas exchange under the effect of long-term AOH.

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REGIONAL CIRCULATION DURING TESTING ON ISOKINETIC DYNAMOMETER FOLLOWING 14-DAY BEDREST

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 30 May 83) pp 26-30

[Article by T. D. Vasil'yeva, V. R. Vysotskaya and G. I. Gevlich]

[English abstract from source] Time-course variations in regional circulation during isometric and isokinetic loads of varying intensity were measured after 14-day head-down tilt. It was found that pulse blood filling of the leg decreased and its vascular response to the load varied. These findings suggest that the impairment of the strength-velocity properties of muscles after hypokinesia is associated not only with their morphological changes but also with their inadequate blood supply during loading.

[Text] It is known that various motor disturbances develop under the influence of spaceflight factors, hypokinesia and immersion. This is related to elimination or change in static loads, deficit of muscular function, change in activity of sensory systems and other influences on motor function. As a result, the mass of muscles is reduced and they present dystrophic and atrophic changes, which leads to decline of physical endurance, worsening of velocity and strength properties of muscles. However, muscular work capacity does not depend only on the condition of the muscles themselves, but on the quality of their blood supply. For this reason, it was interesting to investigate the dynamics of regional circulation during use of isometric and isokinetic loads of varying intensity before and after 14-day antiorthostatic hypokinesia (AOH).

Methods

We examined 7 healthy men 30-40 years of age before and after 14 days of bedrest in antiorthostatic position, with -8° tilt of the head end of the bed.

The physical load consisted of active flexion (4 modes) and extension (4 modes) of the foot on an isokinetic Cybex dynamomter, at different rates of pedal movement (120, 80, 160 and 40°/s), as well as alternate cyclic flexion and extension of the foot at pedal movement rate of 120°/s [10].

We recorded rheograms (RG) of the functioning and nonfunctioning leg before and after each exercise mode for 15 s. Upon completion of all loads (in the recovery period), we recorded the RG for 10 min [sic] during each odd-numbered min. In addition, we recorded the electrocardiogram (ECG) in the second standard lead.

The RG was recorded by means of a bipolar rheographic 4 RG 1M attachment to the Montedel electroencephalograph.

We analyzed the following parameters: heart rate (HR), maximum rheographic wave amplitude (A), which reflects pulsed filling of the tested region, parameter α/T, which reflects tonus of large- and medium-caliber arteries, dicrotic index (DCI) as an indicator of tonus and elasticity of small arteries and arterioles and diastolic index (DSI) as an indicator of venous efflux and tonus. The data were submitted to statistical processing.

Results and Discussion

There was virtually no change in HR during isokinetic exercise before hypokinesia (Table 1). There was merely an insignificant increase in these parameter (by a mean of 3/min) in strength-requiring exercise modes (pedaling rate 40°/s) and during cyclic work.

Pulsed delivery of blood to the leg increased in accordance with the assumed magnitude of the load, and during function of the sural triceps (STM), the increase in blood supply was more marked than during function of the anterior tibial muscle (ATM). More delivery of blood was noted during intensive exercise modes (40 and 80°/s) than with rapid modes (120 and 160°/s), i.e., the strength load made greater demands of the system of blood supply to muscles than the velocity load.

During exercise, there was reliable increase in tonus of large-, medium- and small-caliber arteries, arterioles and veins; this increase also corresponded to magnitude of the load and was particularly noticeable during strength modes of STM function. The corresponding parameters of vessels of the nonfunctioning leg showed virtually no change.

Thus, when healthy subjects performed isokinetic exercises before hypokinesia there were changes in regional hemodynamics. The changes in peripheral circulation were more marked than parameters of systemic circulation. Thus, during exercise, parameter A increased by a mean of 37% (at 40°/s), α/T rose by 71%, DCI by 172% and DSI by 116%, whereas HR remained virtually unchanged (it increased by a mean of 2.8/min, or 3.6%). Changes in peripheral circulation that are specific to functional hyperemia were observed only in the exercising limb.

Examination on the 3d day after 14-day AOH (Table 2) revealed greater changes in HR with isokinetic loads than before hypokinesia. For example, HR constituted a mean of 78.9/min during exercise of STM at the rate of 160°/s before hypokinesia and 88.3 after AOH, i.e., it increased by 9.4/min or 11.9%.

Table 1. Change in hemodynamic parameters of leg ($M \pm \sigma$) with different modes of isokinetic loads before hypokinesia

Parameter	Background	Pedal velocity, degrees/s							
		120	80	160	40	120	80	160	40
		ATM				STM			
Exercising leg									
A, Ω	0,091±0,007	0,094±0,007	0,098±0,007	0,104±0,007	0,097±0,006	0,115±0,009	0,122±0,015	0,122±0,014	0,124±0,021
α/T, %	14,5±0,732	18,3±1,051	18,9±1,135	18,1±1,118	19,7±1,466	23,4±1,161	25,6±1,165	22,6±0,735	24,8±1,746
DCI, %	16,7±6,671	22,5±12,76	20,9±8,343	24,4±12,33	27,3±21,81	38,6±15,41	42,3±13,58	40,5±14,76	45,5±11,99
DSI, %	16,7±8,380	24,3±12,21	21,4±9,913	24,2±8,871	27,8±20,26	33,0±12,25	35,2±10,86	34,8±12,81	36,3±11,38
Nonexercising leg									
A, Ω	0,086±0,006	0,081±0,005	0,083±0,006	0,088±0,007	0,090±0,006	0,092±0,006	0,088±0,007	0,091±0,007	0,094±0,008
α/T, %	13,7±0,810	14,6±0,644	15,1±0,764	14,7±0,919	15,6±0,561	15,1±0,788	16,5±1,074	14,8±0,825	14,8±0,460
DCI, %	16,3±8,356	14,7±4,764	15,4±9,221	14,5±7,784	12,6±3,850	13,7±7,336	14,0±7,002	17,1±7,661	14,6±7,868
DSI, %	18,1±9,583	19,2±8,199	16,5±9,781	16,0±7,519	13,9±5,447	15,7±8,883	19,5±8,861	20,7±10,49	16,8±7,690
HR/min	76,3±6,639	75,4±5,533	77,1±4,973	77,1±5,143	79,7±5,022	78,0±4,899	78,0±3,703	78,9±3,569	79,1±4,616

Parameter	IT		CW	RP, min			
	ATM	STM		1	3	5	7
Exercising leg							
A, Ω	0,110±0,008	0,110±0,007	0,123±0,013	0,107±0,007	0,102±0,013	0,092±0,012	0,108±0,015
α/T, %	20,7±1,298	22,2±1,359	30,2±1,088	23,3±1,367	23,4±1,313	19,6±1,759	19,8±1,751
DCI, %	28,9±16,31	38,0±14,81	48,2±13,27	38,8±20,22	31,2±13,55	20,0±14,62	18,9±11,86
DSI, %	27,1±11,69	35,1±12,81	39,3±11,92	34,2±19,71	28,4±12,38	23,7±11,60	23,4±12,26
Nonexercising leg							
A, Ω	0,090±0,008	0,091±0,007	0,095±0,010	0,096±0,009	0,096±0,009	0,101±0,010	0,109±0,011
α/T, %	14,3±0,961	15,2±0,884	18,9±0,537	14,8±0,453	15,5±1,201	15,8±1,332	15,4±0,971
DCI, %	16,3±8,140	11,8±3,652	16,3±9,983	10,7±5,176	10,7±4,693	12,4±6,287	11,0±3,930
DSI, %	18,1±8,408	16,5±7,800	19,5±10,83	13,9±7,062	13,2±5,920	16,5±10,12	12,6±5,359
HR/min	78,4±5,255	76,3±4,849	91,7±3,130	80,6±5,533	77,1±5,518	73,0±5,675	73,0±5,000

Key, here and in Table 2: IT) isometric tension RP) recovery period
CW) cyclic work

There was reduction of leg perimeter by an average of 1.8 cm.

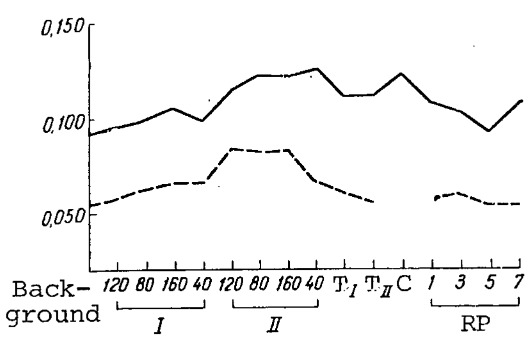
The parameters of pulsed delivery of blood to the leg after hypokinesia at rest were reduced, by 39% as compared to data obtained before AOH. There was change in reaction of the vascular system of the lower leg to the load (see Figure). While an increase in load corresponded to increased pulsed delivery of blood before hypokinesia, such a pattern was observed after AOH only at velocity-demanding modes, whereas with increase in strength-demanding load there was decreased delivery of blood to the leg, i.e., a paradoxical reaction of the peripheral circulatory system to the load was observed. Such a reaction to an isokinetic load was observed in parameters of tonus of small arteries and arterioles. After AOH, we observed increase of DCI paralleling the magnitude of load in velocity-requiring exercise modes; when STM functioned in strength-demanding modes there was decline of parameter of tonus of small-caliber arteries and arterioles. No changes were demonstrable in parameters of venous efflux and venous tonus during isokinetic loads after AOH, as compared to test results before hypokinesia.

Table 2. Changes in hemodynamic parameters (M±σ) of leg after 14-day AOH

Parameter	Background	Pedal velocity, degrees/s							
		120	80	160	40	120	80	160	40
		ATM				STM			
Exercising leg									
A, Ω	0,055±0,006	0,057±0,006	0,060±0,005	0,064±0,007	0,065±0,008	0,084±0,013	0,081±0,011	0,083±0,011	0,067±0,007
α/T, %	16,2±0,888	18,2±1,462	20,6±1,524	19,7±1,414	20,3±1,352	24,9±2,801	26,9±2,530	24,5±1,697	22,0±2,733
DCI, %	16,4±9,252	25,2±5,897	26,9±8,406	26,4±10,98	28,7±8,333	40,2±17,76	42,9±15,95	35,0±11,81	34,4±13,83
DSI, %	20,8±8,608	28,0±7,190	28,4±6,919	26,0±10,44	28,7±13,78	37,4±18,07	37,8±14,82	29,7±10,31	33,1±10,61
Nonexercising leg									
A, Ω	0,060±0,005	0,062±0,006	0,060±0,007	0,059±0,007	0,059±0,006	0,060±0,007	0,063±0,006	0,061±0,008	0,057±0,006
α/T, %	15,5±0,689	16,7±2,338	15,8±1,065	14,7±0,923	14,4±1,320	14,6±1,511	14,3±1,338	14,4±1,557	14,3±0,916
DCI, %	14,2±5,468	13,1±5,382	13,5±7,127	15,2±9,009	17,0±7,417	15,3±7,786	18,0±8,914	13,1±7,083	14,8±6,524
DSI, %	23,8±9,865	23,3±10,17	22,4±13,61	29,1±12,84	24,4±9,125	27,8±9,203	24,8±8,161	21,3±5,086	24,3±10,46
HR/min	78,9±4,973	80,1±4,930	82,9±4,916	83,1±5,143	81,4±3,897	82,3±5,959	85,7±4,481	88,3±4,849	83,1±4,798

Parameter	IT		CW*	RP, min			
	ATM	STM		1	3	5	7
Exercising leg							
A, Ω	0,060±0,004	0,056±0,008	—	0,057±0,005	0,060±0,005	0,055±0,005	0,054±0,004
α/T, %	19,0±1,380	21,0±2,679	—	18,3±1,661	16,5±1,558	16,4±1,502	16,7±1,375
DCI, %	28,1±9,271	27,3±14,80	—	22,9±11,68	18,5±3,880	19,2±5,094	15,3±2,857
DSI, %	31,7±11,65	29,9±12,90	—	29,3±12,47	24,3±5,485	22,4±4,883	24,9±8,386
Nonexercising leg							
A, Ω	0,058±0,005	0,060±0,006	—	0,066±0,007	0,061±0,005	0,063±0,006	0,064±0,006
α/T, %	13,7±1,135	14,8±0,864	—	13,8±1,255	14,6±1,046	14,6±0,538	13,9±0,800
DCI, %	20,1±7,701	20,5±10,37	—	15,8±4,825	16,9±5,942	17,2±7,211	18,6±7,696
DSI, %	24,0±9,038	29,2±10,99	—	22,8±8,708	23,1±7,784	22,7±8,460	25,0±9,339
HR/min	81,4±5,686	80,7±4,202	—	78,9±3,801	79,4±4,111	79,7±4,081	78,3±2,843

*There was no cyclic work after AOH.



Pulsed delivery of blood to leg during isokinetic exercise before (solid line and after (dash line) 14-day AOH.
X-axis, exercise modes: 120, 80, 160, 40--pedal velocity (degrees/s)
I) ATM T_I) isometric ATM tension
II) STM T_{II}) isometric STM tension
C) cyclic work
RP) recovery period (min)
← Y-axis, A (Ω)

I. B. Kozlovskaya [3, 5] demonstrated that all subjects presented significant decline of strength properties of STM after 7-day spaceflights and 7-day immersion. The strength deficiency constituted 30% at various velocities of motion. The strength capacity of ATM did not change appreciably in dynamic modes of movement after immersion, which is consistent with the results of our studies of hemodynamics of the lower leg. Our findings enable us to assume that worsening of strength properties of STM after exposure to real or simulated weightlessness is related to decrease in tonus of arteries and their diminished blood supply during physical exercise.

The reduction in crural perimeter as a result of AOH was indicative of reduction of muscle volume. Such changes were reported after hypokinesia and spaceflights in the works of N. S. Molchanov, A. G. Panov, M. A. Cherepakhin and many other researchers [6, 7, 9]. Several authors [2, 4, 8] established that there is reliable and significant decrease in contractile proteins (actomyosin and fraction T protein), as well as in muscular sarcoplasmic proteins, under the effect of immobilization and actual spaceflights.

The change in reaction of the crural vascular system to exercise (less delivery of blood than before hypokinesia and absence of parallel between blood supply and increased load) could be attributed to diminished conditioning of muscles as a result of 2-week bedrest. Blood supply to muscles during exercise is determined by the degree of their conditioning: peripheral circulation is more intensive in more conditioned muscles [1]. The decrease in muscle conditioning as a result of hypokinesia also confirms the fact that there was a more marked HR reaction to exercise after AOH, while local hyperemia was less marked. This was indicative of changes in control of circulation, diminished share of autonomic peripheral circulation and increased role of central circulation.

Our findings enable us to define the direction of therapeutic and rehabilitation measures needed after real and simulated weightlessness. Along with restoration of functional state of the muscular system, it is necessary to perform measures aimed at improving peripheral circulation, stimulation of vessels and increase in their tonus.

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PRIMATE ADRENAL REACTIONS TO ANTIORTHOSTATIC HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 17 Jan 83) pp 30-34

[Article by Ye. A. Savina, A. S. Pankova, O. Ye. Kabitskaya, G. S. Belkaniya and D. S. Tavadyan]

[English abstract from source] The following experiments were performed to study the morphology of the adrenals of male rhesus monkeys: six monkeys were exposed to clinostatic hypokinesia for 7 days and then to head-down tilt at -6° for 12 days; two monkeys were exposed only to head-down tilt for 7 days and 5 monkeys were used as controls. The adrenals exhibited changes of three types: stress-reaction manifestations, activation of the glomerular area of the cortex and synchronization of the medullary matter to noradrenaline production. All these changes reflect adaptive reactions of the animal body to head-down tilt.

[Text] According to data in the literature, the first 2 weeks of submitting animals to hypokinesia lead to development of a stress reaction, the morphological signs of which have been repeatedly described for small laboratory animals in studies of their adrenals [4, 6, 8, 9]. We were unable to find such studies in the available literature pertaining to primates. Yet it is interesting to investigate adrenal reactions of such highly organized animals as monkeys, particularly during antiorthostatic hypokinesia (AOH), which simulates best the hemodynamic effects of weightlessness.

Methods

We examined the adrenals of 5 control and 8 experimental Macaca rhesus monkeys (males). A combined morphobiochemical experiment was performed at the Institute of Experimental Pathology and Therapy, USSR Academy of Medical Sciences (Sukhumi). Hypokinesia was produced by a method developed by the staff of this institute for use on primates.

In 2 experiments perfomred at different times, the monkeys (6 animals) were submitted to clinostatic hypokinesia for 7 days, then antiorthostatic hypokinesia (AOH) at an angle of -6° for 12 days. In addition, the animals were submitted to 7 days of AOH in the second experiment. In the first experiment, the weight of control and experimental animals was about 5 kg, and in the second 3-4 kg before its start. The animals were sacrificed by means of intravenous infusion of 2-3 mℓ 10% hexenal. Death occurred immediately after injecting the anesthetic.

Fatty tissue was removed from the adrenals, and they were weighed. Tissue samples were fixed in calcium-formol, Bouin and Wood fluids. Lipids were assayed by the method of Berg using oil red O and sudan black B dyes; cholesterol was assayed in polarized light; ketosteroids were stained with Schiff reagent according to Kiselya; activity of 3-β-ol-steroid dehydrogenase was tested on cryostat sections of unfixed tissue according to Wattenberg [10]. An RA-6 projection attachment was used for karyometry of glomerular (300 nuclei at a time) and fascicular (100 nuclei) zone cells, as well as of medullary substance (100 nuclei), at a 2000× magnification. Nucleus volume was determined by conventional methods. Wood's stain was used to examine the medullary substance; catecholamines were demonstrated after Erenko.

Results and Discussion

Mean absolute and relative weight of adrenals from monkeys in the 7- and 19-day experiments did not differ appreciably from that of control animals. However, we were impressed by the fact that the relative adrenal mass fluctuated over a narrow range, from 0.18 to 0.20 mg/g in intact monkeys, whereas individual differences were substantial among experimental animals. Thus, relative weight of adrenals in the 19-day experiment ranged from 0.22 to 0.29 mg/g; in the 7-day experiment, it constituted 0.18 mg/g in one monkey and 0.27 mg/g in another.

Histological examination of the adrenal cortex of monkeys used in the 7- and 19-day experiments revealed signs of hypertrophy of the fascicular zone and increase in its functional activity.

After 7 days of AOH, one monkey showed fascicular hypertrophy that was mainly focal, whereas in another it was more uniform, which also affected individual differences in relative mass of the adrenals. Active proliferation of cells was observed in both animals, on the boundary between the glomerular and fascicular zones, among the drastically dilated capillaries, and it was possible to detect various stages of their transformation into column cells. The glomerular layer proper was narrowed, in comparison to both control findings and especially the 19-day experiment, being represented by 1-2 rows of rosette-like cells. Fascicular hypertrophy was associated with increased accumulation of lipids (triglycerides) in the cells of this zone and ketosteroids in the external and central parts of the columns. The signs of increased functional activity consisted of reliable increase in cell nucleus volume (183.5±1.15 μm^3 in the experiment, versus 162.08±2.27 μm^3 in the control) in the fascicular zone, significant decline of cholesterol content over its entire thickness, extensive delipoidization of internal parts of the column and reticular zone. Because of delipoidization of internal regions, the adrenal cortex on preparations treated by the Berg method appeared even narrower than in control animals.

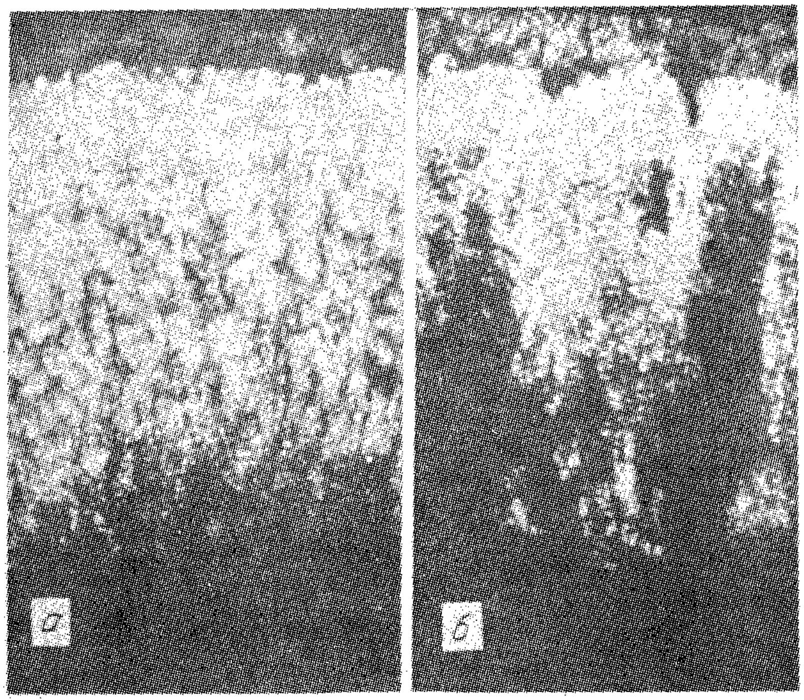

Figure 1. Lipid content of adrenal cortex
a) control; normal distribution of lipids in cortex: glomerular zone can barely be seen because of low lipid content; in fascicular zone, lipid level diminishes in direction of medullary substance
б) 19-day AOH; hypertrophy and elevated lipid level in glomerular zone; section of fascicular zone without lipids.
Berg technique; lens 10×, eyepiece 8×

In the 19-day experiment, hypertrophy of the fascicular zone became more uniform and its width increased due to narrowing of reticular zone. Assay of lipids and measurement of nucleus volume of fascicular zone cells revealed distinct individual differences. In two out of six monkeys, hypertrophy of the fascicular layer was associated with considerable accumulation of lipids, cholesterol and ketosteroids; at the same time, volume of cell nuclei was close to the control value. The other animals present focal delipidization, very limited in some cases (2 monkeys) or more extensive involving larger areas and reaching the external parts of the columns (Figure 1, *a*,*б*). At the lipid-free sites we observed a decrease in cholesterol and ketosteroids, as well as increase in activity of 3-β-ol-steroid dehydrogenase, an enzyme involved in corticosteroid synthesis. In these animals, the volume of cell nuclei in the fascicular zone remained increased, but no reliable differences from control values were established, due to the wide individual fluctuations (from 166.3 to 185.4 μm^3).

Unlike the animals used in the 7-day experiment, those in the 19-day one showed increase in width of the glomerular zone and hypertrophy of its cells (Figure 2, *a* and *б*). The external parts of the zone consisted of 3-4 layers of large rosettes or trabeculae, in the center of which lumen with granular contents was often demonstrable. The cells were enlarged, their cytoplasm clear, and they contained a large amount of lipids (see Figure 16). While droplets of lipids were localized mainly in the basal parts of cells in control animals, in this experiment they were distributed over the entire cytoplasm. Along with cell hypertrophy, there was increase in volume of cell nuclei (mean of 114.6± 5.4 μm^3 in the experiment versus 94±5.5 μm^3 in the control). The internal segments retained processes of alteration of cells of the glomerular zone into those of the fascicular zone. However, while there was prevalence of cell proliferation in the 7-day experiment, in the 19-day one the trabeculae of de novo formed cells resembled cells of the fascicular zone in structure and lipid content.

Thus, histological examination of the adrenal cortex of monkeys used in 7- and 19-day experiments revealed morphological signs of a stress reaction, the intensity of which depended not only on the nature and duration of the experiment, but individual differences in animal reactions. The changes found in the adrenal cortex with 7-day AOH can be evaluated as a combination of processes of hypertrophy of the fascicular zone with signs of hyperfunction. In the 19-day experiment (7 days of horizontal hypokinesia followed by 12-day AOH), hypertrophy of the fascicular zone was more significant, while signs of increased functional activity were less marked in most animals. Nevertheless, the absence of normalization of nucleus volume in cells of the fascicular zone, as well as complete restoration of cholesterol and lipid content in the adrenal cortex of most monkeys, indicates that, by this time, they had not yet had time to fully adapt to experimental conditions. Two monkeys in the 19-day exepriment were an exception: according to the basic parameters, their cortex was consistent with the resistance stage of the general adaptation syndrome.

Examination of the adrenal cortex revealed phasic changes in the glomerular zone, in addition to signs of a stress reaction: while this zone was narrow and its cells had a low lipid content with 7-day AOH, after 19-day hypokinesia we observed hypertrophy and increased functional activity of cells (increased volume of cell nuclei, accumulation of lipids) producing aldosterone in the glomerular zone. In man, impairment of fluid-electrolyte balance and increased aldosterone secretion are observed during horizontal hypokinesia and AOH. Thus, an increase in blood aldosterone activity was found on the 26th, 46th and 86th days of AOH [1]. Aldosterone excretion also increased with 30-day hypokinesia [2]. It was also assumed [5] that there is intensification of mineralocorticoid activity of the adrenal cortex during AOH. The presence of morphological manifestations of increased functional activity of the glomerular zone in this experiment is indicative of the similarity of human and primate reactions to hemodynamic and fluid-electrolyte metabolism changes caused by AOH.

Studies of the medullary substance of the adrenals by the methods we used (Erenko, Wood) failed to demonstrate two types of cells, secreting epinephrine (A cells) and norepinephrine (N cells) in monkeys. The question of morphological identification of the two types of cells in primates is still open. The opinion has been voiced that in monkeys, as in man, the same cells can produce both epinephrine and norepinephrine [3].

When the adrenal medulla is stained by the Wood method, N cells of small laboratory animals, in particular rats, are stained a distinct yellow and A cells, pink. A comparison of medullary preparations stained after Wood in control and experimental monkeys revealed that the color of the cells changed with increase in duration of the experiment. Considerable polychromia was found in cells of control animals; they either took stain homogeneously (brick red or yellow shades) or else part of the cytoplasm of the same cell was yellow and another presented orange-red shades. In experimental animals, there was an increase in number of yellow-stained cells with increase in duration of the experiment. In the 19-day experiment, there was prevalence of cells in the cytoplasm that were different shades of yellow. Karyometry of medullary cells revealed that there was a tendency toward increase in nucleus volume ($184.8 \pm 18\ \mu m^3$, versus $155.9 \pm 9.8\ \mu m^3$ in the control) in the 7-day experiment and normalization ($151.3 \pm 2.6\ \mu m^3$) in the 19-day one. Judging by karyometry data and Wood staining, with 7-day AOH there is increase in functional activity of cells in the medullary substance as a whole, whereas with 19-day AOH the function of most cells changes to norepinephrine production.

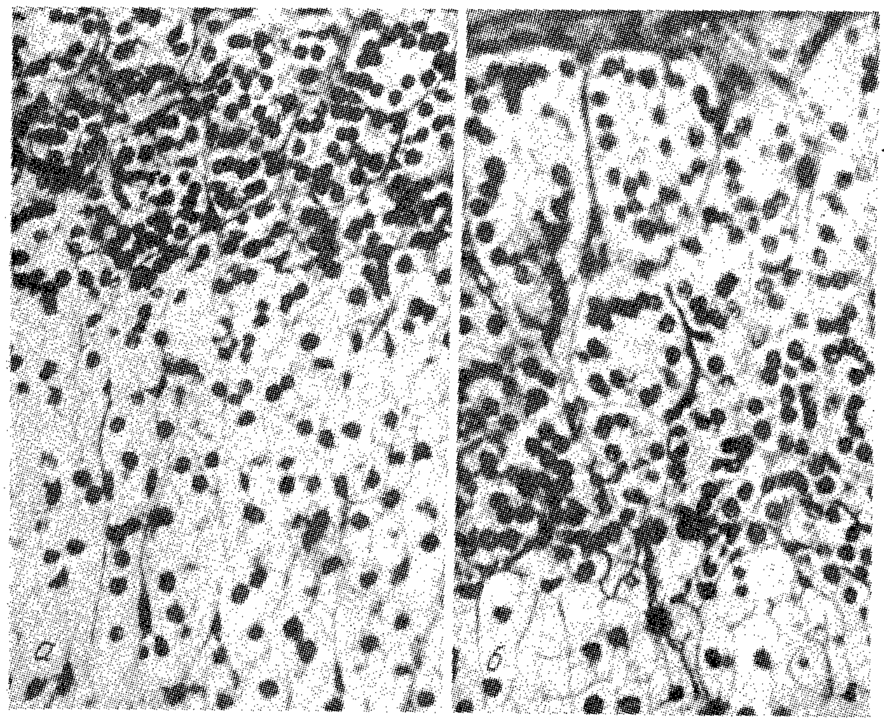

Figure 2. Glomerular zone of adrenal cortex; (Khel'mi) stain; lens 16×, eyepiece 10×

а) control; glomerular zone consists of 2-3 rows of small cells
б) 19-day AOH; hypertrophy of glomerular zone; large honeycombs formed by hypertrophied cells with cleared cytoplasm

Thus, the demonstrated changes in the adrenals are a reflection of adaptive reactions, some of which are referable to manifestations of the stress reaction (alteration of fascicular zone) and others (activation of glomerular zone and medulla) to the response to hemodynamic changes and disturbances of fluid-electrolyte metabolism that develop in primates under AOH conditions.

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LONG-TERM EXPOSURE OF ANIMALS TO ANTIORTHOSTASIS (-90°) AS A MODEL OF CRITICAL HOMEOSTATIC DISTURBANCES

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 1 Jul 83) pp 34-38

[Article by V. V. Bogomolov, V. Ya. Tabak, V. V. Lenskiy, M. S. Bogushevich, L. L. Stazhadze, G. G. Ivanov, V. V. Gal'chin, Zh. M. Kudryashova and V. A. Vostrikov]

[English abstract from source] The cardiovascular effect of head-down tilt (at an angle of -90°) was investigated in 25 mongrel dogs exposed to general anesthesia, myorelaxation or pulmonary ventilation. Changes in the circulation and contractility parameters can be subdivided into three periods. At the early stages of the exposure an increase in contractile function and hemodynamic changes typical of preload were seen. At later stages progressive disorders of systemic and regional hemodynamics, inhibition of contractile function, and increasing metabolic changes were observed. All this resulted in the death of the animals after 12-20 hours of head-down tilt. Gross structural changes that occasionally were irreversible were detected in organs of the dead animals.

[Text] Hemodynamic deviations due to shifting of fluids in a cranial direction, which is manifested the most distinctly at the early stages of adaptation, hold one of the key places in the set of functional changes in the body during exposure to actual or simulated spaceflight factors [6, 8, 17].

Although it is known that spaceflights are not associated with any pathological changes in man [3-5], the possibility cannot be ruled out of inflight development of various diseases or traumatic injuries [2, 11]. Theoretically, it is plausible to expect that redistribution of fluids in a cranial direction could have some relevance to the genesis of critical disorders.

In this study, we tried to obtain a model (on dogs) of one of the most adverse conditions of redistribution of blood in a cranial direction during prolonged (many hours) antiorthostasis (AOS) with a tilt angle of -90°, in order to induce the most changes in the body for subsequent experimental refinement of different elements of resuscitation. Although the proposed model is not adequate to the actual redistribution of blood in weightlessness, it does enable us, making certain assumptions, to follow the direction of disturbances of homeostasis to the extent of critical disorders when there is breakdown of compensatory and adaptive mechanisms of controlling body functions in AOS position. Thus, in this study, the proposed experimental model does not reflect hemodynamic effects of weightlessness, but the critical homeostatic disturbances that are possible with a number of pathological states that occur against a background of cranial redistribution of fluids.

We know of the high functional capacity of compensatory mechanisms of controlling systemic and regional circulation in dogs with relatively brief and moderate AOS [7, 12, 14]. In choosing this model of critical homeostatic disorders, we took into consideration the anatomical and physiological distinctions of dogs, namely the predominantly horizontal location of great vessels, marked capacity for deposition of a large volume of blood in parenchymatous organs and vessels of the abdominal cavity, natural head position that is more often lower than the body [12].

Methods

Experiments were conducted on 25 mongrel dogs of both sexes weighing 2.5-25 kg. The animals were submitted to general anesthesia and given muscle relaxants (intravenous promedol 8 mg/kg, ketalar 2-2.5 mg/kg and ditiline), after which the trachea was intubated and artificial ventilation was administered using an RO-3 or Phase-Aero respiratory in a mode of moderate hyperventilation (respiratory volume 30-40 mg/kg, rate 16-18/min). Under these conditions we tested the animal's physiological functions in horizontal position (base data) and at different stages of -90° AOS (until the animals expired, but no longer than 20 h). At different stages of the experiment, we pursued dynamic neurological and ophthalmological observations, recorded systolic (BP_s) and diastolic (BP_d) pressure in the femoral artery, central venous pressure (CVP), the ECG, polycardiogram and apexcardiogram and calculated the following parameters: preejection period (PP), sphygmic period (SP), contractility parameter (CP: relationship between PP and SP), mechanical systole time (MST), period of isometric contraction (IC), relaxation period (RP), minute volume ejection time (MVET), initial rate of elevation of intraventricular pressure (IREP), intrasystolic index (II), index of myocardial tension (IMT) and output fraction (OF). In some cases we monitored hematocrit and acid-base status of venous blood. The organs of dead animals were submitted to morphological and histological examination. The results were processed statistically.

Results and Discussion

In the base state, with the animal in horizontal position on the table, the parameters studied were within the permissible normal range for this species [1, 12] (see Table). When the animal was changed to AOS of -90°, we demonstrated phasic changes in hemodynamics and homeostasis as a whole, which we could arbitrarily divide into three periods.

During the first minutes of -90° AOS there was drastic elevation of BP_s and BP_d, significant fluctuation of heart rate (HR), elevation of CVP and ventricular extrasystole. Subsequently there was gradual stabilization of hemodynamic parameters.

Parameters of central hemodynamics and phase structure of left ventricular contraction during -90° AOS (M±m)

Parameter	Before AOS	-90° AOS period		
		first	second	third
Observation time, h	2,6±0,5	1,09±0,22	6,55±1,62	2,69±0,92
HR/min	108±7	69±6*	109±8	**64±7***
BP_s, mm Hg	150±8	128±3,9*	102±8,9*	**68±7,0***
BP_d, mm Hg	125±6,9	105±5,0*	88±6,0*	**55±6,9***
CVP, mm water	30±3	43±5*	6±3*	+5±2*
PP, ms	68,1±1,2	62,2±1,4*	71,8±1,9*	124,0±4,4*
SP, ms	145,1±5,1	163,3±6,2*	154,3±7,9	**220,7±8,2***
CP, relative units	0,460±0,013	0,461±0,051	0,493±0,011*	**0,626±0,025***
MST, ms	198,4±14,0	204,0±13,0	201,1±11,2	**284,1±18,0***
IC, ms	53,2±3,4	41,1±2,4*	47,6±7,4	**64,3±2,5***
RP, ms	73,8±2,1	91,3±6,5*	85,8±6,3	85,8±4,1*
MVET, s	13,75±1,34	9,85±0,71*	10,88±1,20	**16,96±0,60***
IREP, mm Hg/s	2843±31,1	2807±40,4	1891±33,4*	859±26,4*
II, %	76,71+0,51	79,51±0,91*	76,61±0,84	81,28±1,21*
IREP, mm Hg/s	2843±31,1	2807±40,4	1891±33,4*	859±26,4*
IMT, %	31,9±1,2	27,5±1,5	31,5±1,4	**36,4±1,6***
OF, %	54,8±1,1	55,2±0,9	50,3±1,2*	**34,3±1,3***

Note: Boldface numbers indicate values reliably different from parameters for second period of AOS.
*P<0.05, as compared to background.

The first period (2-3 h) of adaptation to AOS was characterized by slowing of HR, drop of BP_s and BP_d ($P<0.05$), shortening of IC, PP, extension of SP and RP of ventricles, extension of MST against a background of decreased MVET, IMT and increased II ($P<0.05$). Ophthalmological studies at this stage revealed a drastic spasm of retinal vessels.

In the second period of -90° AOS (next 5-7 h), we observed increase in HR, continuing decline of BP_s and BP_d, increase of PP, tendency toward decrease of SP, IC and MST. Further regression of OF parameters was associated with decrease of IREP and a tendency toward increase of RP. Retinal vascular spasm was replaced by venous dilatation, which then changed into pathological dilatation of veins, plethora and cyanosis. Later on, we demonstrated dilatation of retinal arteries, increased plethora and progressive edema of the retina.

With increase in time of exposure of animals to -90° AOS (more than 3-4 h), there was aggravation of disorders referable to the blood-clotting system, which was manifested by progression of the hemorrhagic syndrome (diapedetic tissue hemorrhage from wound surfaces, build-up of cutaneous hematomas in the neck region, and blood-clotting time tested according to Lee and White increased to many hours). Already in the 4th-5th h of AOS, it was no longer necessary to give muscle relaxants; against the background of continuing controlled respiration we observed profound muscular atonia and depression of reflexes.

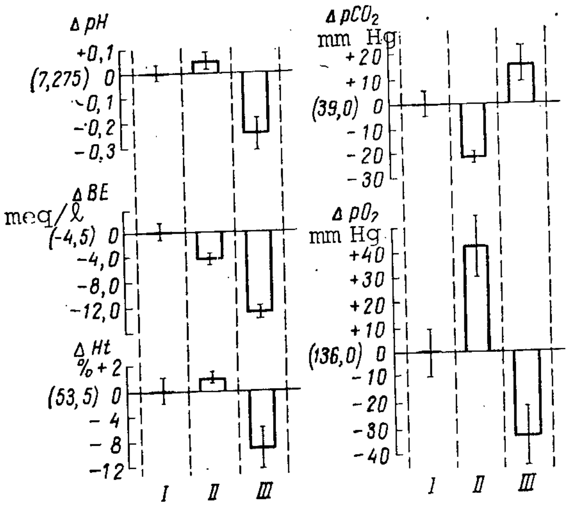

Figure 1.
Changes in some parameters of acid-base balance of animals' venous blood during -90° AOS. Mean absolute base values are given in parentheses

- I) background
- II) 2-h AOS
- III) 6-7-h AOS
- Δ) change in relation to base values of parameters
- BE) base excess (deficit)
- Ht) hematocrit

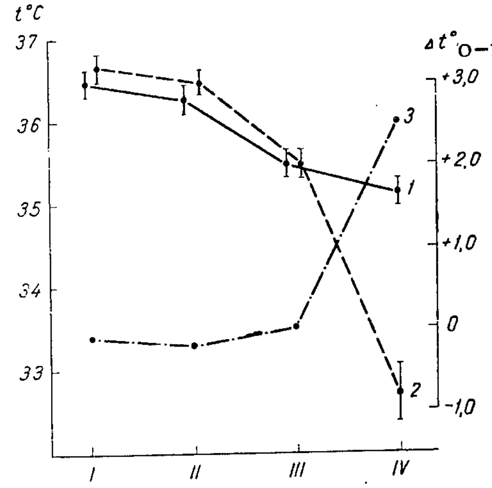

Figure 2.
Dynamics of oral and rectal temperature of animals during -90°

- I) background
- II-IV) 1-2, 3-4 and 8-12 h of -90° AOS, respectively
- Δt_{o-r}) oral-rectal temperature gradient
- 1) oral temperature
- 2) rectal temperature
- 3) oral-rectal temperature gradient

In the third period (next 1.5-4 h) there was significant increase in PP, SP, MVET, IC, with further decrease in OF and IREP. There was progression of sinus bradycardia, increase in electrical systole time, IMT and II ($P<0.05$). In all stages of AOS there was progressive increase in P-Q and Q-T intervals, decrease in amplitude of R wave, change in terminal part of the ventricular complex (reduction of S-T segment, inversion of T wave). Studies of retinal hemodynamics revealed dehydration, first of arteries and then of veins of the retina, drastic cyanosis of retina changed to pallor and there was pathological pulsation of retinal arteries.

The progressive hemodynamic disorders during long-term -90° AOS were observed against a background of gross metabolic disorders and progressive decompensated metabolic acidosis (Figure 1).

Deaths occurred 12-20 h after the start of -90° AOS. In four cases, terminal cardiac rhythm disturbances were due to changing the animals to horizontal position in an attempt to correct hemodynamic disturbances after 15-h AOS. This may be indicative of extreme manifestations of "orthostatic intolerance." In the rest of the dogs, we observed total depression of spontaneous respiration already after 7-10 h of -90° AOS; when attempts were made to switch the animal to spontaneous breathing we found only isolated contractions of the diaphragm with no pulmonary ventilation. This warrants the belief that, at the early stages of the experiment, irreversible changes occurred in the central nervous system, which is indirectly confirmed by close to critical disturbances of retinal hemodynamics. It is known that changes observed in retinal vessels reflect processes in the carotid system and intracranial vascular changes [9, 13]. The fact that progressive drop of body temperature and increase in temperature gradient between cranial and caudal regions (Figure 2) is also indicative of disturbances in central control of body functions.

Alteration of homeostasis during long-term exposure to -90° AOS is complex and on different levels. One of the chief causes of these changes is probably the redistribution of fluids in a cranial direction.

The change in phase structure of left ventricular contractions at the early stages of -90° AOS was characterized by increased myocardial contractility in response to increase in volumetric load. However, not all of the changes associated with AOS can be attributed to this alone. Shortening of IC creates an optimum mode of isotonic hyperperfusion, while extension of blood expulsion time from the left ventricle is inherent in hydraulic resistance loads. In the opinion of some authors [16], in the first phase of left ventricular adaptation to volume overload, hyperfunction of the heart is effect chiefly through inotropic mechanisms and to a lesser extent the Franke-Starling mechanism. The elevation of CVP noted in the first period of AOS is indicative of developing inconsistency between functional state of the right ventricle and increased venous influx. Elevation of systemic venous pressure could cause development of cerebral edema and intracranial hypertension [10], which in turn could cause decrease in systemic vascular resistance [15], blood pressure drop, slowing and impairment of cardiac rhythm.

Alteration of autonomic nervous control of cardiac function in response to impulsation of cardiopulmonary and vascular baroreceptors and drop of systemic BP are perhaps other factors involved in the pathogenesis of hemodynamic disturbances during prolonged -90° AOS. Hyperfunction and hyperdynamia of the myocardium at the early stages of AOS is followed by progressive decline of myocardial contractility against the background of depressed systemic and regional circulation, which is a reflection of decompensation of hemodynamic regulatory mechanism and homeostasis as a whole. The disturbances in the blood-clotting system during AOS and the genesis of hemostasis disorders remain unclear, and they require further comprehensive investigation.

Pathoanatomical examination of organs of dead animals after long-term -90° AOS revealed gross morphological changes. The muscles of the hind legs were anemic, the bladder contained no urine, stasis was found in parenchymatous organs of the abdominal cavity, with isolated and multiple hemorrhages. Typically, there was plethora of chest organs with sites of thrombus formation, and several dogs presented signs of pulmonary edema. The heart of all animals presented multiple subepicardiac and endocardiac hemorrhages, extravasations of blood deep into the myocardium and perivascular regions. We found plethora of cerebral vessels, multiple perivascular hemorrhages, diapedetic effusion of blood into brain matter, extensive hematomas under the pia mater against a background of hyperhydration of the brain, pericellular edema, fibrinoid swelling of vascular walls. These gross structural disturbances in the animals' brain were apparently indicative of their irreversibility.

Thus, prolonged (many hours) exposure of dogs to -90° AOS, with muscles relaxed and artificial ventilation of the lungs, is associated with phasic changes in function of vital systems, which ultimately lead to irreversible changes in the animals' organs and system. Progressive disturbances of central regulatory mechanisms, hemodynamic disorders, impaired myocardial function against a background of a set of metabolic disturbances are the most prominent.

This model of critical functional disturbances is promising for experimental development of resuscitation methods for different acute states when there is cranial redistribution of fluids (dehydration therapy for intracranial hypertension, electric pulse therapy of critical disturbances of cardiac rhythm, respiratory disorders).

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RAT BONE TISSUE AFTER FLIGHT ABOARD COSMOS-1129 BIOSATELLITE

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 8 Jul 83) pp 39-44

[Article by I. V. Rogacheva, G. P. Stupakov, A. I. Volozhin, M. N. Pavlova and A. N. Polyakov]

[English abstract from source] Bones of rats flown for 19 days onboard Cosmos-1129 were examined. The examination included bone mass, density, mineral composition, reconstruction parameters and elemental composition at R+1, R+6, and R+29. After flight the rats developed osteoporosis in the spongy structures of tubular bones and a smaller thickness of the cortical layer of the diaphysis; they showed no mineralization of the microstructure, a slight decrease of the Ca concentration, and a normal content of P. At R+6 these changes progressively developed and at R+29 they returned to normal.

[Text] Spaceflights lasting 60-90 days elicited some osteoporosis in epiphyses and metaphyses of long tubular bones of turtles, which led to decrease in strength of spongy bone [4]. Analogous changes, but more marked than in turtles, were demonstrated in supporting skeletal bones of rats after a 19-day flight aboard Cosmos-936 biosatellite [3]. Inhibited osteogenesis was demonstrated in rats exposed to weightlessness [6]. In model experiments, there was an increase in osteoclast population [5]. At the present time, there are still insufficient data about the patterns of restoration of biophysical properties of bone tissue when the body readapts to earth's gravity. This prompted the present investigation.

Methods

Experiments were conducted on Wistar SPF rats with initial weight of 210 g. After launching Cosmos-1129, a synchronous experiment (SE) was started on the ground, in which the animals were kept in a mockup of the satellite, where the same life-support conditions were simulated as in spaceflight. Control animals were kept in the vivarium ("vivarium control" group--VC).

After termination of the 19-day spaceflight, part of the animals (6-7 from each group) were decapitated 1 day into the recovery period, others on R+6 and others yet on R+29. We isolated and skeletized the femurs and stored them under refrigeration in 0.5% neutral formalin. We determined the weight, volume and cross section of the bones. Osteometry was performed on x-rays on the central part of the bone using an MBS-2 microscope. Degree of porosity, i.e., severity of osteoporosis, was determined on the basis of density and mineralization parameters. All of the methods used have been described previously [1]. Histological preparations were made of femoral diaphyses of control rats and animals decapitated 1 day after landing. The sections were stained with hematoxylin and eosin. We determined mineralization of bone microstructures by contact microroentgenography [2]. To improve objectivity of evaluation of the results, two sections from the SF [spaceflight] and VC groups were exposed simultaneously on each microroentgenogram. On the micro-x-ray of each section, we determined mineralization of microstructures in 20 points over the entire width of the cortical layer. We determined calcium content of the bone tissue zone by atomic absorptiometry and phosphorus spectrophotometry.

Results and Discussion

We previously demonstrated [3] and confirmed here that the biophysical characteristics of bones depend on the age of animals. However, SF, SE and VC group rats were decapitated at different times, so that comparison of their parameters could have distorted the differences between them. For this reason, we introduced a so-called extrapolated control (EC) for the tested parameters, which was determined by extrapolating each parameter (as a function of time) in VC and SE groups in accordance with the time of decapitation of experimental groups of animals. It was assumed that change in bone property was a linear function of rat age for 29 days.

Table 1. Change in rat femur weight after 19-day spaceflight

Part of femur	Group		
	VC	SE	SF
		R+1	
Fresh bone	914,6±18,4	841,3±3,21*	811,4±19,3
Dry distal epiphysis	58,5±2,2	44,1±1,9*	45,8±2,1
Dry head	25,6±1,2	20,3±1,41*	20,2±0,77
		R+6	
Fresh bone	899,2±16,1	852,2±17,6	895,7±40,7
Dry distal epiphysis	49,9±1,82	51,3±1,96	42,7±1,09**
Dry head	21,4±1,03	22,6±1,52	19,6±1,08
		R+29	
Fresh bone	952,2±32,6	1059,2±44,9	902,2±12,5**
Dry distal epiphysis	54,6±1,64	64,3±2,03*	51,5±1,44**
Dry head	23,8±1,85	26,9±2,00	24,4±1,38

Here and in Tables 2 and 3: *P<0.05 with increase in parameters for SE and VC
**Same for SF and SE.

It was established (Table 1) that the mass of the femur was less after the spaceflight than in the control. The mass of the distal epiphysis and head of the femur decreased by a mean of 6-7%, as compared to EC, which had virtually no effect on weight of the entire bone. The difference in weight of these bone fragments between the above groups increased even more 6 days after the flight, and constituted 14.9 and 11.1% for the distal femoral epiphysis and head, respectively. Normalization of mass of spongy bone occurred by the 29th day of the recovery period.

Table 2. Change in cross section of rat femur after 19-day spaceflight and in recovery period

Parameters	Group		
	VC	SE	SF
		R+1	
Frontal projection:			
thickness of cortical layer	1,39±0,44	1,389±0,034	1,354±0,029
width of diaphysis	3,983±0,078	2,221±0,101*	3,929±0,043**
" " canal	2,608±0,087	2,725±0,043	2,512±0,072
Lateral projection:			
thickness of cortical layer	1,450±0,064	1,246±0,064*	1,250±0,021
width of diaphysis	3,285±0,032	3,142±0,068	3,143±0,042
" " canal	1,861±0,050	1,896±0,040	1,893±0,038
		R+6	
Frontal projection:			
thickness of cortical layer	1,375±0,047	1,29±0,030*	1,275±0,039
width of diaphysis	4,030±0,088	4,015±0,039	4,031±0,058
" " canal	2,608±0,087	2,778±0,087*	2,805±0,068
Lateral projection:			
thickness of cortical layer	1,367±0,027	1,295±0,038	1,225±0,052
width of diaphysis	3,225±0,010	3,217±0,047	3,220±0,059
" " canal	1,842±0,033	1,912±0,054	1,995±0,078
		R+29	
Frontal projection:			
thickness of cortical layer	1,431±0,039	1,525±0,035	1,465±0,038
width of diaphysis	4,100±0,138	4,150±0,029	4,095±0,100
" " canal	2,562±0,168	2,444±0,157	2,694±0,057
Lateral projection:			
thickness of cortical layer	1,475±0,029	1,583±0,019*	1,369±0,041**
width of diaphysis	3,450±0,081	3,406±0,019	3,245±0,038**
" " canal	1,825±0,063	1,812±0,031	1,887±0,024**

Osteometric studies made on x-rays revealed that the outside width of the diaphysis, marrow canal and thickness of cortical layer measured in the frontal projection did not change in the SF group, as compared to EC. In the lateral projection, the thickness of the cortical layer diminished by 6.8% (Table 2), whereas in 6 days of the recovery period the difference increased to 9.2%; in addition, the thickness of the cortical layer also diminished in the frontal projection. The 29-day recovery period was sufficient for normalization of thickness of the cortical layer of the rat bones examined. Dissimilar changes in cross sections of the diaphysis, mainly thinning of the cortical layer in the lateral projection, led to transformation of shape from ellipsoid to round (Figure 1*a* and *б*).

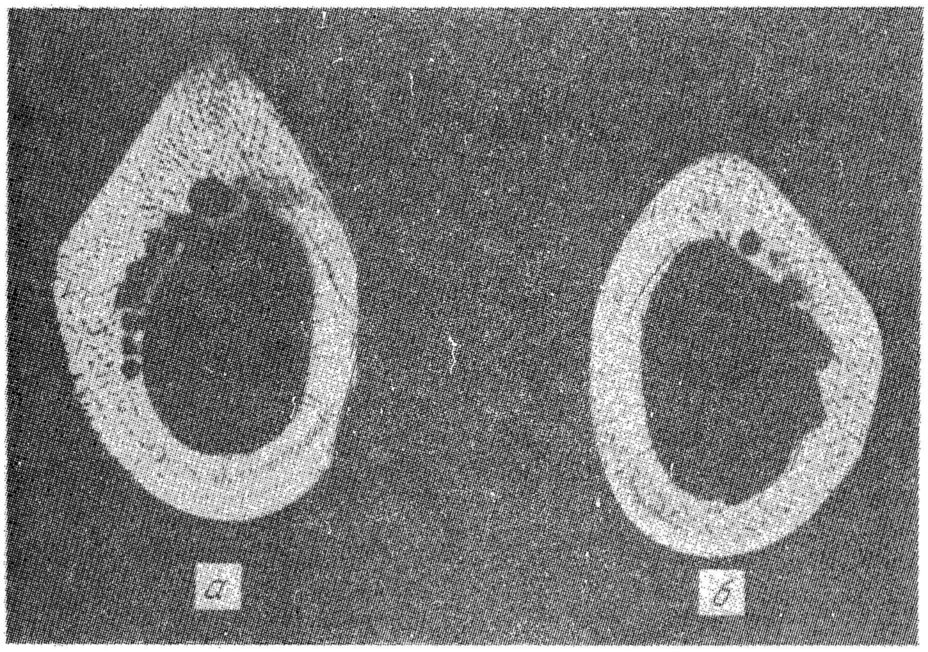

Figure 1. X-rays of sections of central part of femoral diaphysis; Cross section is rounder in SF rats, as compared to the control; mature, fully mineralized bone tissue without signs of osteoporosis; magnification 10×

Here and in Figure 2:
a) VC group *б*) SF group

After the 19-day spaceflight, there was significant decrease in spongy bone density in the femur and humerus, as compared to parameters for EC animals (Table 3), which is a sign of development of osteoporosis. There was less reduction in density of femural diaphysis.

There was also comparative decrease in mineralization to about the same extent as density in the SF group of animals. There were no significant changes in ash content, since bone tissue content per unit bone volume decreased to about the same extent due to the organic and mineral components.

As a result of 6-day recovery, density and mineralization of the bones examined reverted to normal. Lower values for these parameters persisted only in the head of the femur.

Mineralization of the head of the femur was 10.4% lower 29 days after the spaceflight than in EC animals, which is due essentially to reduction of ash. Thus, under the effect of spaceflight factors, osteoporosis developed first in spongy tissue of long bones of the limbs, complete normalization of the head of the femur failing to occur in 6 or even 29 days of recovery period.

External and internal general plates are seen on preparations obtained from the middle part of the femoral diaphysis of control animals (Figure 2*a*). The intermediate zone with mosaic structure contained areas of basic substance of cartilage that stained blue with hematoxylin and eosin. In the SF group of animals, some preparations of the femoral diaphysis showed thinning and, in some regions, disappearance of the external general lamina (Figure 26). Signs of osteoporosis were not demonstrated deep in the cortical layer; however, its thinning down was indicative of change in rate of alteration, with predominant inhibition of the osteosynthesis process in these animals under the influence of spaceflight factors.

Table 3. Change in density (in mg/mm^3) of different parts of the rat femur after 19-day spaceflight

Part of femur	Group		
	VC	SE	SF
		R+1	
Distal epiphysis	1,08±0,01	1,13±0,02*	1,00±0,02**
Head of femur	1,03±0,03	1,01±0,02	0,94±0,02
Bone tissue of diaphysis	2,27±0,02	2,35±0,03	2,18±0,02**
		R+6	
Distal epiphysis	1,12±0,01	1,09±0,01	1,07±0,03
Head of femur	1,03±0,03	0,97±0,02	0,95±0,03
Bone tissue of diaphysis	2,26±0,02	2,26±0,02	2,35±0,03**
		R+29	
Distal epiphysis	1,20±0,02	1,15±0,03	1,14±0,02
Head of femur	1,10±0,08	1,12±0,04	1,05±0,03
Bone tissue of diaphysis	2,42±0,05	2,27±0,05*	2,33±0,04

In the mineral component of the head of the rat femur Ca content was lower after spaceflight than in the control (by a mean of 5%); however, these data are statistically unreliable (Table 4). On the 29th postflight day no differences between groups were demonstrable in Ca:P ratio. The spaceflight did not affect concentration of P in the mineral component of the head of the animals' femur.

Table 4.
Ca and P concentrations in mineral component of femoral head

Stage of study	Group	Element concentration (g/100 g ash, M±m)	
		Ca	P
Preflight	Background	47,40±1,3	18,8±0,27
Postflight	VC	47,1±3,0	18,0±0,20
	SF	45,0±2,0	17,8±0,34
After recovery	6 days		
	VC	45,8±1,7	17,5±0,14
	SF	43,4±0,7	17,7±0,25
	29 days		
	VC	40,5±1,09	17,5±0,43
	SF	42,0±1,20	18,1±0,29

A comparison of parameters of mineralization of microstructures of bone tissue in diaphyses of the femurs in the SF group of rats to those of VC animals established that there were no differences between them (mean indicators of mineralization constituted 1.46 and 1.45 g/cm^3 hydroxyapatite).

These findings enable us to assume that the factors invovled in a 19-day spaceflight do not alter the rhythm of alteration of bone microstructures and, consequently, do not affect the ratio between "young" and "mature" microstructures, which is reflected by some stability of their mineralization parameters.

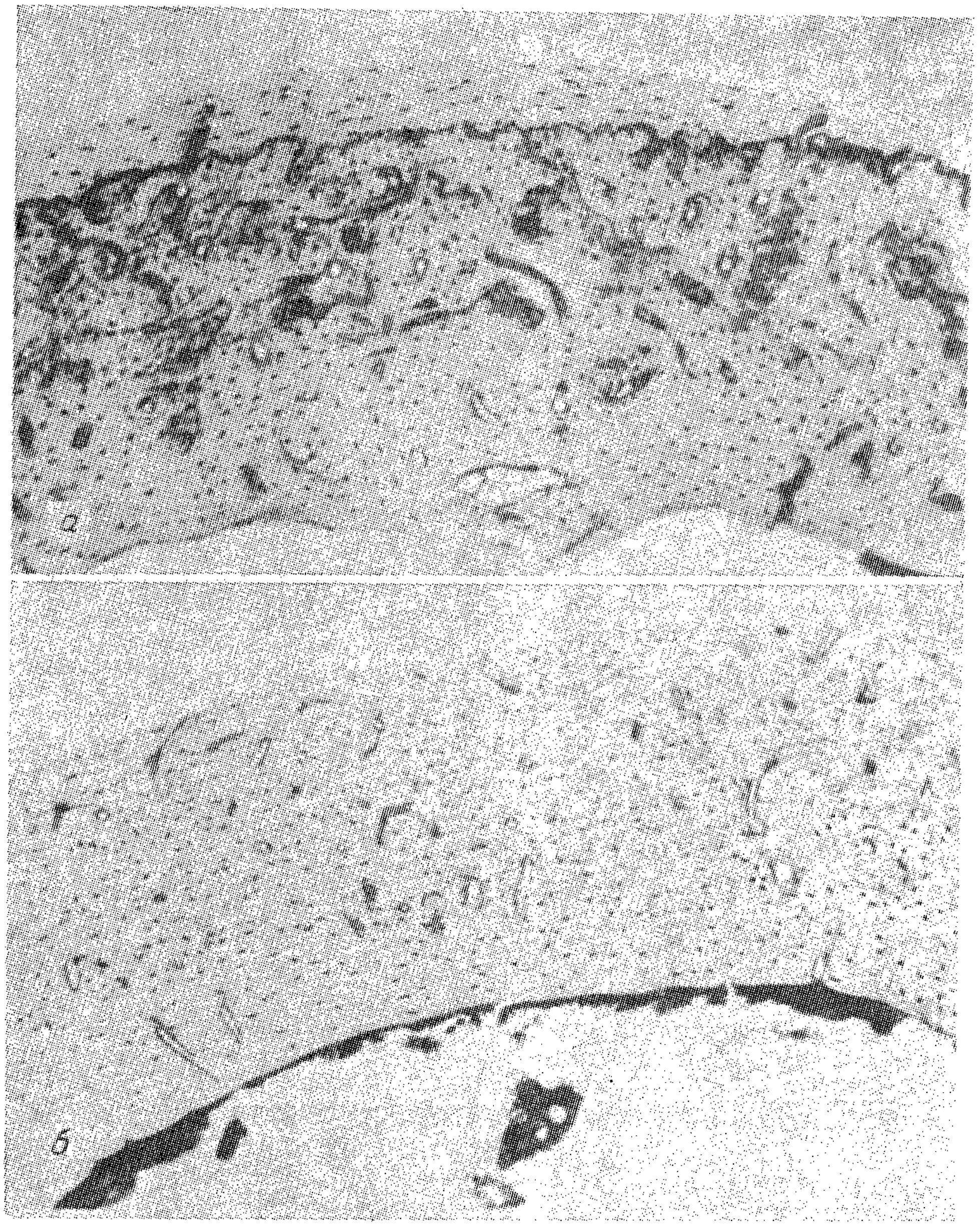

Figure 2. Histological section of middle of femoral diaphysis; section of diaphysis wanting in external general plate. Hematoxylin and eosin stain; magnification 75×

Thus, our data revealed that a 19-day spaceflight elicits in rats development of osteoporosis of spongy structures of epiphyses of long tubular bones and thinning of cortical layer of the diaphysis as a result of inhibited formation of bone tissue. A change in alteration was not associated with impaired mineralization of the bone as a whole and its microstructures in particular.

The condition of bone does not revert to normal within a 6-day recovery period. A 29-day period of free motor activity in earth's gravity after the spaceflight is not sufficient for normalization of alteration of the bone tissue in the head of the femur.

On the basis of our findings, it can be concluded that the condition of human bone must be examined at the early stages of recovery following long-term spaceflights.

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EFFECT OF PERIODIC ACCELERATIONS ON PHYSICOCHEMICAL PROPERTIES AND Ca^{2+} REACTIVITY OF ACTOMYOSIN IN WHITE RAT MYOCARDIUM AND SKELETAL MUSCLES

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 18 May 83) pp 44-47

[Article by B. A. Tikunov, M. A. Kayfadzhyan and S. S. Oganesyan]

[English abstract from source] Under the influence of regular acceleration (5 g for 25 min during 15 days) Mg^{2+}-ATPase activity of native and desensitized actomyosin of the myocardium and femurs of white rats increased. This was in correlation with increases in the rate of actomyosin superprecipitation (V_{spp}) and in the surface charge of macromolecules. The control animals showed a decrease in the inhibition of Mg^{2+}-ATPase and V_{spp} of native actomyosin by tropomyosin-troponin. Ca^{2+} in a concentration of 10^{-7}-10^{-4} M stimulated Mg^{2+}-ATPase of native actomyosin of experimental animals by 50% only, but the maximum activation of V_{spp} was significantly higher than in the controls. It is assumed that these changes tend to increase the efficiency of the actomyosin system.

[Text] The molecular mechanisms of reversible adaptation of contractile function of the heart and skeletal muscles to a hypergravity field have not been sufficiently studied. It is known that single 24-h exposure to acceleration elicits destructive changes in the contractile system of the rat myocardium [4]. It was previously shown that repeated exposure to accelerations leads to development of moderate hypertrophy of the myocardium and skeletal muscles, change in subunit composition and ATPase activity of native actomyosin [3, 6], and the assumption has been expounded that synthesis of new isoforms of myosin is possible under such conditions [7].

However, we still do not know how these changes affect the structural aspects of interaction of actin and myosin, as well as the nature of its Ca^{2+} regulation, particularly since regulatory proteins are also subject to significant quantitative and qualitative changes under hypergravity conditions [2].

Methods

Experiments were conducted with white Wistar rats (total of 60 animals). The control group of animals was kept in the vivarium and the experimental group was submitted to accelerations of 5 G for 30 min a day, for 15 days. During rotation, the rats were in narrow cell-cages which provided for a constant orientation of the vector of generated centripetal accelerations in the head-tail direction.

The animals were decapitated under ether anesthesia; we took the myocardium and femoral muscles of the mixed type (FM) for examination. Native actomyosin (NAM) was isolated according to [15], and desensitized (i.e., without tropomyosin-troponin complex) actomyosin (DAM) was recovered from the NAM suspension [17]. Purity of protein preparations was checked electrophoretically [18]; protein concentration in solution was determined by the Lowry method.

The superprecipitation reaction (SPP) of actomyosin was recorded automatically according to change in opacity of the protein suspension at 660 nm after addition of ATP, while the rate of the process (V_{spp}) was determined as the tangent of the angle of inclination of the rectilinear segment of the kinetic SPP curve. Mg^{2+}-ATPase activity was evaluated according to quantity of inorganic phosphate (P_i) [12].

Spectral of light absorption of the cation dye, acridine orange (AO) were recorded on an SF-14 spectrophotometer.

Results and Discussion

Mg^{2+}-ATPase activity of NAM of the myocardium and FM, as well as V_{spp} of FM was reliably lower in the control group of animals than in the corresponding DAM preparations (Table 1). This is apparently attributable to the presence of regulatory proteins in NAM, which is consistent with data on the inhibitory effect of the tropomyosin-troponin complex on ATPase and V_{spp} of actomyosin [1]. In the control, myocardial NAM had lower Mg^{2+}-ATPase activity and one-third the V_{spp} than NAM of femoral muscles. Since qualitatively analogous differences are observed in the corresponding DAM preparations, it can be concluded that they are attributable to the typical specifics of properties of not only regulatory [14, 16], but contractile proteins proper.

According to the data in Table 2, desensitization of NAM has little effect on the latter's capacity to interact with AO cations, while maximum light absorption of FM NAM- and DAM-bound dye is greater by a mean of 21-23% than for cardiac preparations. Thus, skeletal muscle actomyosin has a stronger negative surface charge than cardiac actomyosin, i.e., greater AO reactivity, and it also has higher Mg^{2+}-ATPase activity and higher V_{spp}. In view of the fact that myosin is the principal AO binding protein in the actomyosin complex [10], it can be assumed that the differences in enzymatic and complex-forming properties of actomysin of different types of muscles are largely determined by the surface charge of actin and, particularly, myosin macromolecules. Thus, it is known that a negative charge plays an important part in providing for the unadulterated nature of myosin [9].

Table 1. V_{spp} and Mg^{2+}-ATPase activity of rat myocardium and femur NAM and DAM in control and hypergravity groups

Animal group	Type of muscle	Protein	V_{spp}, abs.units	P	Mg^{2+}-ATPase, μg P_i/min	P
Control	Myocardium	NAM	4,2±0,8	>0.05	5,4±1,3	<0,001
		DAM	4,8±0,2		7,5±0,1	
	FM	NAM	12,5±0,8	⩽0,01	7,7±1,6	⩽0,01
		DAM	15,3±0,5		9,6±1,0	
Experi-mental	Myocardium	NAM	16,6±1,8	<0,001	12,1±0,4	<0,001
		DAM	9,1±2,4		15,4±0,8	
	FM	NAM	23,8±1,1	⩽0,01	18,2±0,8	<0,C01
		DAM	25,0±0,5		19,1±0,1	

Note: An average of 10 experiments were performed in each series.

Table 2. Change in light absorption maximums (ΔD) related to actomyosin of monomer (ΔD_1) and dimer (ΔD_2) forms of AO in control and hypergravity groups of rats

Animal group	Type of muscle	Protein	ΔD in relation to control solution		$\Delta D_1/\Delta D_2$
			ΔD1 (λ= 496 nm)	ΔD2 (λ= 465 nm)	
Control	Myocardium	NAM	0,050	0,070	0.71
		DAM	0,060	0,075	0.80
	FM	NAM	0,077	0,087	0.88
		DAM	0,083	0,090	C.90
Experimental	Myocardium	NAM	0,083	0,085	1.00
		DAM	0,085	0,090	0,94
	FM	NAM	0,105	0,110	0.96
		DAM	0,105	0,105	1.00

Note: [AO] = 10 μg/mℓ; [AM] = 0.2 mg/mℓ; 0.6 M KCl, 2 mM tris-HCl, pH 6.8; t = 25°C. Control solution contains all constituents except protein.

The higher $\Delta D_1/\Delta D_2$ index in skeletal muscle preparations is attributable to the greater relative light absorption of monomer forms of AO (ΔD_1) than for cardiac actomyosin. This indicates that, in the case of FM, the deconcentrated charges make a greater contribution to the overall negative potential of actomyosin macromolecules [8].

In the experimental group, Mg^{2+}-ATPase activity of NAM and DAM of the muscles studied increased by more than 2 times, as compared to control preparations, which was associated with increase of V_{spp} (see Table 1). After removal of regulatory proteins, the quantitative differences between the parameters in question persisted, and from this it can be concluded that actin and myosin are subject to the most change.

However, it should be noted that the capacity of tropomyosin-troponin to inhibit Mg^{2+}-ATPase was somewhat diminished in the experimental group: while Mg^{2+}-ATPase activity of cardiac DAM and FM DAM was an average of 37.6 and 25.5% higher than in corresponding preparations of NAM, the values dropped to 27.5 and 4.9%, respectively, in the experimental group. This could be due to decrease in relative quantity of inhibitory troponin subunit with hypergravity [6].

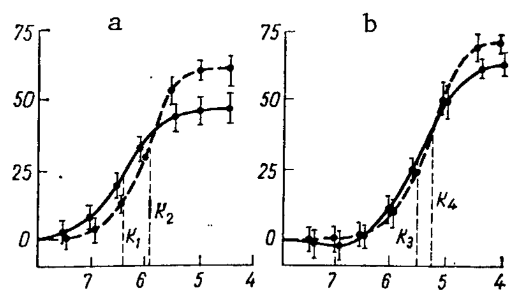

Figure 1.
Change in V_{spp} of myocardial (a) and FM (b) NAM in animals of control (solid lines) and hypergravity (dash lines) groups in the presence of different concentrations of Ca ions in medium
Incubation mixture: [NAM] = 0.5 mg/mℓ; Ca^{2+}-EGTA buffer; 0.15 M KCl, 2 mM tris-HCl; 5 mM $MgCl_2$, pH 7.4; 5 mM ATP; t = 25°C
X-axis, pCa; y-axis, relative change in V_{spp} (%)

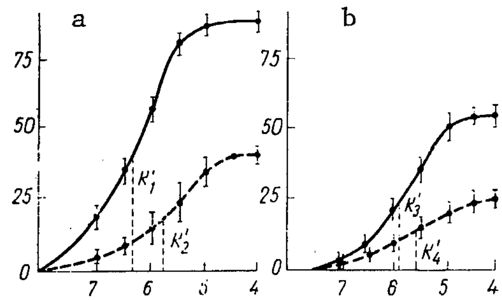

Figure 2.
Change in Mg^{2+}-ATPase activity of myocardial (a) and FM (b) NAM in control (solid lines) and hypergravity (dash lines) groups of rats in the presence of different concentrations of Ca ions in medium
Incubation medium: same as in Figure 1, except 2 mM $MgCl_2$, pH 7.35; 2 mM ATP
X-axis, pCa; y-axis, relative change in Mg^{2+}-ATPase (%)

The reliable ($P<0.001$) increase in AO-sorption activity (see Table 2) correlates well with increase in Mg^{2+}-ATPase and V_{spp}. The increase of index ($\Delta D_1/\Delta D_2$) in the experimental group to 1 is indicative of relative increase in deconcentrated charges localized mainly on the myosin macromolecule.

The next stage of our work was investigation of distinctions of Ca^{2+} regulation of SPP reaction and Mg^{2+}-ATPase activity of NAM in control and experimental groups of animals. As seen in Figure 1a, activation of V_{spp} of preparations of cardiac NAM starts and ends with lower (by almost a factor of 10) of Ca^{2+} in the control than in the case of FM (Figure 1b). The maximum effect of high concentrations of Ca^{2+} on myocardial NAM V_{spp} is 18-20% smaller than for skeletal muscle preparations, although Mg^{2+}-ATPase is markedly activated in cardiac NAM (Figure 2).

Half the maximum activation of V_{spp} (K_1) and Mg^{2+}-ATPase (K_1') of cardiac NAM is obtained with pCa 6.3-6.4, which is quite consistent with the results of fluorimetric titration [11]. In the case of FM, this effect is obtained with concentrations of Ca ions higher by a factor of 10 (see K_3 and K_3') in Figure 2), which is apparently related to the lower Ca^{2+} activity of skeletal muscle troponin [13].

In the hypergravity group, we observed decrease by more than half (see Figure 2) in activation of Mg^{2+}-ATPase of the examined NAM preparations; however, the activating effect of high concentrations of Ca^{2+} on V_{spp} was, on the contrary, enhanced (see Figure 1). Perhaps this reflects the nature of adaptive changes in functionally important properties of contractile muscular proteins when exposed to brief periodic accelerations, the substance of which consists of increasing efficiency of the mechanochemical actomyosin system. Indeed, according to the results obtained V_{spp}, which is proportionate to complex formation of actin with myosin in the presence of physiologically significant Ca^{2+} concentrations, increased in the experiment against a bacgkround of diminished Ca^{2+} activation of Mg^{2+}-ATPase of NAM, which is indicative of change to a more conservative functional mode, which could be more advantageous becasue of the ATP deficiency in the presence of muscular hyperfunction [5].

The "right shift" of half the maximum effect of Ca^{2+} on V_{spp} and Mg^{2+}-ATPase activity of NAM on the pCa axis is rather interesting: it is very marked in heart preparations (K_2 and K_2') and less so in skeletal muscle protein preparations (K_4 and K_4'). There is actually synchronous increase in efficiency of the actomyosin system and decrease in effectiveness of Ca^{2+} effect.

Thus, we observe increase in Mg^{2+}-ATPase activity of myocardial and FM NAM and increase in rate of complex formation between actin and myosin under the influence of short-term exposure to periodic accelerations. This is attributable not only to attenuation of inhibitory effect of tropomyosin-troponin, but changes in physicochemical properties of contractile proteins, in particular, in magnitude and distribution of surface charge of macromolecules. The changes in Ca^{2+} regulation, which are aimed at improving the efficiency of the actomyosin system, are apparently an important element of the adaptogenic reaction of muscles to periodic accelerations.

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OXYGEN UPTAKE AS AN INDICATOR OF ANIMAL ADAPTATION TO ALTITUDE HYPOXIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 5 Apr 83) pp 47-50

[Article by V. B. Malkin and Ye. V. Loginova]

[English abstract from source] Altitude chamber experiments have shown that the quantity of oxygen consumption in the posthypoxic period as an index of adaptation to hypoxia is of low informative value: during the normal course of adaptation, oxygen consumption changes insignificantly or decreases slightly; it increases somewhat if the hypoxic atmosphere contains CO_2 (pCO_2 = 19-27 mm Hg) and declines significantly (by 22.6%) only if adaptation is disordered. At the same time, oxygen consumption can be a highly informative index, characterizing the efficiency of adaptation to hypoxia only if it is measured immediately after exposure to acute hypoxia. In this experimental design the magnitude of oxygen consumption increases with increasing oxygen debt which, as follows from our experiments, shows the degree of conditioning to altitude hypoxia.

[Text] Many authors [1, 5, 6, 8] failed to observe reliable changes in oxygen uptake of white rats adapted to altitude hypoxia when this parameter was measured under normal conditions (breathing air and normal barometric pressure). These data are in contradiction to the results of recent studies [3, 9], in which a significant (33-40%) decline of oxygen uptake was demonstrated under the same conditions in rats following 10, 20 and 40 days of adaptation to altitude hypoxia. This finding served as grounds to advance the conception, according to which the decrease in oxygen uptake--diminished tissue requirement for oxygen--is one of the important indicators of adaptation to hypoxia, and that one can assess effectiveness of animal adaptation to hypoxia according to magnitude of oxygen uptake deficit.

Our objective here was to assess the possibility of using oxygen uptake values, which are determined under normal conditions, as an indicator of effectiveness of adaptation to hypoxia.

Methods

To adapt the animals to altitude hypoxia, we used four different conditioning modes, during which experimental animals in the pressure chamber were exposed to hypoxia daily for 6 h/day. We gradually reached the end altitude, at which conditioning ended. For this reason, in all experimental series we started with 3000 m altitude and then increased it by 500 m each day.

The first mode involved stepped ascent to 6500-7000 m, followed by up to 40 days at these altitudes daily. The second mode was stepped ascent to 5000 m and up to 30 days at this altitude. In a special series of experiments (to demonstrate the role of hypocapnia in the process of forming adaptation to hypoxia) high CO_2 level was maintained in the pressure chamber during the period of conditioning at 5000 m, so that pCO_2 constituted 19 to 27 mm Hg.

During the experiments, we weighed the animals, determined oxygen uptake by the Kalabukhov method at a temperature of 16°C, the "altitude ceiling"--time of survival during stepped ascents to high altitudes, as well as erythrocyte count and hemoglobin of peripheral blood. For determination of the "ceiling," the animals were submitted to stepped ascent in the pressure chamber at the rate of 80-100 m/s, first to 10,000 m with a 10-min plateau, after which we increased ascent by 1000 m with a 5-min plateau at each successive altitude. We determined the "ceiling"--individual resistance of an animal to acute hypoxia--according to time when breathing stopped. Erythrocyte count was determined with an M-60 photoelectric colorimeter in a beam passed through a red filter by the Ye. M. Bessonova method [2]. Hemoglobin concentration was also determined photocolorimetrically on an M-60 instrument in a beam passed through a green filter by the method of G. V. Derviz and A. I. Vorob'yev [7].

Results and Discussion

The Table lists the results of changes in oxygen uptake by rats after different training modes. For the sake of comparison of oxygen uptake in different series of experiments performed in different seasons, the table does not list absolute values for oxygen uptake, but relative changes in comparison to appropriate control.

$$(\Delta\% = \frac{\text{uptake, experimental - uptake, control}}{\text{uptake, control}} \times 100)$$

Oxygen uptake levels listed in the Table were obtained on the ground 16-24 h after the last conditioning ascent.

Oxygen uptake (Δ, %) as a function of conditions and duration of training

Conditions	Duration of conditioning, days									
	10		14		20		30		40	
	% Δ	numb of rats	% Δ	numb of rats	% Δ	numb of rats	% Δ	numb of rats	% Δ	numb of rats
At 5000 м	—	—	+3,3	20	—	—	+0,7	20	—	—
At 5000 м + CO_2	—	—	+10,6	20	—	—	+1,1	20	—	—
At 7000 м	+0,8	20	—4,2	154	—1,9	45	—9,3	58	—9,9	12

The results of the experiments indicate that there were no reliable changes in oxygen uptake in hypoxia-adapted rats after completion of conditioning at altitudes of up to 5000 m, whereas they presented reliable increase in erythrocytes, reticulocytes and hemoglobin in blood. Survival time increased by 71% at high altitudes after 14 days of adaptation and by 166% at the end of the cycle. After 10-15 days of animal conditioning at 5000 m with addition of CO_2 to the gas environment, we observed a reliable increase in oxygen uptake, by a mean of 10.6%, and tolerance to altitude was significantly improved: survival time at high altitude increased by 113% in experimental animals. On the 30th day of adaptation, the parameters of oxygen uptake were virtually restored to those of control animals, while altitude tolerance was 110% greater than resistance to acute hypoxia of control animals.

The results of this series of experiments enable us to assume that the decline in oxygen uptake, which we and other authors observed in adapted animals, could be due to hypocapnia.

There were no reliable changes in oxygen uptake of experimental animals after 10, 14 and 20 days of conditioning at 6000-7000 m, but they presented changes typical of adaptation to hypoxia; increased hemoglobin and erythrocytes in blood, rise of altitude ceiling. The animals presented a decline in oxygen uptake, by a mean of 9.3-9.9%, after 30-40 days of conditioning; in some series of experiments, there were some deaths and decline of ceiling, which was 140% above the background value after 14-20 days of conditioning, whereas after the 40th day of conditioning it exceeded the background value by only 70%.

A special series of experiments, which we conducted to study the physiological changes associated with "breakdown" of adaptation to hypoxia, revealed that with worsening of the animals' condition there was decrease, by 22.6%, in oxygen uptake.

Thus, the results of these studies indicate that oxygen uptake in the posthypoxic period remains unchanged in adapted animals, or else it diminishes insignificantly, and it is only in cases of "breakdown" of adaptation that this parameter diminishes reliably and considerably.

When submitting the animals to conditioning, during which development of hypocapnia was eliminated by adding CO_2 to the pressure chamber atmosphere, at the early stage of adaptation (10th-15th day) there was reliable increase in oxygen uptake against a background of distinct manifestation in experimental animals of all of the principal signs of adaptation to hypoxia.

It can be concluded from the foregoing that oxygen uptake in the posthypoxic period is not very informative as an indicator of effectiveness of adaptation to hypoxia. This had been previously noted by Ye. M. Kreps et al. [8].

It was logical to assume that the oxygen debt in hypoxia-adapted animals, which appeared after brief exposure to acute hypoxia, should be lower than in unadapted animals. To test this hypothesis, in one of the series of experiments we measured oxygen uptake right after exposure to acute hypoxia--brief (15 min) ascent of animals to "altitude" of 7000 m. We found an increase in oxygen uptake, by a mean of 38.2%, right after descent of a control group of 10 animals; oxygen debt was reliably lower in hypoxia-adapted animals: the increase in oxygen uptake reached an average of 19.9%. Thus, we found a form of experiment, in which oxygen uptake in the posthypoxia period was a highly informative indicator characterizing the efficacy of adaptation to hypoxia.

In assessing the results of this investigation, it can be concluded that oxygen uptake of hypoxia-adapted animals does not change appreciably when the course of adaptation is normal. These findings corroborate the results of studies of many researchers [1, 4, 8]. A significant decrease in oxygen uptake is one of the signs of "breakdown" of adaptation. It is significant, as shown in the experiments with addition of CO_2 to the gas atmosphere in the pressure chamber, that manifestation of adaptation to hypoxia may be distinctly present even in animals with high oxygen uptake.

Thus, our findings indicate that the significant [up to 40%) decrease in oxygen uptake reported by some authors [3, 7] in animals after different terms of adaptation was probably due to the extremely rigid conditioning protocol, which elicited pathological changes in experimental animals. For this reason, the conception that is developed [3, 9] to the effect that a decrease in oxygen uptake in the posthypoxia period is an indicator of efficacy of hypoxia conditioning, showing that adapted animals have a lower oxygen requirement, is in contradiction to the data we have submitted here and in the works of many authors [1, 6, 8].

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DISTINCTIONS OF RAT LYMPHATIC ORGAN REACTIONS TO ACUTE STRESS FACTOR DURING HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 14 Oct 83) pp 50-54

[Article by Ye. V. Vorotnikova]

[English abstract from source] Female rats long exposed to hypokinesia were then subjected to an acute stress. In this situation the thymus and spleen were examined. The destructive process in the thymus increased in spite of its hypoplasia. This can be attributed to a greater production of corticosteroids by the adrenals caused by the chronic stress. At the same time the white pulp of the spleen decreased insignificantly because it contained no lymphocytes capable to migrate by the time of the acute stress-effect. It is concluded that enhanced destruction of lymphocytes in the thymus in response to an acute stress can be regarded as a diagnostic test of the adrenal state during a chronic stress-effect, including hypokinesia.

[Text] At the present time, most researchers believe that prolonged restriction of movement elicits development of chronic stress in animals [8, 9], and that it is often associated with change in the body's reactions to extreme factors [1, 3, 10, 14, 15].

Our objective here was to investigate rat reactions to an acute stressor during their adaptation to hypokinesia. We chose lymphatic organs as the object of our investigation, in which changes under stress are rather stable and make it possible to assess with a high degree of reliability the functional state and reserve capacities of body systems responsible for development of the general adaptation syndrome.

Methods

The thymus and spleen from 250 female mongrel rats weighing about 170 g served as material for our study. The animals were divided into four equal groups: the 1st consisted of intact rats kept in the vivarium; the 2d, intact animals in which acute stress was produced; the 3d, rats submitted to hypokinesia and the 4th, rats in which acute stress was produced under hypokinetic conditions. To produce hypokinesia, the rats were placed in individual box-cages.

Hypokinesia lasted 90 days. Acute stress was produced by immobilizing the animals for 5 h having them stretched out in prone position on special stands [16].

Organ samples for examination were taken before the experiment (base control), 1, 2 weeks, 1, 2 and 3 months after the start of hypokinesia, as well as 1 month after its termination. At each of the above times we decapitated 8-10 rats from each group after weighing them.

The thymus and spleen were weighed, fixed in Carnois fluid and neutral formalin, then imbedded in histoplast. Thymus and spleen sections were stained with hematoxylin and eosin, methyl green pyronine and by the Perls method for iron. For quantitative studies of white splenic pulp, we used photographic prints of its cross sections, on which we outlined follicles with India ink, after which they were cut out and weighed on a torsion balance, obtaining overall area of white pulpe expressed in arbitrary units. All of the digital data were submitted to statistical processing according to Student, considering the difference between compared values reliable at $P<0.05$.

Results and Discussion

Throughout the experiment, the rats were in satisfactory condition and there were no deaths. The weight of rats in the 3d group was considerably lower than that of control animals, remaining the same as in the "base control" group. After termination of hypokinesia, the animals began to gain weight rapidly and after 1 month of recovery weight was close to the level of control animals, but did not reach it. Acute 5-h stress caused 10-15 g weight loss in control and experimental rats.

The thymus: Already 1 month after the start of hypokinesia, the rats presented significant reduction of both absolute and relative mass of the thymus. Absolute mass of the thymus remained low to the end of the hypokinetic period, whereas its relative mass began to regain control levels starting in the 2d month. Evidently, this is attributable to slower accidental involution of the organ at the last stage of hypokinesia with concurrent inhibition of animal growth (Figure 1). One month after terminating hypokinesia, the absolute mass of the thymus reached the level inherent in control animals.

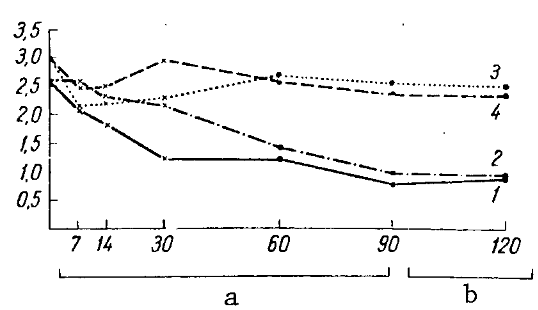

Figure 1.
Dynamics of changes in relative mass of female rat thymus and spleen during 90-day hypokinesia (a) and after its termination (b)
1, 2) relative mass of thymus of rats in 3d and 1st groups, respectively
3, 4) relative mass of spleen of rats in 3d and 1st groups, respectively

X-axis, duration of hypokinesia (days); y-axis, relative mass of lymphatic organs (mg/g); × indicates statistically reliable differences between control and experiment ($P<0.05$)

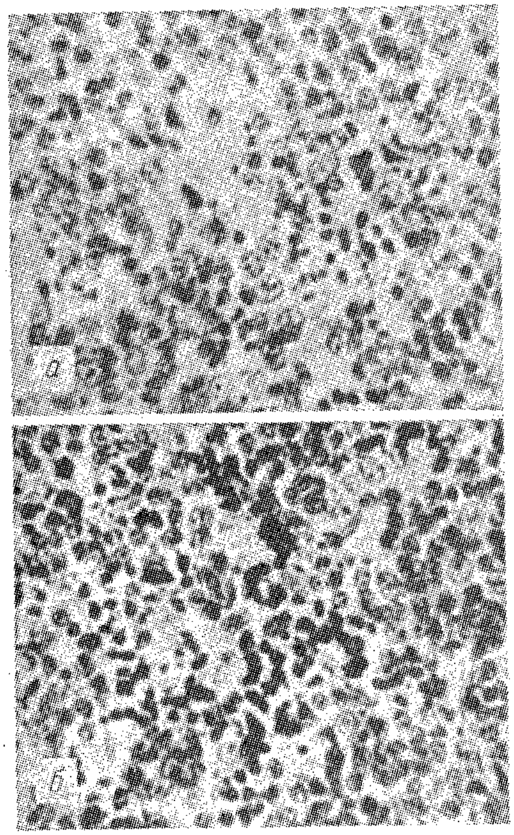

Figure 2. Dissociation of lymphocytes in female rat thymus after 5-h immobilization stress. Hematoxylin and eosin stain; lens 40×, eyepiece 7×

a) dissociation of lymphocytes in thymus of control rat
б) intensified breakdown of lymphocytes in thymus of rat submitted to hypokinesia for 30 days

Acute 5-h stress did not cause reduction of thymus weight in either control or experimental rats, which is consistent with the results of previous studies [6], which indicated that thymus weight reduction is observed under stress only 10 h after the start of exposure to it, when the process of elimination of nuclear detritus is completed.

Histological examination of the thymus revealed progressive atrophic changes. Thus, after 1-2 weeks of hypokinesia, the cortical substance of the thymus appeared rarefied and the number of dividing cells in it diminished. After 1 month of hypokinesia there was reduction in size of thymus lobes, narrowing of cortical substance, increase in number of plasma cells in the cortico-medullary zone, thickening of interlobular connective layers with increase in number of mast cells in them, appearance in thymus lobes of trabeculae of young connective tissue proliferating into the lobe on the side of the connective layers. Three months after the start of hypokinesia, some of the thymus lobes had been replaced with fatty tissue; the boundary between cortical and medullary substance became diffuse in the remaining lobes, and the ratio between cortical and medullary substance changed in favor of the latter. Proliferation of epithelial structures resembling glands was encountered in thymus tissue more often than normally.

Recovery of thymus weight 1 month after termination of hypokinesia was associated with increase in number of lymphocytes and dividing cells in the cortical substance, normalization of histology of the thymus and ratio between cortical and medullary substance, as well as inhibition of sclerotic process in the interlobular connective tissue.

Acute stress elicited massive dissociation of lymphocytes in the cortical substance of the thymus in both control and experimental animals and, in the 3d group of rats, in spite of hypoplasia of the cortex, the quantity of dead cells throughout the hypokinetic period exceeded significantly the number of disintegrating lymphocytes in control animals (Figure 2*a* and *б*). It should be noted that, with increase in duration of hypokinesia, there was some decrease in thymus reaction of experimental rats to the stressor. The differences between control and experimental animals in quantity of nuclear detritus demonstrable in the cortical substance of the thymus diminished after stress, but the number of disintegrating cells was still greater in the thymus of experimental rats than in control animals.

One month after termination of hypokinesia, in some of the rats the thymus reacted to stress immobilization more strongly than control animals, whereas in others the reaction of the thymus did not differ from that of the controls.

The spleen: The absolute and relative mass of the spleen of hypokinetic rats diminished by 25-30%, already 1 week after the start of the experiment, as compared to the control and initial level. At subsequent stages of the experiment, the absolute weight of the spleen remained low, whereas relative mass did not differ from that of control animals starting with the 2d month of hypokinesia (see Figure 1). One month after termination of hypokinesia there was normalization of absolute and relative mass of the spleen. Acute stress elicited a decline of absolute and relative spleen mass by a mean of 20% in both experimental and control rats at all stages of the experiment (Figure 3).

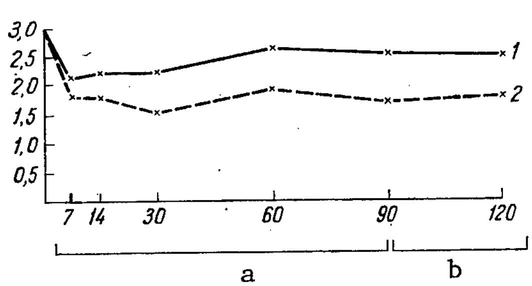

Figure 3.
Change in relative mass of rat spleen with acute immobilization stress
1, 2) relative spleen mass of rats in 3d and 4th groups
a) hypokinesia
b) recovery

X-axis, duration of hypokinesia (days); y-axis, relative weight of spleen (mg/g); × indicates statistically reliable differences in relative spleen weight in stressed and nonstressed rats ($P<0.05$)

Histological and morphometric studies revealed that hypokinesia leads to marked hypoplasia of white pulp of the spleen. One week after the start of the experiment, the area of white pulp diminished by 25% ($P<0.05$) in experimental rats, as compared to the control. Concurrently with hypoplasia of white pulp, there was increase in amount of detritus in the clear centers of lymphoid follicles and decrease in number of dividing cells and blast forms, whereas the red pulp demonstrated inhibition of erythroid hemopoiesis. After 14-30-day hypokinesia, the size of lymphoid follicles and density of lymphocytes in them increased somewhat; mitoses appeared in the clear follicular centers, while the amount of nuclear detritus in them diminished. In rats submitted to hypokinesia for 2-3 months, red pulp of the spleen showed activation of erythroid and, to a lesser extent, myeloid hemopoiesis; hypoplasia of white pulp remained at the former level. Restoration of cellular composition and size of lymphoid follicles of the spleen was observed in experimental rats only after 1 month of readaptation, when the absolute weight of the spleen reached the level of control animals.

In control animals, acute stress elicited drastic decrease in plethora of the spleen, size of lymphoid follicles and number of lymphocytes in them, and, on the contrary, increase in quantity of nuclear detritus in clear follicular centers. In animals submitted to hypokinesia, unlike control rats, acute stress led only to diminished delivery of blood to the spleen. The amount of lymphoid tissue in it did not change appreciably in animals of the 1st group, as compared to the 3d group.

One month after termination of hypokinesia, the reaction of the spleen to acute immobilization stress was identical in control and experimental groups of rats.

The results of this experiment confirm the numerous observations [7, 9, 11-13] indicative of the fact that hypokinesia leads to involution of lymphatic organs of rats as a result of development of chronic stress. The dynamics of changes in mass of lymphatic organs and their histology warrant the belief that the 1st month of hypokinesia corresponds to the anxiety stage of the general adaptation syndrome, the 2d and 3d months, to the resistance stages. At the same time, the stage of depletion of the general adaptation syndrome was not demonstrated in this experiment. The qualitative nature of lymphatic organ reactions in rats submitted to hypokinesia to an acute stressor did not change, and remained the same as in intact animals, i.e., in response to the stressor the thymus reacted primarily by dissociation of lymphocytes and the spleen, by their migration [6]. At the same time, quantitatively, the thymus of rats submitted to hypokinesia reacted considerably more strongly to the acute stressor than the thymus of control animals. This was indicated by the increase in amount of nuclear detritus in it, which was apparently related to intensified discharge of corticosteroids by the adrenals [4] in the 3d group of rats. Some decrease in amount of nuclear detritus in the thymus of the 4th group of rats correlates well with the results of biochemical studies, which demonstrated that, under chronic stress conditions, there is gradual decrease in corticosteroid production by the adrenals, in spite of their hypertrophy [18]. This phenomenon is not attributable to depletion of the adrenals, but to decrease in the stimulating effect of the pituitary on them [17].

On the whole, it can be considered that an acute stressor elicits intensification of destructive processes in the thymus of hypokinetic rats, which could lead to its depletion and impairment of immunobiological reactivity of the body.

In the spleen of hypokinetic rats, the acute stressor had virtually no effect with regard to reduction of lymphoid tissue, and this is most likely related to the absence of T lymphocytes capable of migration at the time of exposure to the stress factor, which migrate from the spleen at the early stages of hypokinesia. At the same time, decreased delivery of blood to the spleen of hypokinetic rats under acute stress is indicative of retention of the organ's capacity to react to activation of the sympathetic nervous system [16].

Our findings warrant the belief that, in the presence of chronic stress caused by long-term hypokinesia, there is increase in animals' sensitivity to additional acute stress, which is manifested by intensification of destructive processes in the thymus. Thus, the intensity of lymphocyte destruction in the thymus under acute stress may serve as a morphological indicator of the condition of functional systems responsible for development of the general adaptation syndrome during the period preceding exposure to stress, i.e., it may be an indicator of chronic stress.

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616.1-008.1-02:615.214.2

NATURE OF POSTURAL CHANGES IN HUMAN HEMODYNAMICS WITH INTAKE OF SYDNOCARB ALONE AND IN COMBINATION WITH OBSIDAN

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 27 Oct 83) pp 54-58

[Article by A. Yu. Modin, V. I. Sokolov, N. V. Degterenkova, V. S. Shashkov and V. A. Gornago]

[English abstract from source] Experiments were carried out to study the effect of sydnocarb 3-(β-phenylisopropyl)-N-phenylcarbamoyl-sydnonimine), a stimulant of mental and physical performance, and its combination with obsidan, a β-adrenoblocking agent, on the central and peripheral hemodynamics during a head-up test (+75°) after a 6-hour head-down tilt (-15°). Sydnocarb increased the tone of brain and leg arterioles, left unchanged stroke volume and cardiac output, and decreased the postural increment of heart rate. Sydnocarb (15 mg) combined with obsidan (20 mg) reduced heart rate and its postural increment, increased stroke volume, and increased the tone of resistive vessels, as was also the effect of sydnocarb taken separately.

[Text] The problem of inadequate response to postural stress following different periods of limited mobility has not been definitely resovled, either from the standpoint of pathogenesis or prevention, including pharmacological.

In view of the multifactor nature of postural circulatory disorders, the search for drug prophylaxis is being pursued among agents referable to different pharmacological groups, chiefly among stimulants, analeptics, vaso-active and hormonal products. There is also information about the beneficial effect on orthostatic tolerance of drugs with β-adrenolytic activity [7, 8].

The information about effective preventive use of the Soviet psychoanaleptic, sydnocarb [1], contains no pharmacodynamic analysis of its beneficial effect on orthostatic tolerance, so that it is of definite interest to investigate the mechanisms through which this effect occurs. It is also known that pharmacoprophylaxis of orthostatic intolerance is more effective when it is based on the principle of polypragmasy [2], for which reason the purpose of our study included evaluation of the preventive effect of sydnocarb and the β-adrenoblocking agent, obsidan (propranolol) together.

Methods

We conducted the studies in a hospital with the participation of 10 essentially healthy men. The protocol included an orthostatic test before and after 6-h antiorthostatic position (AOP) with a -15° angle of tilt twice for each subject, on the day of giving placebo and on the day of giving a drug, which consisted of sydnocarb for 5 subjects (1st group) and sydnocarb with obsidan for the other 5 (2d group).

The tests were performed from 8-9 am to 4-5 pm. Considering the pharmacokinetics of sydnocarb and obsidan, the drug and placebo (saccharose), which were contained in identical capsules, were given once 1.5-2 h before termination of AOP. The dosage of sydnocarb was 15-20 mg, and the combination of drugs contained 15 mg sydnocarb and 20 mg obsidan.

The passive orthostatic test was performed on a turntable. It lasted 20 min at an angle of +75°. We recorded the following parameters before, during and after this test: heart rate (HR), arterial pressure (BP) according to Korotkov, stroke volume (SV) and cardiac output (CO) using tetrapolar rheography [5], as well as characteristics of peripheral hemodynamics by the method of rheoencephalography and rheovasography (REG and RVG). All of the parameters were recorded successively in the 1st, 5th, 10th, 15th and 20th min of the orthostatic test. An RPG2-02 rheoplethysmograph was used to measure SV and CO. A bipolar 4RG-1m rheograph was used to record the REG in the frontomastoid and bimastoid leads, which reflect hemodynamic changes in the pool of the internal carotid artery and vertebrobasilar region, respectively [6], as well as RVG of the lower leg. Tetrapolar rheograms were recorded on a Mingograph-82 and bipolar ones, on a Galileo electroencephalograph.

The parameters recorded during orthostasis after AOP were compared to one another in absolute values, while dynamics of orthostatic tolerance during AOP were expressed in both instances (drug and placebo) as percentage of background, i.e., results of orthostatic test performed on the same day before AOP.

Statistical processing consisted of calculating means and determining the reliability of differences between mean values by the method of variants related in pairs.

Results and Discussion

It was necessary to stop prematurely only one of the 20 post-AOP orthostatic tests due to complaints of vertigo in a subject of the 2d group, who had been given placebo on the day of the tests. In addition, as shown by processing data from bipolar and tetrapolar rheography, one of the subjects in the 1st group presented, also on the day of taking placebo, in the 20th min of orthostasis a marked decline of SV (27.0 mℓ), tendency toward slowing of HR, drastic hypotension of resistive vessels in all examined areas, which made it possible to retrospectively diagnose a precollaptoid state.

Functional orthostatic tests before AOP were performed by all subjects to the full extent; however, subsequent analysis of the results revealed that the level of orthostatic tolerance before AOP manifested some fluctuations on different test days. The differences in base orthostatic tolerance served as an additional guideline in assessing the effects of the tested agents.

As can be seen in Table 1, 6-h AOP on the day of placebo intake reliably worsened orthostatic tolerance according to parameters such as HR, postural increment of HR, SV and CO. Conditions of regional hemodynamics also changed as a result of AOP (Table 2), which was reflected by a reliable decline of the dicrotic index (DCI) of the frontomastoid and bimastoid REG and RVG of the leg--a sign of decreased tonus of arterioles and precapillaries.

Table 1. Effect of pharmacological agents on parameters of human central hemodynamics during orthostatic test

Parameter of central hemodynamics	1st group				2d group			
	placebo		sydnocarb		placebo		sydnocarb+ obsidan	
	abs.	%	abs.	%	abs.	%	abs.	%
HR/min	92,4	105,0	97,9	105,5	89,0	111,5*	72,4*	96,3
HR increment/min	32,2	178,9*	27,1	127,8	31,5	212,8*	17,2*	116,2
Pulsed BP, mm Hg	23,8	89,0	30,6	118,3	31,0	93,9	33,9	89,9
SV, mℓ/beat	45,5	71,4*	42,4	72,6	—	—	64,1	91,2
CO, ℓ/min	4,204	75,0*	4,151	76,6	—	—	4,641	87,8

Note: Here and in Table 2, means for 5 cases are listed. Asterisk indicates $P \leq 0.05$.

Table 2. Effect of pharmacological agents on parameters of human regional hemodynamics during orthostatic test

Parameter of regional hemodynamics	1st group				2d group			
	placebo		sydnocarb		placebo		sydnocarb+ obsidan	
	abs.	%	abs.	%	abs.	%	abs.	%
REG_{fm}:								
A, mΩ	78,3	80,6	75,6	74,7	89,6	75,4	76,0	81,8
DCI, %	30,3	63,8*	41,5*	113,7	44,4	72,3*	56,6*	103,5
REG_{bm}:								
A, mΩ	70,8	71,1	85,3	90,3	59,2	57,3	95,5	121,8
DCI, %	42,7	74,3*	48,7	96,0	53,7	87,3	67,4	107,3
RVG of leg:								
A, mΩ	52,1	88,5	39,5	105,9	45,9	137,8*	—	—
DCI, %	37,9	80,6	54,7*	137,4*	42,3	78,3*	—	—

Note: REG_{fm} and REG_{bm} refer to frontomastoid and bimastoid REG.

Intake of sydnocarb not only reduced the extent of negative dynamics of the parameters but, according to several of them, caused a trend in the reverse direction. Thus, under the effect of sydnocarb the tonus of terminal arterial vessels in the pools of the internal carotid and sural vessels exceeded the base level before AOP, while the tonus of arterioles of the vertebrobasilar pool underwent virtually no change. Analysis of the dynamics of arteriolar tonus convinced us that sydnocarb had an overt tonic effect on vessels in different parts of the body ($P<0.001$ for frontomastoid REG lead, $P<0.05$ for bimastoid lead and $P<0.01$ for RVG of the lower leg).

One of the important mechanisms of orthostatic tolerance is increase in arteriolar tonus in the lower half of the body in response to orthostasis. As we know [3], limited motor activity creates conditions for increase in tonus of peripheral vessels; however, the degree of reaction of this parameter to orthostatic factors diminishes. Our results confirm this also with regard to 6-h antiorthostasis: while DCI of RVG of the leg increased by 236% before AOP when changing from horizontal to erect position, in an analogous situation after AOP it increased by only 95% ($P<0.05$). Intake of sydnocarb diminished somewhat postural hyporeactivity of arteriolar tonus of the leg after AOP; in this case, DCI increased by 129%.

Another parameter of peripheral hemodynamics--indicator of pulsed filling (A)--is, other conditions being equal, a variable function of SV, tonus of vessels in a given region and tonus of vessels in other regions, between which SV is distributed. In view of the fact that bipolar rheograms were taken of a limited number of vascular pools of the body, it is difficult to characterize, even approximately, the latter condition that determines the value of A; this, in turn, makes it difficult to interpret results obtained for parameter A. From the standpoint of providing for orthostatic tolerance, one should still consider it beneficial when the indicator of pulsed filling in the bimastoid REG lead rises with intake of sydnocarb.

There were insignificant differences in absolute values for central hemodynamic parameters after AOP in the 1st group of subjects during the orthostatic test, although changes in relation to the base state with intake of placebo were reliable, whereas with intake of sydnocarb they were in the nature of a tendency.

In the 2d group of subjects, hemodynamics were characterized by lower values for HR and less increment of this parameter during the orthostatic test after intake of sydnocarb with obsidan than under orthostatic conditions after intake of placebo, while pulsed BP underwent virtually no change. Unfortunately, for technical reasons, we were unable to record SV and CO on the day of intake of placebo and RVG of the leg on the day of intake of the drug combination. Nevertheless, if we assume that the direction and severity of changes in SV during AOP coincided in the 1st and 2d groups of subjects with intake of placebo, the obtained values for SV and their relation to the base level for subjects of the 2d group should be interpreted exclusively as being the result of pharmacodynamics of the agents contained in the combination.

Arteriolar tonus in the cerebral hemispheres was reliably greater under the influence of sydnocarb and obsidan than with intake of placebo, and just as it was for subjects in the 1st group who took sydnocarb alone it exceeded the base value. DCI in the bimastoid REG lead underwent analogous, but unreliable changes. Pulsed filling of the vertebrobasilar system was also greater with intake of the drug combination than placebo: in the former case it exceeded the base level and in the latter was almost one-half of it.

Some of the subjects in both groups mentioned the day of intake of sydnocarb or its combination with obsidan when asked on what day they tolerated the orthostatic tests better. They also reported a feeling of lightness, vigor and good mood. None mentioned the day of placebo intake as the time when wellbeing was best during the orthostatic test.

These findings warrant consideration of sydnocarb and its combination with obsidan as potential agents for prevention of orthostatic intolerance. The nature of changes in regional hemodynamics with intake of sydnocarb indicates that this agent has a rather marked vasotonic action. Additional studies are needed in order to determine whether this vasoactive effect is manifested with repeated and frequent intake of the agents.

Analysis of orthostatic tolerance after AOP with intake of both sydnocarb and obsidan involves some difficulties, chiefly due to the fact that, in this case, the HR can no longer be viewed as an integrated indicator of adaptation of the cardiovascular system to orthostasis, which is related to the direct negative chronotropic effect of obsidan. However, if CO is taken as such an integrated indicator, we shall find that the drug combination compensates entirely for inhibition of the heart's chronotropic reaction in the form of increased SV (we compared SV and CO in the 1st and 2d groups of subjects on the basis of identical characteristics of their weight and height, as well as the assumption that the dynamics of these parameters were identical in both groups during AOP). The drug combination is also characterized by vasotonic effects, and this merits a positive rating from the standpoint of providing for orthostatic tolerance.

The increase in pulsed filling of the vertebrobasilar system with intake of the drugs should be viewed as a definitely favorable effect since, according to available information [4], transient ischemic episodes in the brain, which are clinically similar in many respects to orthostatic collapse, occur in the form of impaired delivery of blood to the brain stem.

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CIRCADIAN DYNAMICS OF POTASSIUM EXCRETION IN URINE AS RELATED TO WORKING ON ONE AND TWO SHIFTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 13 Apr 83) pp 58-62

[Article by A. I. Shchukin]

[English abstract from source] Four groups of constructive and industry workers--men aged 19-20--were examined. Group 1 and 3 subjects (10 subjects in each group) worked for 1 or 2 years, respectively, in the day shift only. Group 2 (5 subjects) and 4 (10 subjects) subjects worked for 1 or 2 years, respectively, in the day and night shifts, with the shift alternating every week. The day shift was from 8.00 a.m. to 5.00 p.m. and the night shift was from 5.00 p.m. to 1.00 a.m. The test subjects were examined in a hospital on the day following the working week. Group 1, 3 and 4 subjects were examined once (Group 4 after the night shift), and Group 2 subjects twice (after the day and night shifts). Urine was collected every odd hour with a two-hour interval from 7.00 a.m. to 7.00 a.m. of the next day. The day shift in both groups was accompanied by an early increase in potassium excretion. The shift transition was attended by a change of the daily maximum toward later hours. As compared to the one-shift work, the two-shift work increased the amplitude of the diurnal potassium excretion. This can be considered as a stressful effect of the two-shift work. This effect was very distinct after a week of the day-shift work. Therefore, when assessing the physiological effects of the two-shift work, with respect to daily variations in renal potassium excretion, it is necessary to carry out pertinent examinations after the day-shift work.

[Text] Duirng spaceflights, the schedule could call for around the clock duty by the crew on a shift basis, which involves disruption of the sleep-waking rhythm and is a substantial load on the cosmonauts. According to previously published studies [4, 5], 20% of the representatives of "terrestrial" occupations cannot adapt to work in shifts. No doubt, cosmonauts' adaptation to a different work and rest schedule during spaceflights would take place under more rigid conditions, against the background of already existing strain on adaptive mechanisms due to the stress factors of spaceflights. For this reason, in the interests of space medicine, it was deemed desirable to investigate the physiological effects of working in shifts.

Our objective was to investigate the effect of work on two shifts on 24-h rhythm of potassium excretion in urine.

Methods

Blue-collar workers, men 19-20 years of age, in the building and plant occupations, with work tenure of 1 and 2 years at a given enterprise, participated in this study.

The 1st group of subjects (10 men) had worked only the day shift for 1 year, the 2d group (5 men) had worked for the same period of time on two shifts (day and night) alternating the shifts weekly. Representatives of the 3d group (10 men) had worked for 2 years only on the day shift and the 4th group (10 men) had worked for the same period of time on alternate day and night shifts, switching from one to the other each week.

The day shift was from 8 am to 5 pm, and night shift from 5 pm to 1 am. The distinctions of the sleep-waking and mealtime schedules for both shifts are listed in Table 1. We see that, in case of the day shift, the schedule of the subjects was shifted to the "left" (i.e., to earlier hours) by 8-9 h, as compared to those on the night shift, whereas according to time of rising, going to sleep and taking meals there was a 1.5-4 h shift.

The studies were conducted at a clinical hospital.

The subjects in the 1st, 3d and 4th groups were examined once on the day after finishing the work week (4th group after the evening shift) and those in the 2d group were examined twice, once after a week on the day shift and once after a week on the night shift.

Table 1. Sleep-waking and mealtime schedule when working on day and night shifts (Moscow time)

Shift	Wake-up time	Bed time	Breakfast	Lunch	Dinner
Day	5:30 am	9:30 pm	6:30 am	12:30 pm	6 pm
Night	9:30 am	1:30 am	10 am	2 pm	8 pm

The subjects who worked on the day shift came to the hospital at 8 pm and those working the night shift at 2 am. We started to collect urine after the day shift at 7 am the following morning and after the night shift at 7 am of the same day, i.e., 11 h after the subject arrived at the hospital in the former case and 5 h after, in the latter. It must be noted that all of the subjects had gotten up at 5 am to evacuate the bladder. Thus, the first batch of urine to be analyzed was referable to the interval from 5 to 7 am.

Thereafter, urine was collected at odd hours, every 2 hours through 7 am of the following day. Thus, the entire volume of collected urine was referable to a 26-h period. The subjects were relaxed in bed for 30 min prior to collecting urine samples (during that time several physiological parameters were recorded). During the day, in their leisure time, the subjects read books, watched television and played chess. At night (at 1, 3 and 5 am) they had to be awakened to collect urine samples.

These studies were pursued in April and May of 1981 in Moscow. Potassium content of urine was assayed by flame photometry on a PFMU 4.2 instrument. Excretion was calculated in milliequivalents (meq) per 2 h-periods.

Results and Discussion

Figure 1 illustrates the dynamics of 24-h excretion of potassium in urine in the 1st group of subjects. The distinction of this pattern was that there were two maximums, the first at the first segment of the 24-h curve (7 to 9 am) and the second, at the last segment (5 to 7 am). In other words, maximum values of this parameter were referable to morning hours. It should be noted also that the nocturnal values, from 11 pm to 5 am, corresponded quantitatively to daytime hourly potassium excretion values obtained in the interval from 1 to 7 pm. The lowest values were recorded from 7 to 11 pm.

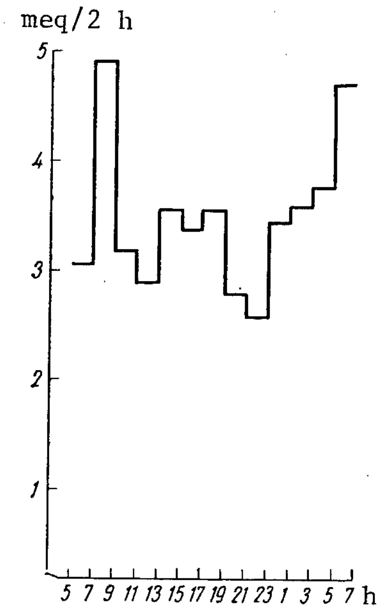

Figure 1.
Circadian dynamics of potassium excretion in urine for subjects in the 1st group (mean data for group)
Here and in Figures 2-4: x-axis time of day (Moscow time); y-axis, potassium excretion (meq/2 h)

Thus, this curve showed a steep ascending branch referable to the night, with morning maximums and subsequent uneven (with drops and rises) decline toward the evening.

It can be assumed that the nocturnal rise in potassium excretion, which attainment of maximum values by morning was related, in this instance, to working on the day shift, i.e., it reflected the process of preparing for an early start of the work day and coordination of the moment of physiological readiness for work with the start of the shift. Indeed, according to Figure 2a, the curve of potassium excretion had the same distinctions in the case of alternate shifts after the week on the day shift: maximum values in the morning (and first half of the day), ascending branch at night (from 1 to 7 am) and uneven, jagged decline of parameters toward evening, with minimums at 11 pm to 1 am. Unlike the curve illustrated in Figure 1, the one in Figure 2a is characterized by high elevation of parameters at the phase of the maximum (difference of 2.8 meq/2 h; $P = 0.05$ according to White's T criterion) and deep drop at the minimum phase (difference of 0.5 meq/2 h; $P > 0.05$ according to White's T criterion), which determines the higher amplitude of the curve in Figure 2a, as compared to Figure 1.

The curve plotted in the case of alternating shifts after working for 1 week on the night shift (Figure 2b) has a different configuration from the curves in Figures 1 and 2a. It can be divided into three zones: maximum, minimum and intermediate values. The area of maximum values is limited to the interval between 11 am and 7 pm; the area of minimum values forms the last segment of

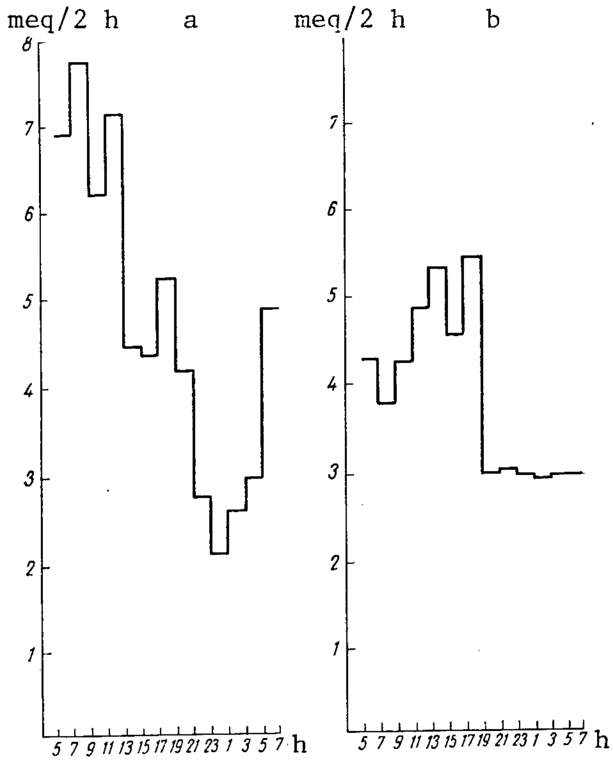

Figure 2.
Circadian dynamics of potassium excretion in 2d group of subjects tested after working for 1 week on the day (a) and night (b) shifts (mean data for group)

the curve (from 7 pm to 7 am) and, finally, the region of intermediate values coincides with the first segment of the curve, from 5 to 11 am. Thus, as compared to the curves illustrated in Figures 1 and 2a, the daily maximum on the curve in Figure 2b was shifted to a later time and the zone of the daily maximum was widened at the expense of morning, i.e., later hours; in addition, the ascending branch of the curve illustrated in Figure 2b was referable to the first half of the day, i.e., it was shifted to a later period. In other words, all of the most important elements of the 24-h curve of potassium excretion after working on the night shift for 1 week, unlike the one for the day shift, were shifted to the right, i.e., later hours, which corresponded to the shift of the work period from morning to evening.

These patterns were demonstrable when we analyzed material obtained for subjects with 1-year tenure working on one and two shifts. As for 2-year tenure, we have data referable only to working on the day shift (Figure 3) and the results of testing subjects working on alternate shifts after working for a week at night (Figure 4). Analysis of the curve in Figure 3 shows that it, like the curve in Figure 1, was characterized by signs of physiological mobilization that coincided with early start of work--build-up of parameters from evening to morning hours and high morning values. The curve in Figure 4, like the one in Figure 2b, is influenced by the prior week's work on the night shift, the sign of which (as compared to Figure 3) was a shift of region of maximum values in the direction of the work period, i.e., to the right, from morning to daytime hours.

Thus, the nature of work in shifts (only on the day shift, or with weekly change from morning to night shift) superimposed a distinctive imprint on circadian dynamics of potassium excretion. An early beginning of the work day (day shift), in both the case of one-shift work alone and alternation of two shifts, was characterized by early rise of values of this functional parameter, whereas the change from day to night shift was associated with a shift of maximum potassium excretion toward later hours. These distinctions cannot be considered solely situational, i.e., demonstrable during work. As shown by the results of our studies, they persisted for at least 24 h after stopping work and were demonstrable in a state of physical and emotional calm (at the hospital). This indicates that the weekly alternation of shifts is associated

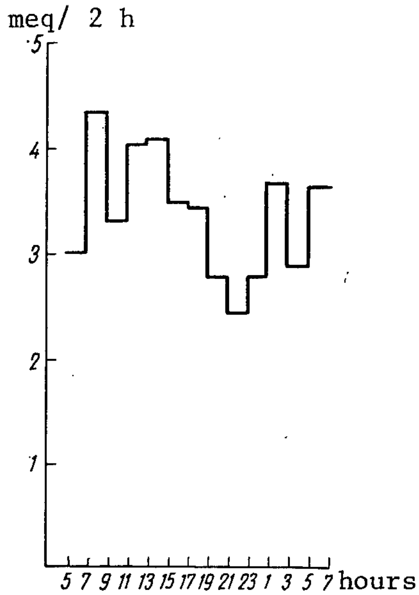

Figure 3.
Circadian dynamics of potassium excretion in 3d group of subjects

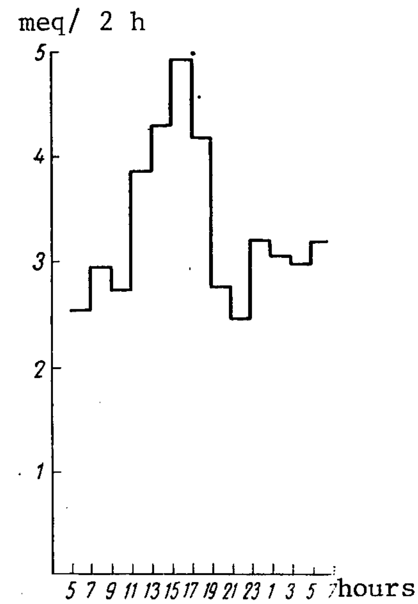

Figure 4.
Circadian dynamics of potassium excretion in 4th group of subjects

(In both figures, mean data for group are given)

Table 2. Amplitude of circadian rhythm and total daily (26-h) excretion of potassium in urine (arithmetic means of individual values and mean errors)

Group of subjects	Work tenure, years	Amplitude, meq/2 h	Total 26-h excretion, meq
1	1	4,53±0,36	45,25±3,65
2 (day shift)	1	6,70±1,01*	61,26±3,76*
2 (night shift)	1	4,68±0,75	50,22±2,08
3	2	3,34±0,48	43,16±3,15
4	2	4,09±0,49	42,96±2,86

*Differences in comparison to 1st group of subjects are statistically significant with 0.01<P<0.05 according to White's T criterion.

with disruption of the former stereotype of circadian dynamics of potassium excretion and formation of a new stereotype, which unqestionably requires a strain on adaptive mechanisms, i.e., has a stressor effect. The stressful nature of work on alternating shifts is also confirmed in our studies by the fact that, under such conditions, the amplitude of circadian rhythm of potassium excretion, with tenure of both 1 and 2 years, was greater than in the case of one-shift work with the same tenure (Table 2). According to some data [1-3], an increase in amplitude of biological rhythms is one of the signs of stress.

As can be seen in Table 2, with tenure of 1 year, the indicated amplitude in the case of work on two shifts (as compared to one shift) was associated with increase in daily (more precisely, 26 h, i.e., covering the entire period of the study) potassium excretion. In addition, it should be noted that the stressful effect of work on different shifts was manifested more clearly when the examinations were made after the day shift than after the night one. This is indicated by the statistically substantial differences in amplitude for subjects in the 2d (day shift) and 1st groups, and none in subjects of the 2d (night shift) and 1st groups (see Table 2). Thus, in assessing the effect of two-shift work on the body with use of a functional parameter such as potassium excretion in urine, one must make the analyses primarily after working on the day shift.

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INVESTIGATION OF BIOCHEMICAL AND PSYCHOLOGICAL PARAMETERS OF AIR TRAFFIC CONTROLLERS IN 'PRESTART' STATE BEFORE BEGINNING TO WORK

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 26 Mar 83) pp 62-68

[Article by Ye. L. Kan, O. O. Malinovskaya, V. A. Kupriyanov and A. F. Denisov]

[English abstract from source] The biochemical parameters (renal excretion of catecholamines, lipid metabolism, cholinesterase activity in blood, excretion of sodium and potassium in the saliva) and psychological parameters (attention concentration, anxiety, rate of information processing) of air controllers were determined immediately before their work shift. Most of the parameters were significantly changed.

[Text] At the present time, much significance is attributed in industrial and sports physiology to investigation of "prestart" states. This question is widely covered in the literature and has been reflected in several surveys and monographs by both Soviet and foreign authors [6, 13, 16]. Most often, evaluation was made of activity of the adrenosympathetic (ASS) and hypophysio-hypothalamic-adrenocortical (HHAS) systems in prestart states. Several works were devoted to the study of the psychological status, as well as parameters of lipid metabolism and circulation. Changes have been described in the prestart state of pilots, parachutists [10, 14], students during the period of studying for tests [12], before stomatological operations [2], in soldiers during the period of being transported to sites of combat operations [17], healthy individuals when hospitalized without explanation of work-up program [19], in railroad dispatchers [3].

Analysis of extensive factual material enables us to conclude that the changes in the parameters studied in the prestart state are determined chiefly by individual distinctions, in particular, nature of reactions of the autonomic nervous system, as well as extent of adjustment of the subjects to a given type of forthcoming work.

The value of information obtained from studies of changes that occur in the prestart state is that it can be used, to some extent, in assessing professionally important traits and reliability of a subject to provide for unfailing performance for air traffic control (ATC), and it also permits prediction of future physiological expenditures. To perform this task, we examined several biochemical and psychological parameters of air traffic controllers before working at an airport control tower.

Methods

We examined 25 air traffic controllers at the Pulkovo Airport (men 20-30 years of age). Functional state of the ASS was evaluated according to levels of excretion of epinephrine (E) and norepinephrine (NE) in batches of urine collected before going to work at the control tower on the day shift (from 7:30 to 9:30 am). The data obtained from analysis of these parameters in urine collected at the same hours on days off serve as a control. Catecholamine (CA) levels in urine were assayed with a modification of the trioxyindole method [11]. All other biochemical parameters were assayed just prior to the start of work on ATC. Sodium and potassium content of saliva was assayed by flame photometry, cholinesterase (CE) activity was measured by the Ellman method [15] in blood drawn from a finger. We assayed venous blood serum levels of total fraction of β- and pre-β-lipoproteins (TFBL) by the turbidimetric method [5], as well as total cholesterol.

To assess the psychological status of the subjects, we used the Bourdon cancellation test [9] and parameter of situational anxiety, which was evaluated by means of the Lusher color test [7]. In the cancellation test, we determined the parameter of attention (A) and rate of information processing in bits/s (H) using the following formulas:

$$A = \frac{V}{m - 1} \cdot 100$$

where V is the speed of scanning symbols per second and m is the number of errors.

$$H = \frac{C}{t}$$

where C is the quantity of information processed (in bits) and t is performance time.

Results and Discussion

Examination of renal excretion of CA (Table 1) enabled us to single out three groups of subjects: in the 1st group, prior to work at the control tower we found predominant activation of the hormonal element of the ASS (increased E excretion); in the 2d group, activation of its transmitting element (increased NE excretion), whereas traffic controllers in the 3d group presented a decline in both E and NE excretion. Accordingly, the NE/E ratio decreased in the 1st group, increased in the 2d and decreased insignificantly in the 3d group. We know from the literature [13] that a 2-2.5-fold increase in renal excretion of E and 3-3.5-fold increase (in relation to control) in that of NE is indicative of development of an emotional stress reaction in a healthy body. Consequently, changes in E excretion observed in the 1st group of subjects could be viewed as exceeding the range of normal physiological fluctuations. NE excretion increased by a mean of 2.6 times in the 2d group. However, individual analysis of the results revealed that NE excretion increased by more than 3.5 times in 45% of the subjects. Thus, in almost half the 2d group of subjects there was also development of emotional stress.

There is a relationship between changes in CA excretion before starting to work and the level of excretion on days off. Thus, in operators with a lower level of CA excretion on a day off, we observed increase in E and NE excretion before working on the control tower. Subjects who had higher excretion levels on their day off presented a decline in the "prestart" state. The demonstrated changes in parameters analyzed as a function of their base values are consistent with data in the literature, where analogous functions are described for other autonomic reactions in man, which arise in response to the most diverse stimuli, including emotional tension [20]. It was demonstrated that, the higher the base autonomic tonus and, accordingly, parameters of a given function, the less change is induced by the tested stimulus. All the other parameters we analyzed were examined for the above-mentioned three groups of air traffic controllers, which were formed according to CA excretion. We found that there was the most marked decline of sodium excretion in saliva ($P<0.05$) in the 2d group of subjects in a prestart state (Table 2); in the 1st group, the decline in sodium excretion was considerably less marked ($P>0.05$), whereas it showed virtually no change in the 3d group. There was increase in potassium excretion in saliva in all of the tested controllers before work on the control tower. However, the Na/K ratio decreased reliably in all groups. As we have already mentioned, during the period preceding work at the control tower we observed significant increase in CA excretion in most cases, which enabled us to assume that there was an emotional stress reaction in these cases. In addition, sodium excretion in saliva, which reflects, as we know, a state of tension when performing both mental and physical work [1], changed to a lesser extent. It should be noted that parameters of CA excretion and excretion of sodium in saliva were tested at different stages of development of prework changes in functional state. Thus, the established level of CA excretion in urine integratively reflected its excretion over a longer peirod of time (2 h) preceding work at the control tower, whereas sodium ion content of saliva was measured just prior to starting to work. We know from the literature that, in the course of development of a stress reaction in the body, there is first activation of the ASS, after which HHAS activity increases [8]. In particular, animal experiments showed the order of appearance in blood of E, ACTH and corticosteroids in the course of development of a stress reaction in response to threatening stimuli. Immediately after exposure to the stressor, significant amounts of E appeared in the blood, while increase in ACTH concentration was discovered 10 s later. Adrenocortical hormones appeared in large quantities only 15-20 min after the start of exposure to the stressor. By assaying saliva sodium content just prior to starting to work, we evaluated the condition of the body, which corresponded most to the second phase of stress, when there has already been an increase in adrenocortical activity. In favor of this assumption also is the decline we demonstrated in saliva Na/K ratio which, according to data in the literature, reflects the process of increase in activity of the adrenal cortex [8].

Table 3 shows that there was decrease in blood CE activity in the prestart state, which is indicative of diminished tonus of the parasympathetic branch of the autonomic nervous system (ANS). Thus, the decrease in tonus of the

Table 1. Levels of renal excretion of CA in air traffic controllers before starting to work

Group of subjects	CA excretion parameters, ng/min									
	E				NE				NE/E	
	BG	PS	CH, %	P_{BG-PS}	BG	PS	%	P_{BG-PS}	BG	PS
1 (n=9)	2,6±0,8	10,3±2,1	+296	<0,05	34,6±7,0	24,8±5,0	—26	>0,05	13,3	2,4
2 (n=11)	6,2±1,0	5,7±0,9	—8	>0,05	12,3±3,1	31,7±2,7	+158	<0,05	2,0	5,6
3 (n=5)	7,2±1,1	6,0±0,6	—17	>0,05	42,8±14,9	21,8±0,8	—49	>0,05	5.9	3,6
P_{1-2}	<0,05	>0,05			<0,05	>0,05				
P_{1-3}	<0,05	>0,05			>0,05	>0,05				
P_{2-3}	>0,05	>0,05			>0,05	<0,05				

Key for this and Tables 2-4:
- BG) excretion on day off (background)
- PS) same before air-traffic control work
- CH) change in excretion (%) in prestart state, as compared to day off, taken as 100%

Table 2. Electrolyte excretion in saliva in air traffic controllers before work

Group of subjects	Sodium, mg-eq/ℓ				Potassium, mg-eq/ℓ				Sodium/potassium			
	BG	PS	CH, %	P_{BG-PS}	BG	PS	%	P_{BG-PS}	BG	PS	%	P_{BG-PS}
1 (n=9)	9,4±0,8	8,3±1,4	—12	>0,05	12,0±1,5	23,7±3,0	+97	<0,05	0,82±0,20	0,35±0,08	—57	<0,05
2 (n=11)	11,7±1,2	8,2±0,7	—30	<0,05	12,9±2,0	27,4±4,1	+112	<0,05	1,17±0,18	0,33±0,04	—72	<0,05
3 (n=5)	9,0±1,0	8,8+0,8	—2	>0,05	11,7±1,8	24,9±2,5	+113	<0,05	0,87±0,24	0,35±0,04	—50	<0,05

parasympathetic branch of the ANS was combined with rather high tonus of its sympathetic branch (although the 1st and 3d groups of subjects presented a decrease in NE excretion, its parameters were rather high before going to work on the control tower); no reliable differences were demonstrated between prestart excretion levels in the 1st and 2d groups. Such functional changes in the ANS are indicative of some impairment of compensatory mechanisms, since there should be synchronous increase in activity of both branches of the ANS in the case of an adequate reaction to a load [6]. In contrast, with significant nervous and emotional tension, along with activation of the sympathetic branch of the ANS, we observed depression of activity of its parasympathetic branch, i.e., so-called "scissor" development of the reaction, and this is what was observed in our cases. We also demonstrated that there was reliable increase in blood serum levels of both TFBL and cholesterol (see Table 3). It should be noted that blood TFBL did not exceed the conventional normal range (360-640 mg%) in the prestart period in the 1st group of subjects, whereas in the 2d and 3d groups this parameter did exceed this range. Blood serum cholesterol was above the top limit of normal range (118-240 mg%) in all groups of subjects.

According to the data listed in Table 4, there was significant decline of attention parameter in the prestart state, in all groups of controllers. In addition, before starting ATC work, the 1st group of subjects presented an increase in anxiety indicator, whereas in the other two groups it decreased. We should call attention to the correspondence between anxiety levels and E excretion on days off. Thus, we demonstrated lowest background values for excretion of E and anxiety in the 1st group, while the highest values for these parameters were found in the 3d group. In the prestart state, however, there was increase in E excretion in the 1st group of subjects, with concurrent increase in anxiety. In the other two groups, the parameter of E excretion and anxiety level decreased before starting work on the control tower. Thus, we demonstrated that the dynamics of the parameter of E excretion (change in prestart state, as compared to background) were similar in all groups to changes in the anxiety indicator. It also follows from our findings that, while various levels of anxiety were demonstrated on days off in the subjects of the groups studied, in the prestart state this parameter became about the same in all groups. The most marked decline of parameter of rate of information processing was observed in the 2d group of subjects ($P<0.05$).

Evaluation of biochemical and psychological parameters of air traffic controllers in the prestart state enabled us to establish the following: significant activation of the ASS occurs long before starting to work on ATC; just prior to the start of such work, several parameters reached about the same level in all groups (the nature of changes in some parameters is determined by their values on days off). As already indicated before, just prior to air-traffic control work, the controllers developed the second stage of stress, i.e., the stage of resistance. Perhaps this is why there was a decline at this time of attention indicator (as compared to background), apparently related to the fact that the subjects are set for their impending highly responsible work that required much strain on their intellectual and emotional sphere and, for this reason, they cease to react with the former intensity to nonspecific test loads. We know from the literature [4, 14] that significant functional changes due to activation of the ANS, including increased CA excretion, as well as

Table 3. Parameters of lipid metabolism and blood CE activity in air traffic controllers before work

Group of subjects	TFBL, mg%				Cholesterol, mg%				CE activity, μmol/mℓ•h			
	BG	PS	CH, %	P_{BG-PS}	BG	PS	%	P_{BG-PS}	BG	PS	%	P_{BG-PS}
1 ($n=9$)	476,3±38,9	604,1±25,2	+27	<0,05	189,8±4,9	313,3±19,7	+65	<0,05	126,1±15,6	85,3±9,0	—32	<0,05
2 ($n=11$)	508,4±46,8	804,2±43,3	+58	<0,05	203,1±22,5	330,2±32,4	+63	<0,05	140,8±8,2	97,1±16.0	—31	<0,05
3 ($n=5$)	415,7±43,8	706,4±85,7	+70	<0,05	179,6±18,2	339,9±29,5	+89	<0.05	124,5±8,5	94,6±11,4	—24	>0.05
P_{1-2}	>0,05	<0,05			>0,05	>0,05			>0,05	>0,05		
P_{1-3}	>0,05	>0,05			>0,05	>0,05			>0,05	>0,05		
P_{2-3}	>0,05	>0,05			>0,05	>0,05			>0,05	>0,05		

Table 4. Psychological parameters of air traffic controllers before work

Group of subjects	Psychological parameters (arbitrary scores)											
	attention				anxiety according to Lusher				rate of information processing			
	BG	PS	%	P_{BG-PS}	BG	PS	%	P_{BG-PS}	BG	PS	%	P_{BG-PS}
1 ($n=9$)	252,4±52,9	73,9±24,4	—71	<0,05	1,2±0,4	2,2±0,5	+83	>0,05	5,93±0,71	6,10±0,20	+3	>0,05
2 ($n=11$)	306,1±75,2	108,8±17,3	—65	<0,05	2,5±1,2	1,9±0,8	—24	>0,05	7,78±0,42	6,00±0,28	—23	<0,05
3 ($n=5$)	255,7±84,9	71,6±27,4	—72	>0,05	3,5±1,4	1,7±0,9	—51	>0,05	7,36±0,42	6,36±0,34	—14	>0,05
P_{1-2}	>0,05	>0,05			>0,05	>0,05			>0,05	>0,05		
P_{2-3}	>0,05	>0,05			>0,05	>0,05			>0,05	>0,05		
P_{1-3}	>0,05	>0,05			>0,05	>0,05			>0.05	>0,05		

changes in several hemodynamic parameters (which we do not discuss here) that occur in the prestart state, are indicative of high professional training of the subjects. These data were obtained in a study of pilots and parachutists [4, 14]. Thus, the results of our studies are entirely consistent with data in the literature, indicating development in air traffic controllers of noticeable signs of prework activation of several parameters of metabolism, functional state of the ANS and closely related parameters of current psychological status. This is an indirect indication of the high professional training of most of the air traffic controllers examined. At the same time, we cannot fail to note that the changes were quite marked in some controllers, exceeding significantly the allowable and physiologically warranted levels.

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CHROMOSOME ABERRATIONS IN CREPIS CAPILLARIS EXPOSED TO GAMMA RADIATION AND CLINOSTAT

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 14 Jan 83) pp 68-71

[Article by G. P. Parfenov and V. P. Zhvalikovskaya]

[English abstract from source] The rate of cell division and emergence of spontaneous and radiation chromosomal aberrations in Crepis capillaris exposed to clinostating were determined. The plants were gamma-irradiated with 300 R during clinostating when the primary roots were 1-2 mm long. The velocity of clinostat rotation was 2 rpm. The mitotic index was not affected either by clinostating alone or combined with irradiation. The exposure to clinostating did not change significantly the total frequency of nuclear aberrations or the distribution of the aberrations of the chromosomal and chromatin type as well as aberrations resulting from one or two radiation events. Thus, the effect of clinostating combined with gamma-irradiation can be considered zero.

[Text] As we know, the clinostat is the main laboratory instrument that compensates for the effect of gravity on plants or, in other words, that stimulates the effect of weightlessness. However, there are very few studies of genetic effects with use of clinostat, in spite of the fact that some researchers consider weightlessness to be an active mutagenic factor [1]. We know of only two works, in which studies were made of the combined effect of ionizing radiation and weightlessness simulated with a clinostat [9, 10].

The first of these studies [9] was pursued on rooted Tradescantia cuttings as one of the controls for the experiment aboard Biosatellite-2 [2]. Exposure to clinostat, γ-radiation in a dosage of 1.97 Gy and a combination of these factors had no effect on blooming of Tradescantia. The time characteristics of blooming and number of buds per inflorescence were considered. Eight different parameters were recorded to investigate genetic processes. The genetic parameters studied included spindle anomalies and metaphase chromosome aberrations in cells of the root meristem. Clinostating had no influence on the radiation effect.

The second study [3] was conducted on horse bean seedlings. The authors found that clinostat treatment altered circadian periodicity of the mitotic index and nucleus volumes. By recording the incidence of radiation-induced chromosome aberrations due to desynchronization of cell division, time of fixation of material was actually determined. Ruling out the possibility of direct effect of weightlessness on genes and chromosomes, the authors believe that the interaction effect can, in some cases, be attributed to impairment of circadian rhythms.

In view of the fact that there have obviously been insufficient laboratory studies of the combined effect of ionizing radiation and gravity compensation, we performed an experiment with Crepis seedlings. We determined the mitotic index and incidence of chromosome aberrations in metaphase chromosomes of the root meristem after individual and simultaneous exposure to physical factors.

Methods

We used seeds of diploid Crepis capillaris L. (Wallr.) at the age of 10 months, which we had raised ourselves, in the experiment. We put 200 seeds on filter paper soaked in tap water into Petri dishes. Right after soaking the seeds, the Petri dishes were placed in a horizontal clinostat. Rate of rotation was 2 r/min. Controls were kept on the laboratory table, next to the clinostat. The experiment was performed at room temperature (16-20°C). The radiation unit was turned on 46 h later, when control series seedlings were 1-2 mm long. We used ^{60}Co γ-rays. Radiation was delivered in a dosage of 3 Gy at a dose rate of 0.0222 Gy/min. Thus, exposure to radiation lasted 2 h and 15 min. The laboratory control was shielded during irradiation. The clinostat continued to operate for another 2 h after turning off the γ unit, then it was stopped and seedlings referable to the entire series were transferred into 0.01% colchicine. The procedure to transfer seedlings took 20 min. The seedlings in colchicine solution were put in the clinostat for 2 h. They were fixed in acetalcohol; the material was stored in 70% ethyl alcohol; the rootlets were stained with acetocarmine and we prepared temporary squash preparations.

We recorded the number of dividing and nondividing cells to determine the mitotic index and chromosome aberrations in cells at the metaphase stage. Since 0.01% colchicine blocks cytokinetic processes, the dividing cells are arrested at the metaphase stage. The number of metaphase cells increases significantly after colchicine treatment, and this enhances appreciably the resolution of the technique.

Results and Discussion

We examined meristem cells of 5 roots in each variant (total of 17,141 cells) to calculate the mitotic index.

The values for the mitotic index in the 4 experimental variants can be divided into 2 groups according to whether or not the material was exposed to radiation. It was virtually identical in the variants with irradiation (Table 1, Figure 1). In the 2 variants without irradiation, i.e., in the control and clinostat, the mitotic index was 5-8% higher (statistically unreliable). Thus, rotation in the clinostat had no effect on mitotic index in both irradiated and nonirradiated seedlings. Radiation lowered unreliably the mitotic index.

Table 1.
Mitotic index in different variants of experiment

Variant	Total cells	Dividing cells	$M \pm m$, %
Control	4403	1469	33,36±2,07
Clinostat	5776	2111	36,54±2,13
Radiation	3431	961	28,09±4,87
Clinostat & radiation	4151	1185	28,54±2,98

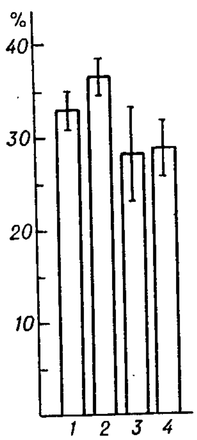

Figure 1.
Mitotic index

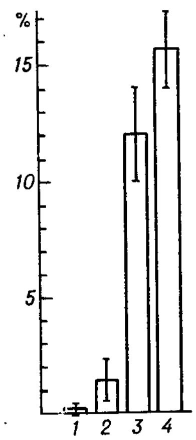

Figure 2.
Aberrations

Key to both figures:
1) control
2) clinostat
3) radiation
4) clinostat and radiation

The results do not give grounds to state either that clinostat rotation affects synchronization or, on the contrary, desynchronization of cell division.

The decline of the mitotic index in both series exposed to radiation indicates that duration of the cell cycle increased in these series. This was to be expected, since it is known, for example, that the G_2 stage increases by 30 min/Gy [4]. The other stages of the cell cycle also grow longer with irradiation. Rotation in the clinostat in itself had no influence on the mitotic index and did not modify the effect of radiation.

Data on incidence of chromosome aberrations are furnished in Table 2 and Figure 2.

The general results on chromosome aberrations are the same as for the mitotic index. They can be divided into two groups. One group consists of variants where radiation was used and the other, where it was not. The differences from data on the mitotic index consist of the fact that the postradiation incidence of aberrations rose by a statistically reliable value (see Table 2). Clinostating elicited some rise in chromosome aberrations, both spontaneous and due to radiation. The difference between the "control" and "clinostat" variants constituted 1.26±0.88%, and between the "radiation" and "clinostat" variants, 3.51±2.56%. In both instances, the differences were unreliable. Table 2 singles out chromatic and chromosome types of aberrations, as well as one- and two-hit types. It is known that chromatic aberrations occur as a result of radiation events at the G_2 stage and at the end of the S stage. A comparison of frequency of chromatid and chromosome aberrations in the "radiation" and "clinostat and radiation" variants shows that neither the relative duration of phases of the cell cycle nor their radiosensitivity changed as a result of clinostat rotation.

Table 2. Chromosomal aberrations with use of clinostat

Variants	Number of root-lets	Number of meta-phases	Aberrations				
			total	chro-matid	chromo-some	one hit	two hits
Control	35	964	1	1	—	1	—
Clinostat	47	585	8	5	3	8	—
Radiation	39	1043	126	91	35	116	10
Clinostat & rad.	55	795	124	96	28	117	7

The number of two-hit chromosome aberrations (we put in this class dicentrics and rings), within the range of the margin of error, equals the square root of one-hit aberrations, as it should be with exposure to ionizing radiations.

The results of our experiment indicate that the magnitude of the radiation effect on genetic factors did not change under the influence of use of the clinostat. In essence, nothing else could have been expected. The levels on which ionizing radiation and weightlessness have an effect are too different. Ionizing radiation has genetic effects only on the cell, more precisely only on the chromosomes, only on genes. Conversely, cells are, in our opinion, "blind" to the effect of weightlessness and the organism is the area of its application.

The stability of molecular structures, including DNA molecules, is achieved by electromagnetic forces. It is known that electromagnetic interactions between electrons and protons are stronger by a factor of 10^{39} than gravitational interaction between these particles [5]. Hence, it is impossible for mutations to occur with change in gravity. Of course, accelerations to which chromosomes are exposed may reach intensities comparable to electromagnetic forces. We know of experiments with plants, in which some type of mutation or other is described that appeared under the influence of centrifuging [6-10]. In all these studies, the mutagenic effect was reliably demonstrable at accelerations on tens of thousands of units.

Altered gravity could modify the mutagenic radiation effect. This was first demonstrated by Sax [11]. Later on, the modification phenomenon was repeatedly corroborated and submitted to quantitative studies [12, 13]. The modification phenomenon occurs when accelerations amount to thousands of units, when the interval between irradiation and acceleration is measurable in seconds and when accelerations follow irradiation.

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EFFECT OF TRIPHTHASINE AND ELENIUM ON CHANGES IN EVOKED BIOELECTRICAL ACTIVITY OF THE BRAIN EXPOSED TO STATIONARY MAGNETIC FIELD

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 23 Dec 82) pp 71-74

[Article by L. D. Klimovskaya and A. S. D'yakonov]

[English abstract from source] Experiments were carried out on white rats anesthetized with nembutal. Evoked potentials (EP) of the sensorimotor cortex of the large hemispheres, reticular formation of the midbrain and cerebellum resulting from the stimulation of the sciatic nerve were recorded. The exposure to a constant magnetic field of 0.4 T led to an increase of the amplitude and a complication of the shape of EP's due to the appearance of new components. Pretreatment with triphthasine and elenium suppressed the magnetic field effect.

[Text] One of the important questions pertaining to the mechanism of effects of magnetic fields on central nervous system function is the genesis of exaltation of evoked bioelectrical activity of the brain, which develops consistently when an animal is placed in a stationary magnetic field (SMF) of high intensity [5]. Studies pursued in this direction revealed that preadministration of analeptics modifies appreciably the SMF effect. Against the background of intake of corazole and strychnine, there was considerable intensification of SMF effect on evoked activity of the brain [3, 9]. It is interesting to explore the possibility of preventing exaltation of evoked activity of the brain under the effect of SMF. This question is important from the standpoint of both determination of the mechanisms of this phenomenon and prevention of receptive function of the brain when exposed to magnetic fields. In this regard, the data of N. P. Smirnova concerning appearance of signs of depression of SMF effect on somatosensory evoked potentials (EP) of the brain in some rats after preadministration of aminazine in a dosage of 5 mg/kg [5] merit attention.

In this study, we used another neuroleptic of the phenothiazine class, triphthasine, to depress the SMF effect. This agent is superior to aminazine in some respects, with regard to potency of effect on central nervous system functions. It elicits less hypotonia and hypothermia, it is less toxic and is tolerated by rats in doses of up to 100 mg/kg [8]. In addition, we used elenium, a tranquilizer of the benzodiazepine class, which is also easily tolerated by rats in relatively large doses [2].

Methods

Experiments were conducted with 50 white rats under nembutal anesthesia (40 mg/kg intraperitoneally). The sciatic nerve was stimulated with 0.5-ms square-wave pulses. EP were derived unipolarly from the cerebral cortex, reticular formation of the mesencephalon and cerebellar cortex using manganin electrodes and, after summation on a medical ATAK-401 computer, they were recorded on an ink-writing recorder. Each recorded potential was the average of 10 responses. We used an SP-15A electromagnet with flat parallel tips 300×400 mm in size. The magnetic field was virtually homogeneous in the central part of the interpole space 300×200 mm in size, and decline of intensity in the rest of it did not exceed 15-20% of the value for the center. Voltage pulsation constituted 1.8%. The rats were submitted to whole-body vertical SMF with induction of 0.4 T. EP were recorded for each rat before, during and after exposure to SMF. We then gave them intraperitoneal injections of elenium in a dosage of 40 mg/kg or triphthasine in a dosage of 25 mg/kg, then repeated the SMF exposure.

Results and Discussion

The electrical responses of the sensorimotor cortex, mesencephalic reticular formation and cerebellum to stimulation of the sciatic nerve consisted mainly of two-phase negative-positive potentials with a latency period of 13-17 ms and amplitude of 100-300 μV from peak to peak.

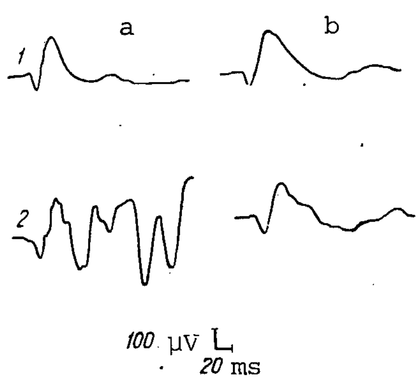

Figure 1.
Effect of preadministration of elenium on change in EP of reticular formation with exposure to SMF

Here and in Figure 2:
1) before SMF
2) during exposure to 0.4 T SMF
a) before giving elenium
b) after giving elenium

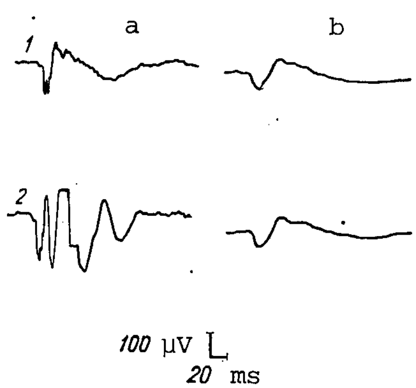

Figure 2.
Effect of preadministration of triphthasine on change in EP of reticular formation of mesencephalon with exposure to SMF

a) before triphthasine
b) after giving triphthasine

In a special series of experiments, we tested the effect of the pharmacological agents used on evoked activity of the brain of animals that were not exposed to SMF. Injection of elenium had no noticeable influence on amplitude and time parameters of EP, which is consistent with data in the literature [10, 12]. With regard to triphthasine, there are indications in the literature to the effect that it could, in relatively small doses (0.01-5 mg/kg), lead to some intensification of evoked brain activity [1, 4]. In our experiments, injection of 25 mg/kg triphthasine elicited in most rats a decrease in amplitude and increase in duration of the first negative phase of EP. We could also notice simpler forms of response, disappearance of interstructural and individual differences. The effect of the agent developed within 10-15 min after injection and persisted for at least 1 h. We found that the tested brain structures were equally sensitive to triphthasine. Thus, after administration of the neuroleptic, the first phase of EP decreased from 117.81±22.28 to 43.12±6.03 μV (P<0.05) for the sensorimotor cortex, from 118.37±18.4 to 53.26±9.77 μV (P<0.05) for the reticular formation and from 71.6±17.3 to 33.10±6.6 μV (P<0.05) for the cerebellum.

Effect of SMF on EP parameters in different brain structures before and after administration of triphthasine

Brain structure	Conditions	Group	Latency period, ms	Number of phases	Amplitude, μV
Sensorimotor cortex	Before injection	A	17,00±1,72	2,50±0,37	168,12±19,38
		B	16,90±1,23	6,00±0,72*	564,10±129,69*
	After injection	A	18,88±2,58	2,11±0,11	135,55±29,21
		B	18,63±2,09	2,27±0,56	155,80±15,52
Mesencephalic reticular formation	Before injection	A	14,30±1,08	2,60±0,16	201,46±28,91
		B	14,53±1,25	7,92±0,66*	722,53±140,58*
	After injection	A	14,00±0,52	2,13±0,07	120,33±10,29
		B	13,15±0,82	2,53±0,37	133,46±10,97
Cerebellum	Before injection	A	13,25±1,21	2,50±0,48	170,26±26,09
		B	11,75±0,97	8,00±0,97*	490,75±133,90*
	After injection	A	14,25±1,50	2,50±0,24	118,00±31,70
		B	12,25±1,21	3,50±0,97	203,00±43,17

*P<0.05 in comparison to level before exposure to SMF.

A) before SMF B) in SMF (0.4 T)

In the main series of experiments the animals were exposed to SMF with induction of 0.4 T, which is considerably above the threshold level for changing evoked activity of the brain (0.05-0.1 T) [5]. Before injection of the pharmacological agents, SMF elicited substantial changes in electrical responses of the brain in all rats. While in the magnetic field, the animals presented an increase in amplitude and significant complication of structure of EP. Figures 1a and 2a show that the relatively simple forms of responses of the mesencephalic reticular formation demonstrated in intact rats during exposure to 0.4 T SMF changed into complicated multiphase potentials with additional high-amplitude waves.

Evoked activity of the brain rapidly regained its initial features when the electromagnet was turned off. Previously, no statistically reliable differences had been demonstrated in EP parameters between the first and second exposure to SMF of the same induction at an interval of 20-30 min [3]. This makes it possible to compare the effects of the magnetic field on the same animal before and after administration of a pharmacological agent. The studies revealed that triphthasine and elenium attenuated substantially the effect of the magnetic field on evoked activity of the brain. After injection of these agents, there was drastic decrease in SMF effect on all rats, and in most of them it virtually disappeared (see Figures 1 and 2). Administration of elenium prevented appearance of the SMF effect, without affecting the magnitude and form of responses (see Figure 1b). Administration of triphthasine also elicited in most cases typical changes in EP, according to results of control experiments. Figure 2b shows that there was a decrease in amplitude and widening of the first phase of the response under the influence of the neuroleptic, with disappearance of low-amplitude components; the form of EP became simpler and rounder, and against the background of triphthasine use of SMF of 0.4 T did not elicit any changes in the responses.

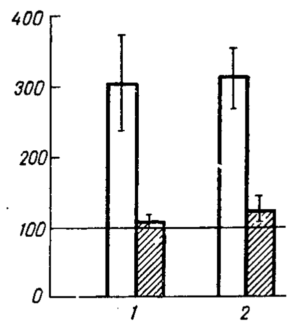

Figure 3.

Effect of preadministration of elenium (1) and triphthasine (2) on change in duration of EP of reticular formation exposed to SMF

Y-axis, duration of EP (% of level before exposure to SMF). White bars--before injection of agent, striped--after injection.

It should be noted that the very reaction to SMF and its attenuation with use of pharmacological agents were generalized and distinctly demonstrable upon analysis of EP parameters for all brain structures studied. Thus, before giving triphthasine, SMF elicited a statistically reliable increase in number of phases and amplitude of EP for the sensorimotor cortex, mesencephalic reticular formation and cerebellum, without affecting the latency period; after giving this agent, there was no reliable change in these EP parameters in any of the brain structures under the influence of SMF (see Table).

Analogous results were obtained from analysis of amplitude and time parameters of EP in the experiments with use of elenium. In the dosage used, both agents had the same inhibitory influence on the SMF effect (Figure 3). However, the ratio of dosage that depressed the SMF effect on evoked bioelectrical activity of the brain to LD_{50} constituted about 1:9 for triphthasine and 1:13 for elenium.

Thus, the results of these studies indicated that it is possible to prevent disturbances in receptor function of the brain during exposure to SMF by means of psychotropic agents with sedative properties. Our data support the previously expounded hypothesis that appearance of multiphase high-amplitude electrical responses to an afferent impulse is related to the alleviating influence of the magnetic field on appearance and irradiation of the excitatory process in brain tissue [5]. From this point of view, some of the results of testing the effects of elenium and triphthasine on electrical activity of individual neurons are of definite interest. When delivered directly to brain tissue (experiments on sections of olfactory cortex and cerebellum), elenium enhances presynaptic and postsynaptic inhibition, emerging as an antagonist of picrotoxin and strychnine [11, 13]. The latter, as we have already mentioned, enhances significantly the effect of SMF on evoked activity of the brain [3]. The effects of triphthasine on neuronal function are manifested by worsening of conditions for temporary summation of impulses in the postsynaptic neuron, inhibition of synpatic transmission and, as a result, restricting the possibility of irradiation of signal over brain tissue [6, 7]. It is quite likely that these mechanisms are the basis of the inhibitory influence of the tested pharmacological agents on the SMF effect.

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RADIOPROTECTIVE EFFICACY OF ATP AND ADENOSINE WITH EXPOSURE TO HIGH-ENERGY PROTONS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 18 Feb 83) pp 75-77

[Article by M. V. Tikhomirova, P. N. Yashkin, B. S. Fedorenko and K. S. Chertkov]

[English abstract from source] The radioprotective effect of ATP and adenosine was investigated on CBA and $C_{57}Bl$ mice hybrids F_1 irradiated with 9 GeV protons. The prophylactic treatment of the animals with ATP at a dose of 350-700 mg/kg increased their survival to 63-80% for $LD_{78-83/30}$ (7.5-8.0 Gy) and to 40% for $LD_{96/30}$ (8.5 Gy). The administration of adenosine at a dose of 340 mg/kg, equimolar to 700 mg/kg ATP, increased their survival to 93-100% and 73%, respectively. It was found that ATP produced a favorable effect on the hemopoiesis of irradiated mice.

[Text] Corpuscular radiation from solar flares, which consists mainly of protons and α particles, presents the greatest radiation hazard during spaceflights. For this reason, to solve problems of pharmacological protection of man against the deleterious effect of radiation it is necessary to conduct studies to demonstrate the efficacy of proposed radioprotective agents against protons and α particles. However, there are few works in this direction. There are indications of manifestation of radioprotective effect of agents such as adenosine triphosphate (ATP) and adeturon [S-2-aminoethyl isothiuronium adenosine triphosphate] with exposure to protons with energy of 640-660 MeV [1, 5]. At the same time, material has been accumulated in recent years indicating that, with increase in energy of charged particles to 4-9 GeV, their relative biological effectiveness increases, compared to γ radiation, and according to some indications reaches 1.5-2.0 [6, 10]. There are also data conerning a decline of radioprotective properties of protective agents with exposure to charged particles with high linear energy transfer [4, 8].

Our objective here was to test the radioprotective properties of ATP and adenosine with exposure to protons with energy of 9 GeV.

Methods

The studies were conducted on F_1 hybrid ($CBA \times {}_{57}Bl$) mice, mainly females, weighing 22±2 g, submitted to protons with energy of 9 GeV in different doses on a synchrophasotron of the Joint Institute for Nuclear Research (in Dubna). The animals were divided into an experimental (with use of protective agents) and control (without these agents) groups. ATP or adenosine in aqueous solutions were injected intraperitoneally to experimental mice 10-20 min before exposing them to radiation: 350 or 700 mg/kg ATP, 340 mg/kg adenosine. In addition, ATP in a dosage of 700 mg/kg was given intragastrically 40-50 min before irradiation. The doses of 700 mg/kg ATP and 340 mg/kg adenosine are equimolar. The efficacy of the protective agents was evaluated according to 30-day survival of mice after exposure to radiation, and for ATP also according to decrease in radiation depression of hemopoietic function. The effect of ATP on hemopoiesis in irradiated mice was determined 5, 10 and 15 days after exposure to protons, according to changes in peripheral blood parameters and condition of hemopoietic centers (femoral bone marrow, spleen). At the same times, we recorded changes in weight and number of cells in the thymus.

Results and Discussion

Exposure to protons in a dosage of 8.5 Gy led to death of 96% of the control animals. Doses of 8.0 and 7.5 Gy constituted $LD_{83/30}$ (lethal dose, 83% death in 30 days) (see Table). Preventive administration of ATP or adenosine increased significantly the mouse survival rate. ATP in a dosage of 350 mg/kg increased survival by 36-46% (see Table). When the dosage of ATP was raised to 700 mg/kg, there was enhancement of the radioprotective effect: mouse survival constituted 75-80%, versus $LD_{83-78/30}$ in the control. With higher radiation dosage, we failed to observe intensification of radioprotective efficacy of ATP with increase in its dosage. Some increase in survival was also obtained with intragastric administration of ATP.

Radioprotective efficacy of ATP and adenosine with exposure to 9 GeV protons

Radiation dose, Gy	Agent and route of administration	Agent dosage, mg/kg	Number of mice	30-Day survival		P (accord. to survival)
				absolute	%	
8.5	ATP, i/p	350	15	6	40,0	$<0,01$
	ATP, i/p	700	15	3	20,0	$>0,05$
	ATP, per os	700	15	1	6,7	$>0,05$
	Adenosine, i/p	340	15	11	73,0	$<0,001$
	Without protection	—	26	1	3,9	
8.0	ATP, i/p	350	33	21	63,5	$<0,001$
	ATP, i/p	700	16	12	75,0	$<0,001$
	ATP, per os	700	15	6	40,0	$<0,1$
	Adenosine, i/p	340	15	14	93,0	$<0,001$
	Without protection	—	42	7	16,6	
7.5	ATP, i/p	350	33	20	60,5	$<0,001$
	ATP, i/p	700	15	12	80,0	$<0,001$
	ATP, per os	700	15	6	40,6	$>0,05$
	Adenosine	340	15	15	100,0	$<0,001$
	Without protection	—	42	9	21,3	

Note: i/p--intraperitoneally; P was determined by the χ^2 criterion in comparing experimental and control groups.

Adenosine (in a dosage equimolar to 700 mg/kg ATP) was more effective than ATP. Adenosine had protective action with all doses of radiation (see Table). With it, we obtained 100% survival of irradiated mice.

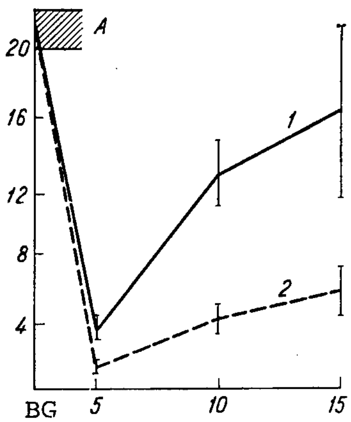

Figure 1.
Changes in quantity of myelokaryocytes in mouse femur after exposure to protons in a dosage of 7.0 Gy
1) ATP in dose of 350 mg/kg 10-20 min before irradiation
2) irradiation alone
Here and in Figures 2 and 3:
X-axis, postradiation days, A--background values; y-axis, number of myelokaryocytes (10^6)
BG) background

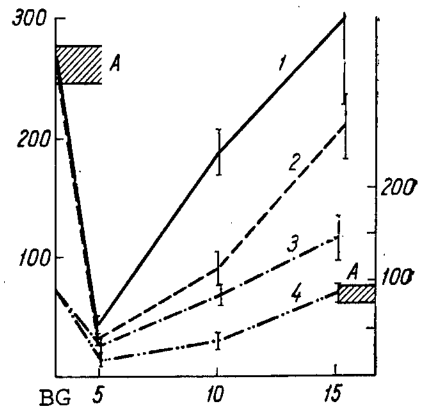

Figure 2.
Changes in mass (1 and 2) and number of karyocytes in spleen (3 and 4) after exposure to protons in a dosage of 7.0 Gy
Here and in Figure 3:
1,3) ATP in dose of 350 mg/kg 10-20 min before irradiation
2,4) irradiation alone
Y-axis: on the right--number of spleen karyocytes (10^6), on the left--spleen weight (mg)

In addition to the distinct beneficial effect of adenylates on mouse survival, we demonstrated a positive effect of ATP on hemopoiesis in irradiated animals. By the 5th postradiation day, all animals presented a reduction in weight of the spleen and thymus. However, in ATP-protected mice, reduction in weight of organs and number of cells in them was less marked than in the control. Thus, while thymus mass decreased to 8.7 mg and number of cells in it, to 8.3 million, the figures for protected mice were 10 mg and 12.9 million, respectively. There was a drastic drop in number of myelokaryocytes. In protected animals it was 3 times higher than this level (Figure 1).

By the 10th, and particularly 15th, postradiation day, active recovery processes were observed in both the thymus and spleen, which was manifested by increase in organ weight and number of cells in them. ATP caused faster recovery of these parameters (Figure 2). There was demonstrative increase in number of myelokaryocytes in the femur (see Figure 1).

With administration of ATP there was less decline and faster recovery of quantity of leukocytes and thrombocytes (Figure 3).

A dosage of 7.0 Gy, which constituted $\sim LD_{50/30}$ according to survival, did not elicit a reduction in number of erythrocytes in peripheral blood (at the tested times). By the 5th postradiation day, virtually no reticulocytes were demonstrable in either control or protected mice. By the 10th-15th day, reticulocyte count was twice as high in experimental animals as in the control.

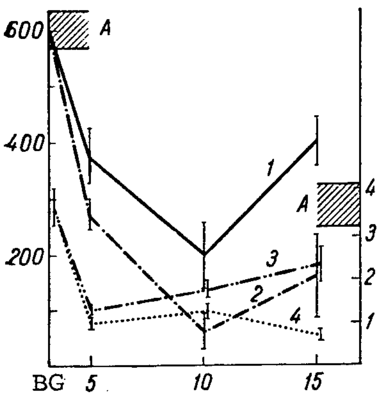

Figure 3.
Changes in number of thrombocytes (1 and 2) and leukocytes (3 and 4) in peripheral blood of mice after exposure to 7.0 Gy protons
Y-axis: on the left--thrombocyte count per mm^3 blood (10^3); on the left--the same for leukocytes

Thus, our data indicate that there is a distinct radioprotective effect from adenyl compounds against damage by high-energy protons.

The radioprotective effect of adenylates may be attributable, on the one hand, to the pharmacological effects of the compounds used (such as, for example, decreased oxygen uptake by tissues and the body as a whole [7]), general hypotensive and vasodilating effect [9], and on the other hand, their influence on energy balance of cells that had been impaired by exposure to radiation. Postradiation macroerg deficit prevents repair processes, including DNA repair. ATP diminishes the degradation changes in DNA, lowering formation of single- and double-strand breaks, and preventing activation of acid DNAase [2]. The effect of ATP, like that of other adenine nucleotides, on energy supply of the cell is apprently not implemented directly by exogenous agents, but by means of stimulating formation of endogenous macroergs. Most probably, adenosine is the active element of adenine nucleotides, and it is capable of penetrating into cells. This is confirmed by the results we obtained here, which revealed that preventive administration of adenosine in equimolar doses, in relation to ATP, provides a stronger effect on animal survival. As indicated previously [3], another route for expression of the radioprotective effect of adenylates may be to act on adenylate cyclase receptors (via adenosine), which leads to increase in intracellular stock of cAMP which, being a universal regulator of biochemical processes, normalizes postradiation disturbances of cellular metabolism.

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BRIEF REPORTS

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MORPHOLOGICAL STUDY OF PRIMATE HYPOTHALAMUS AND HYPOPHYSIS AFTER EXPERIMENT WITH ANTIORTHOSTATIC HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 17 Jan 83) pp 78-81

[Article by Ye. I. Alekseyev, Ye. A. Savina and G. S. Belkaniya]

[Text] Investigation of large-cell neurosecretory nuclei of the hypothalamus and adenoneurohypophysis of primates is rather important to comprehension of the mechanisms responsible for impairment of fluid metabolism and tissue growth in animals and man exposed both to weightlessness and model experiments using long-term hypodynamia [2, 4]. The data obtained to date warrant the assumption that the partial discharge of fluid, as well as slowing of intracellular metabolic processes and growth of skeletomuscular system of tissues, are attributable, to some extent, to decline in level of secretion of antidiuretic hormone (ADH)--vasopressin--and somatotropic hormone [5, 6].

Our objective here was to make a morphological study of the hypothalamo-pituitary neurosecretory system (HPNS) and cell population of the primate adenohypophysis, which produces somatotropin, after 7- and 19-day antiorthostatic [head-down tilt] hypokinesia (AOH).

Methods

Experiments on male Macaca rhesus monkeys were performed at the Institute of Experimental Pathology and Therapy (Sukhumi), USSR Academy of Medical Sciences. To create hypokinesia, we used a special method of immobilizing the animals in horizontal position [8]. In two experiments conducted at different times, 6 monkeys (3 in each series) first remained under horizontal hypokinetic conditions for 7 days, then for 12 days under AOH conditions at an angle of -6°. In the first experiment, the animals' weight was about 5 kg (sexually mature animals) and in the second, 3-4 kg (immature). In the second experiment, 2 monkeys were submitted to AOH for 7 days in order to simulate the acute period of adaptation to weightlessness. All of the experimental and intact monkeys were sacrificed by means of intravenous injection of 10% hexenal solution (2-3 mℓ per animal). Death occurred immediately after injecting this agent.

Morphological examination was made of the hypothalamus and hypophysis of 5 control and 8 experimental monkeys. The material was fixed in Bouin liquid, then imbedded in paraffin and series of horizontal sections, 5 μm in thickness, were prepared. The hypothalamus and neurohypophysis sections were stained with paraldehyde fuchsin according to Gomori-(Gab) for demonstration of neurosecretory substance (NSS) and with gallocyanin after Einarson for demonstration of ribonucleoprotein substance (RNP). Adenohypophysis sections were stained with paraldehyde fuchsin and Khel'mi's mixture [3] for identification of somatotropic cells (STC). Karyometry of neurons of supraoptical (SON) and paraventricular (PVN) nuclei, as well as somatotrophs, was performed using an RA-6 projection attachment at a mangification of 2000×. We outlined 100 nuclei of SON, PVN and STC neurons in the hypothalamus and adenohypophysis of each animal. Subsequent procedures for measurement of nucleus diameters and determination of nucleus volumes were performed using conventional morphometric methods [7, 9].

Results and Discussion

Examination of large-cell neurosecretory nuclei of the hypothalamus of monkeys used in the AOH experiments revealed that the most significant changes occurred on the SON level. With 7-day AOH, there was enlargement of SON neurons, change in their shape (marked angularity) and significant accumulation in them of neurosecretory granules which merged to form optically opaque massive conglomerates, particularly on the periphery of the cytoplasm (Figure 1*б*). In addition to excessive accumulation of neurosecretion, there was increase in RNP content. Within the limits of the examined nuclei, we often encountered axons densely filled with NSS. We were impressed by the fact that the lumen of most capillaries was not demonstrable due to severe swelling of endothelium. Brain tissue was edematous. We failed to observe significant changes in PVN neurons, with the exception of increase in NSS content of their axons.

An extremely high NSS content was also demonstrated in the neurohypophysis, as in the bodies of SON neurons. Most of it filled all of the gland's tissue uniformly and with exceptional density. At the same time, there was noticeable enlargement of Herring bodies. Deposition of NSS in the neurohypophysis was combined with marked vascular spasm (Figure 2*б*).

In monkeys used in the 19-day experiment, as in those in the 7-day one, the most substantial changes were found in SON neurons. However, they differed qualitatively: we observed enlargement not only of cell body dimensions but volume of their nuclei (by 30.7%, particularly in immature animals); most cells acquired a round shape. Unlike the 7-day experiment, we observed drastic dilatation of capillaries and small veins, with concurrent decrease in amount of neurosecretory granules both in the bodies of neurons and their axons. Against such a background, some cells remained with signs of NSS deposition (Figure 1*в*). On the level of the nuclei we studied, we encountered many axons with isolated neurosecretion granules in their lumen.

The morphological appearance of the monkey's neurohypophysis was close to normal on the 19th day of the experiment. Most of the neurosecretions were localized around numerous blood vessels. However, unlike the control, most capillaries had dilated lumina (Figure 2*в*). We were also impressed by the retention of an increased number of Herring bodies on gland sections from experimental animals, which were densely filled with neurosecretory substance.

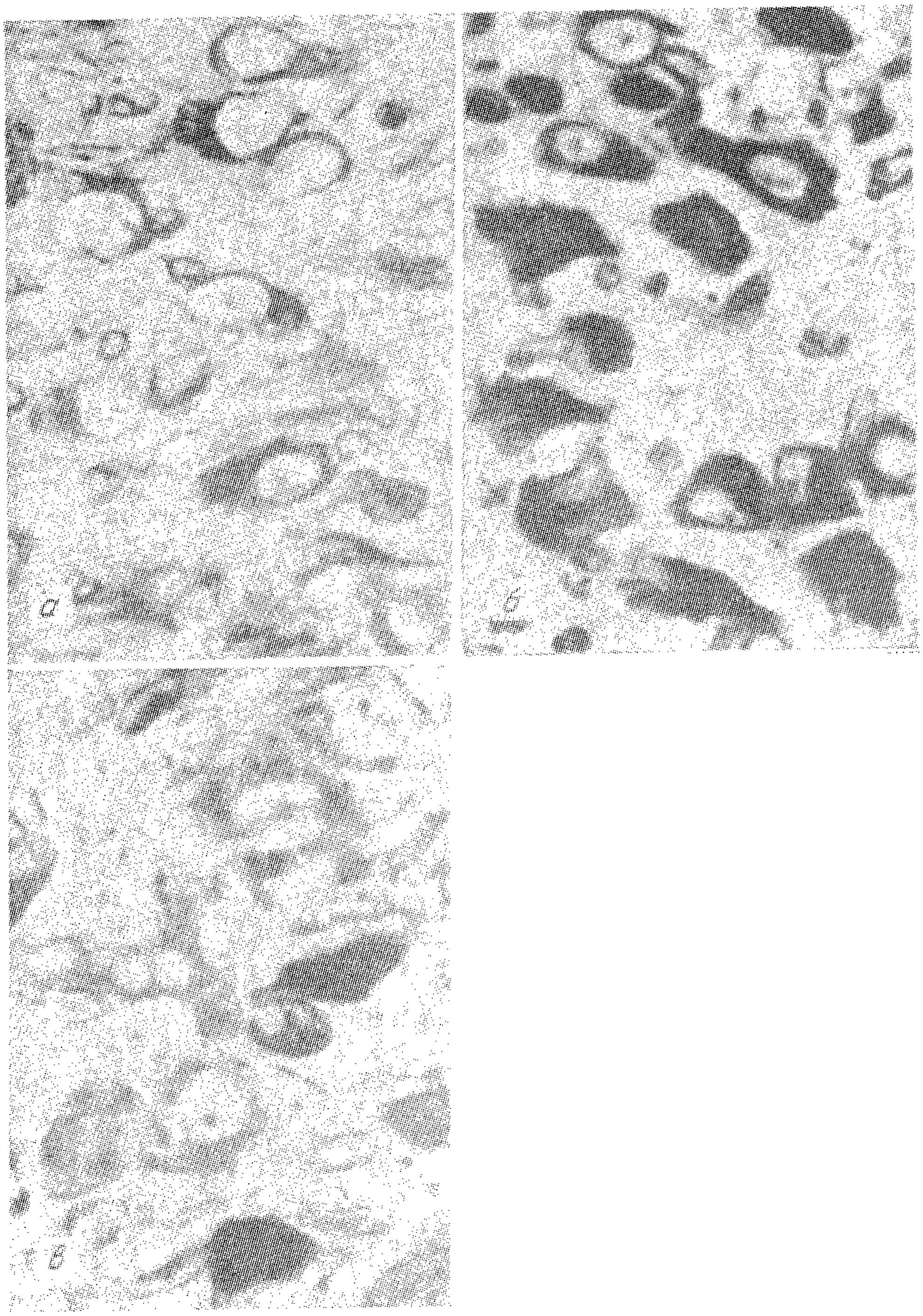

Figure 1. Neurosecretory cells of hypothalamic supraoptical nuclei
а) control: neurons at different stages of functional activity
б) 7 days of AOH: accumulation (deposition) of NSS in neuronal cytoplasm, edema of brain tissue
в) 19th experimental day: enlargement of neurons and their nuclei, decreased NSS content in them, signs of deposition persisted in a few cells
Paraldehyde fuchsin stain; lens 40×, eyepiece 10×

In our examination of the adenohypophysis, we concentrated mainly on the functional state of somatotrophs that produce growth hormone. It was established that, after 7-day AOH, there was distinct degranulation of somatotropic cell cytoplasm and, for this reason, a decrease in their oxyphil properties. Cells in direct contact with dilated capillaries appeared to have taken up the least stain. Upon termination of the 19-day experiment, we observed the reverse: accumulation of oxyphil substance in the cytoplasm of somatotrophs, for which reason they became somewhat enlarged and acquired a round shape. The increase in optical density of cytoplasm was particularly typical of cells adjacent to capillaries with narrow, slit-like lumina. In spite of the differences in amounts of oxyphil (secretory) material in the STC, the volume of their nuclei in both experiments showed virtually no difference from the control, constituting 201.3-214.5 and 211.7 μm^3, respectively.

Considering the data in the literature to the effect that there is a correlation between oxyphilia (acidophilia) of somatotrophs and amount of growth hormone they contain [12, 13], it can be concluded that there were phasic changes in amounts of somatotropic hormone in the monkeys' adenohypophysis during AOH. Our findings agree, to some extent, with data obtained by other scientists in studies involving long-term hypokinesia in man [10, 15]. In particular, with 49-56-day bedrest, the blood plasma growth hormone concentration in the subjects decreased appreciably for the first 4-10 days, then increased drastically on the 14th-20th days, and consistently decreased in the subsequent experimental period.

Thus, with 7-day AOH we observed a set of morphological signs reflecting deposition of NSS in the main elements of the HPNS (significant accumulation of NSS in bodies of neurons, axons on the level of nuclei and their endings in the neurohypophysis) against the background of marked spasm of blood vessels.

In the 19-day experiment (7 days of hypokinesia followed by 12-day AOH), there was activation of both processes of NSS synthesis (enlargement of neurons and their nuclei) and (particularly) its excretion (decrease in NSS content of neuronal bodies and axons). At the same time, morphological signs of prior deposition of NSS in some SON cells, as well as terminal axons of neurons of hypothalamic nuclei on the level of the posterior lobe of the hypophysis (increase in number of Herring bodies and in their optical density), were retained in the 19-day experiment.

The significant accumulation of NSS in the main elements of the HPNS during 7-day AOH could be due to inhibition of ADH--vasopressin excretion into blood because of the hemodynamic distinctions under AOH conditions in monkeys, in particular, as a result of the Henry-Gauer reflex. As we know, elevation of transmural pressure in the "left atrium--pulmonary artery" region is associated with activation of volumobaroreceptor zones [1, 14], intensification of impulsation flow of which has a tonic inhibitory effect on the HPNS as a whole, and leads to depression of the base level of ADH-vasopressin secretion, with decrease of its concentration in blood [11].

With increase in duration of the experiment, the phase of NSS deposition is replaced by activation of processes of elimination of ADH-vasopressin, which could be directed at establishment of a new level of hemodynamics and fluid metabolism, and it can be viewed as one of the manifestations of the body's adaptation reactions to AOH.

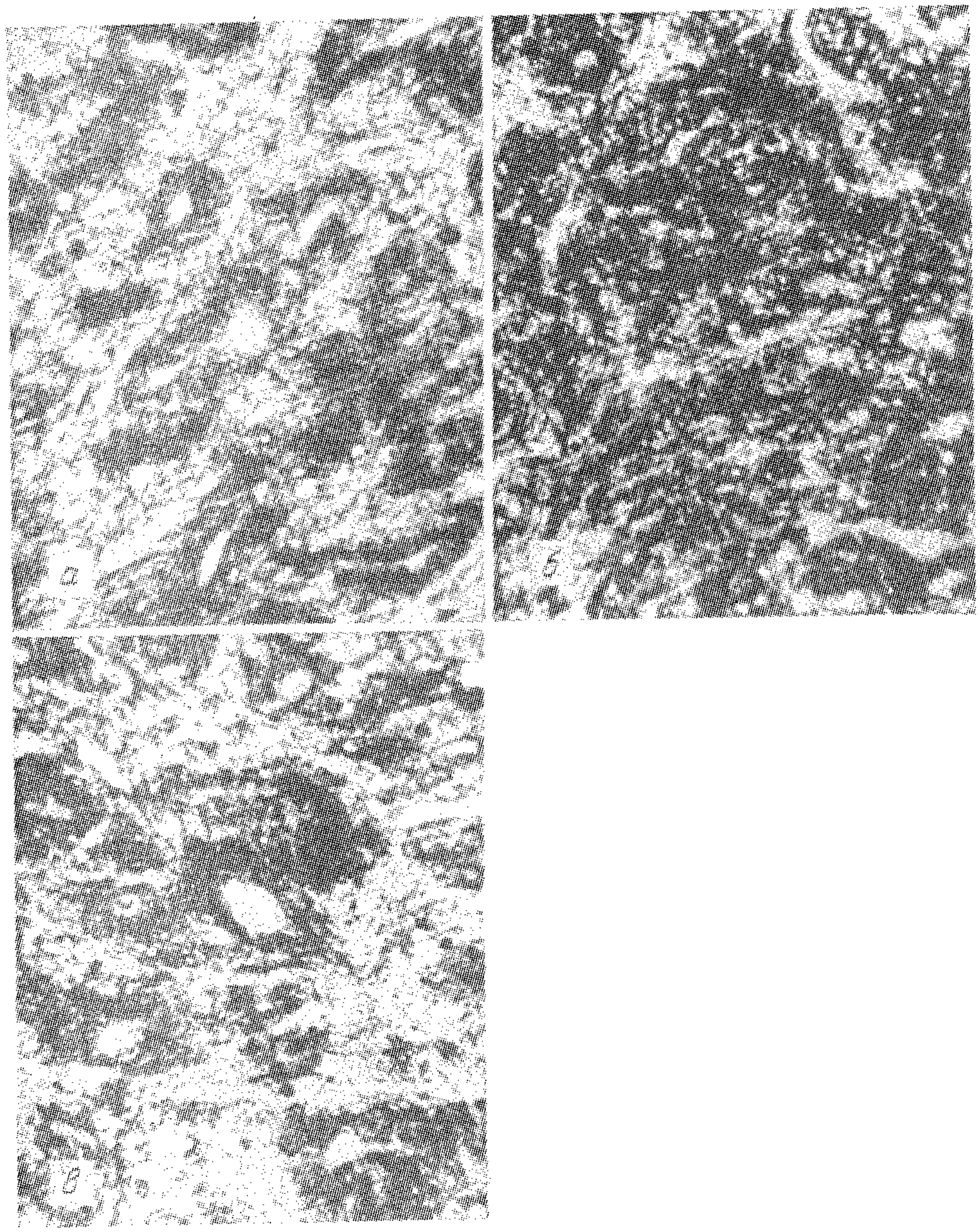

Figure 2. Neurosecretory substance levels in neurohypophysis tissues. Paraldehyde fuchsin stain; lens 16×, eyepiece 10×

а) control

б) 7th day of AOH

в) 19th day of experiment

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BLOOD SERUM ENZYME ACTIVITY FOLLOWING LONG-TERM SPACEFLIGHTS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 19 Apr 83) pp 81-82

[Article by I. A. Popova, Ye. G. Vetrova and T. Ye. Drozdova]

[Text] At the present time there is much information about changes in blood enzyme activity in people with different states of stres, such as maximum physical loads, gravitational accelerations, hypodynamia, etc. [1, 4, 6]. Since man is exposed to a set of factors during spaceflights, which include both the ones mentioned above and others, among which one of the most important is weightlessness, we can expect that a change in blood serum enzyme spectrum would be one of the distinctions of spaceflight aftereffects.

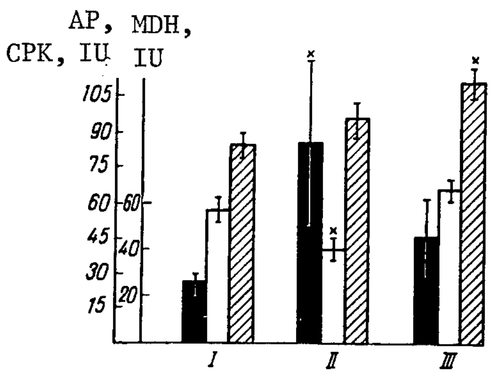
Preliminary analysis of the results of each of the 5 main missions (MM) of the Salyut-6 scientific orbital space complex failed to reveal a definite correlation between duration of the missions (from 73 to 185 days) and tendency toward change in enzyme activity. For this reason, we have combined here for analysis the tests covering all of the main missions, which are viewed as long-term spaceflights. This approach enabled us to assess with a high degree of reliability the patterns of enzymatic reactions of the body to spaceflight conditions.

Methods

Twice before each main expedition, as well as on the 1st and 7th-32d postflight days, we tested activity of the following blood serum enzymes of the cosmonauts: aspartate aminotransferase, alanine aminotransferase, lactate dehydrogenase (LDH) and its isozymes, NAD-dependent malate dehydrogenase (MDH) and its isozymes, creatine phosphokinase (CPK), NADP-dependent isocitrate dehydrogenase, alkaline phosphatase (AP) and its isozymes. Enzymospectrophotometry methods using standard sets of Beringer (FRG) reagents were applied to measure the activity of these enzymes. The distribution of the isozyme spectrum of LDH and MDH was examined by electrophoresis in polyacrylamide gel [3], while isozyme composition of AP was determined by the method of heat inactivation [7].

Results and Discussion

Analysis of enzyme activity in cosmonauts' blood after the missions revealed statistically significant changes in activity of MDH, CPK and AP (see Figure).



Blood serum enzyme activity in crews of the 5 main missions aboard the Salyut-6 orbital complex
Total number of cases, 20 preflight and 10 postflight.

I) preflight
II) 1st postflight day
III) 7th-32d postflight days
CPK--black bars
MDH--white bars
AP--striped bars
IU--international units
×--$P<0.01$

On R-1, we found insignificant but reliable change in MDH activity ($P<0.01$) and increase in CPK activity. CPK activity increased by a mean of over 1.6 times, as compared to preflight level ($P<0.01$). By the 7th-32d postflight days, MDH and CPK activity did not differ from background values, whereas AP activity increased in comparison to initial values ($P<0.01$). According to the prevailing opinion, CPK is an enzyme that is specific to striate tissue, whereas it is present in small quantities or not demonstrable at all in other tissues. Myocytes of skeletal muscles have considerably more creatine kinase activity than myocardial cells [2]. Considering also the relationship between total mass of skeletal muscles and the myocardium, it can be assumed with a high degree of probability that the increase in blood CPK activity is related to changes in skeletal muscle cells. The probable cause of increased blood CPK activity may be either activation of processes of energy metabolism or change in membrane permeability of cellular structures. Nor can we rule out the possibility of destructive changes in cells [5].

A decline in blood MDH activity was demonstrated only after long-term flights. Since MDH is an enzyme of substrate oxidation, which is involved in conversions of the Krebs cycle, the reduction of its activity in blood may be a reflection of lower intensity of oxidative processes and energy potential in tissues. The absence of definite organ specificity of MDH does not allow us to relate these changes to any particular organ. The reliable increase in AP activity, as compared to base values, which was manifested only on the 7th-32d day after landing, is another distinction of the blood enzyme spectrum of cosmonauts involved in the main missions following long-term exposure to weightlessness. Analysis of the isozyme spectrum of AP revealed that the increase in general activity of this enzyme in blood occurred due to uniform activation of both the hepatic and bone isoforms of AP, and it is probably a reflection of compensatory intensification of anabolic processes in these tissues during the recovery period.

While the changes in blood AP activity are definitely related to biochemical shifts of a recovery nature, we cannot consider answered the question of stage of spaceflight, at which changes occur in oxidative processes that lead to decline of blood MDH activity. Additional studies are required to answer it.

Thus, on the 1st day following long-term missions there is increase in blood CPK activity, which could be a reflection of metabolic or structural changes, which very probably occur in skeletal muscles. The decrease in blood MDH activity, which was demonstrated on the 1st day after completion of long-term spaceflights, could be related to diminished intensity of oxidative processes in tissues.

By the 7th-32d days of the recovery period, there is increase in general activity of blood AP, with uniform increase in activity of the hepatic and bone isoforms of this enzyme, which is probably attributable to compensatory intensification of anabolic processes in these tissues.

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CHANGES IN NEPHRON AND JUXTAGLOMERULAR SYSTEM OF PRIMATE KIDNEYS UNDER THE EFFECT OF ANTIORTHOSTATIC HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 30 May 83) pp 83-86

[Article by A. S. Pankova and M. A. Pal'tsev]

[Text] In recent years, many studies were pursued in order to demonstrate the mechanisms of action of clinostatic hypokinesia on the body, including the kidneys; however, no detailed morphological studies of primate kidneys had been made. There are merely indications [1] of accumulation of lipids in renal tubules during long-term hypokinesia. Very few experimental studies of primates with antiorthostatic hypokinesia (AOH) have been conducted, and no morphological analysis of organic changes had been made. Yet it is known that one observes redistribution of blood in the body, loss of fluid and some electrolytes, change in activity of the renin-angiotensin-aldosterone system in humans under AOH conditions [2, 3]. All this prompted us to undertake a morphological study of primate kidneys under AOH conditions, in particular, of the renal circulatory system and juxtaglomerular system (JGS), which secretes renin.

Methods

The kidneys from 3 Macaca rhesus monkeys, which spent 7 days in clinostatic hypokinesia and 12 in AOH at an angle of -6°, in head-down position, and 2 monkeys submitted for 7 days only to AOH served as the material for our study. We also examined the kidneys of 3 control animals whose activity was not restricted. The kidneys were fixed in 10% formalin and Zenker's formol, then imbedded in paraffin. Sections were stained with hematoxylin and eosin, elastic fibers were demonstrated according to Weigert and connective tissue, after Van Gieson. For the morphometric studies, renal sections 5 μm in thickness were prepared from 5 different levels at intervals of 150 μm. In each case, we analyzed 50 small arteries in the renal cortex. Using an ocular ruler, we measured the outside diameter, lumen and thickness of the arterial muscular tunic; we determined the Kernogen index (ratio of thickness of muscular tunic to inside diameter). The area of the cross section of the muscular tunic was calculated using the formula, $S = \pi m(D - m)$, where $\pi = 3.14$, m is the thickness of the muscular tunic and D is outside diameter of arteries. Granules in epithelioid JGS cells were demonstrated according to Bowie. In addition, we submitted the kidneys to electron microscopy (including the JGS). For this purpose, pieces of renal tissue from the external part of the cortex were fixed in 2% glutaraldehyde, with additional fixation in 1% OsO_4 solution; they were dehydrated in ascending strengths of alcohol and imbedded in araldite. Semifine sections, 1 μm in thickness, were prepared from all the araldite blocks. The semifine sections were stained with methylene blue--azure II--fuchsin and used for light optic examination and reference. Ultrafine sections were prepared on an LKB ultramicrotome (Sweden). They were contrasted with lead citrate according to Reynolds and viewed under an EVM=100L electron microscope.

Results and Discussion

Absolute and relative weight of monkey kidneys was reliably greater with both 7- and 12-day AOH than in the control. We had previously observed such increase in weight of the kidneys (29%) in rats flown aboard biosatellites of the Cosmos series (605, 690, 782 and 936). Since these rats presented excess fluid in renal tissue (upon lyophilization of pieces), the hypothesis was expounded that the increased hydration of renal tissue could be the cause of increase in mass of this organ [4]. In this experiment, fluid content of the kidneys was not measured, but microscopy of the monkeys' kidneys revealed enlargement of interstitial spaces in the medullary substance, which partially appeared to be optically empty or filled with amorphous eosinophil substrate. Such changes are indicative of increase in free or bound fluid, which could be due to the most diverse reasons (impaired hemodynamics and others).

The results of a special study of renal vessels revealed that in large-caliber arteries the internal elastic tunic was split into 2-3 lamina. Dissociation of the external tunic is observed in isolated cases. In medium-caliber arteries, dissociation of the internal tunic over the entire circumference of the vessel was observed rather seldom and most often it was focal. In small arteries, there was a distinctly demonstrable internal elastic tunic, while the external one could barely be outlined or was wanting. In small and medium-sized arteries, there was a well-developed muscular layer, which is apparently a species-specific distinction of monkeys. It should be noted that we failed to detect differences in histological structure of vessels between experimental and control monkeys. However, the experimental animals presented signs of spastic contraction of small cortical arteries (more marked up to the 7th day) in the form of marked folds in the internal elastic tunic, protrusion of endothelium into the nuclear lumen and some increase in thickness of the tunica media. However, the results of morphometric studies (thickness and area of cross section of arterial muscular tunic, Kernogen index) failed to demonstrate reliable differences between the condition of arteries in experimental and control monkeys (see Table). Nor did we demonstrate significant changes in delivery of blood to glomerular capillaries. Experimental monkeys presented merely moderate plethora of juxtamedullary glomerules and anemia of cortical ones, as well as moderate plethora of straight medullary vessels. Electron microscopy revealed signs of intravascular coagulation--fibrin and thrombocytes--in the capillaries of some glomerules.

It must be stressed that on the light level, no dystrophic changes were found in renal tubule nephrocytes. Electron microscopy revealed droplets of protein of different sizes and oval vacuoles in the cytoplasm of nephrocytes of some proximal tubules, which were evaluated as a manifestation of granular dystrophy with change to hydropic.

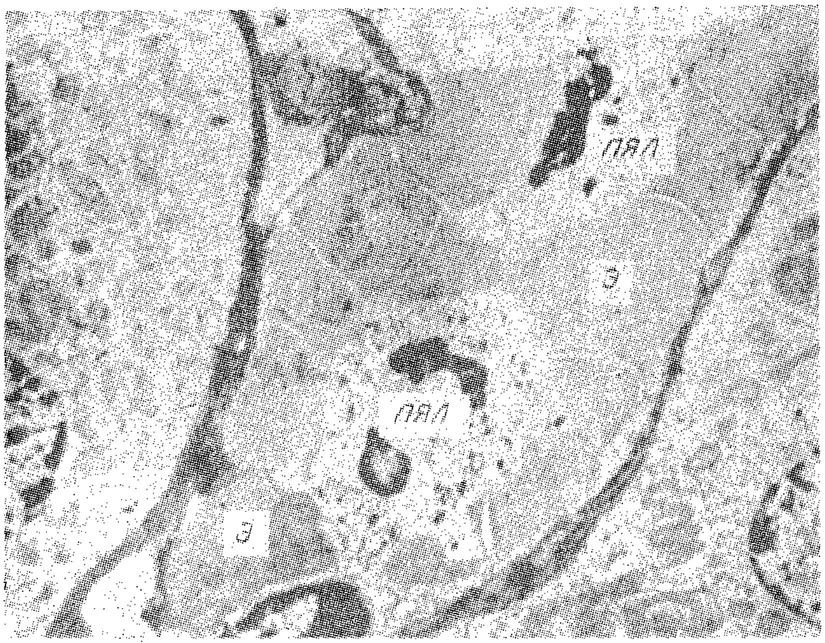

Figure 1. Polymorphonuclear leukocytes (*ПЯЛ*) and sludged red blood cells (*Э*) in peritubular capillary lumen; magnification 4000×

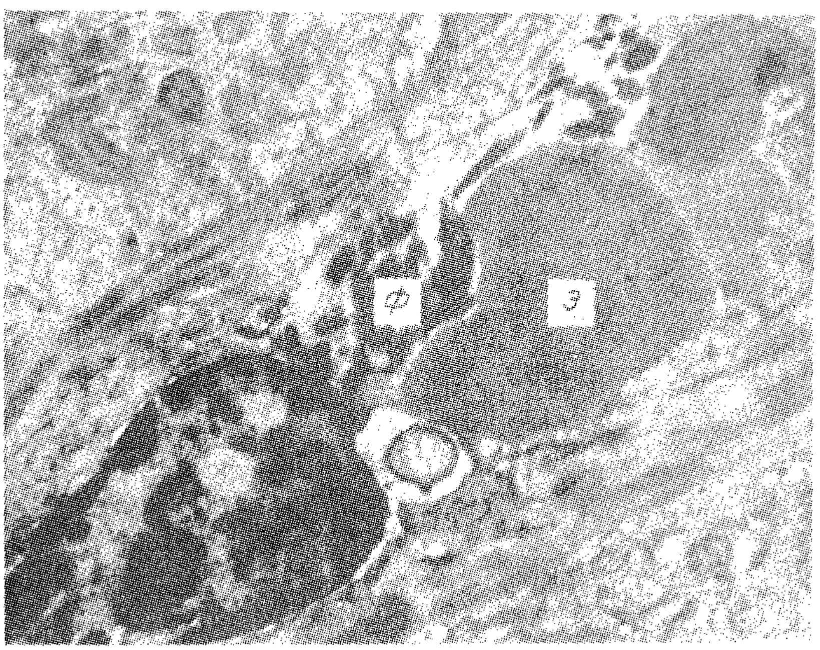

Figure 2. Red cells (*Э*) and fibrin (*Ф*) in peritubular capillary lumen; magnification 6000×

Morphometry of small arteries of monkeys' renal cortex

Group of animals	Outside diameter, μm	Lumen, μm^3	Muscular tunic thickness, μm	Muscular tunic cross section, μm	Kernogen index
Control					
№ 24	24,1±0,32	15,08±0,49	4,52±0,12	274,95±10,2	0,30±0,021
№ 25	26,1±0,32	12,3±0,41	5,07±0,12	334,3±11,27	0,33±0,015
№ 26	24,2±0,24	14,5±0,41	4,68±0,12	284,7±9,5	0,35±0,012
AOH, 12 days					
№ 21	24,4±0,39	13,9±0,32	5,25±0,07	315,6±10,4	0,38±0,018
№ 22	22,6±0,41	11,4±0,32	5,7±0,12	302,3±14,9	0,5±0,017
№ 23	24,18±0,49	12,84±0,24	5,6±0,12	323,75±14,5	0,46±0,021
AOH, 7 days					
№ 27	24,85±0,33	14,7±0,49	5,09±0,16	314,18±13,4	0,39±0,02
№ 28	25,7±0,32	15,2±0,49	5,22±0,16	334,15±13,4	0,36±0,012

We should dwell in particular on the changes noted in the peritubular capillaries under an electron microscope. This consisted of plethora of these capillaries, sludging of red blood cells and appearance of polymorphonuclear leukocytes (Figure 1). Along with erythrocytes, accumulations of fibrin (Figure 2) were discovered in some peritubular capillaries, while some capillaries presented early signs of thrombus formation, consisting of agglutination of red blood cells, adhesion of thrombocytes and elimination of fibrin (Figure 3). In rare cases integrity of the peritubular capillary wall was impaired. We tend to believe that all of the above-mentioned capillary changes are attributable to stasis in the kidneys related to change in position of the body, redistribution of blood and appearance of obstacles to venous efflux, overload on the cardiovascular system, as well as a stress reaction which, according to our examination of the renals, persisted to some extent throughout the experiment in most monkeys. It is a known fact that a stress state is usually associated with increase activity of the clotting system [5, 6], with which the possibility of thrombus formation appears. In humans submitted to prolonged hypokinesia, a tendency toward hypercoagulation [7] and signs of impaired capillary permeability [8] have been observed.

The changes in the JGS can be referred to compensatory and adaptive reactions, which developed in the monkeys' kidneys in response to the hemodynamic changes that occur under AOH conditions. It must be noted that, unlike rats and mice, the epithelioid cells of monkeys have few granules. Evidently, this is why no quantitative assay of JGS activity had been made in the few existing studies of the JGS [9].

The morphology of the JGS with 7-day AOH was similar to that of the control. Monkeys used in the 19-day experiment revealed a reduction in number of granule-containing epithelioid cells and their partial degranulation. Electron microscopy played an important part in determining whether degranulation of epithelioid cells is a reflection of JGS activation or, on the contrary, an indication of depressed renin synthesis. We observed hyperplasia of the endoplasmic network and laminar complex of epithelioid cells (Figure 3) which confirms activation of renin synthesis that is probably secreted into blood, without accumulation in granules. In our experiment, mobilization of renin could also be related to increased adrenosympathetic

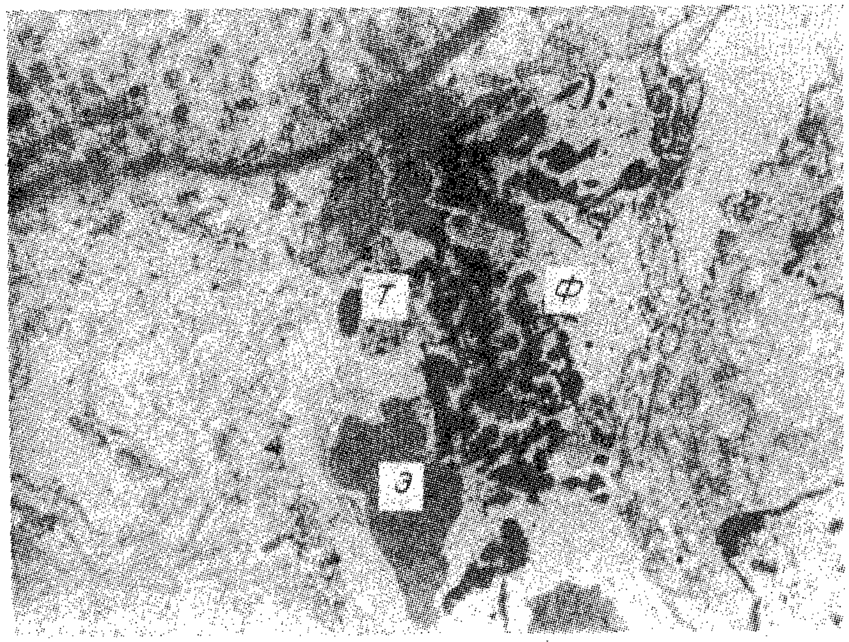

Figure 3. Erythrocytes (Э), thrombocytes (T) and fibrin (Ф) in lumen of peritubular capillary

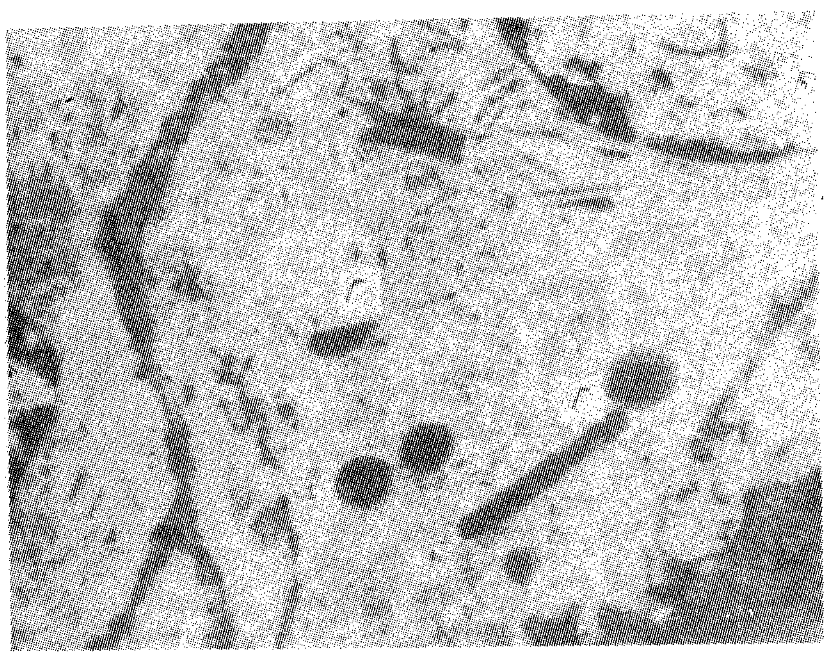

Figure 4. Granules (Г) in cytoplasm of epithelioid cell (JGS); magnification 15,000×

system activity. This is indicated by data on increase in blood epinephrine in people who were submitted to AOH for a long time [10]. In turn, activation of the renin-angiotensin system is, as we know, instrumental in alteration of adrenals for increased aldosterone production. Hypertrophy of the glomerular zone of the cortex (which produces aldosterone) and reliable increase in volume of its cell nuclei, which we demonstrated in monkeys submitted to AOH for 12 days, serve as evidence of this.

To sum up the foregoing, it can be concluded that, in response to hemodynamic disorders in the kidneys of monkeys, there is triggering of adaptive and compensatory mechanisms (activation of renin-angiotensin-aldosterone system), which ultimately should lead to equalization of fluid-electrolyte homeostasis that had been altered under AOH conditions.

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RAT BLOOD SERUM AND LIVER CARBOHYDRATES AND LIPIDS IN RECOVERY PERIOD AFTER 15-DAY HYPOKINESIA

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 22 Jul 83) pp 87-88

[Article by P. P. Potapov and N. A. Tikhomirova]

[Text] Restriction of motor activity leads to rather serious metabolic and functional disturbances [3, 4, 9]. Systematic and comprehensive investigation of metabolic processes in the recovery period is necessary in order to work out some simple and effective rehabilitation measures. There are relatively few works dealing with this matter. Some authors have found considerable fluctuations of blood lipid and sugar levels in man and animals in the recovery period following long-term restriction of movement. In some cases, the changes were even more significant than with immobilization [2, 5, 6, 9, 10]. These studies also revealed that even a prolonged recovery period is not sufficient for normalization of many metabolic parameters. We report here on a study of lipid and carbohydrate content of the liver and blood serum at different stages of recovery following relatively brief (15 days) restriction of mobility.

Methods

Experiments were performed on 45 white male rats with initial weight of 160-180 g. After 15-day immobilization of animals in individual plexiglas cages, they were transferred to common cages. Control rats were kept in common vivarium cages for the entire time. The animals were decapitated on the 15th day of hypokinesia, on the 7th, 15th and 30th days of the recovery period. We assayed total lipids (Bragdon method), cholesterol (color reaction of Libermann-Burchardt) and phospholipids (method of Svenborg and Svennerholm as described by A. A. Pokrovskiy [1]). Triglycerides were assayed by the method of Stolz et al. [14], free fatty acids of blood serum, by the Duncombe method [11] and blood sugar, by the o-toluidine method. Glycogen was isolated from the liver as recommended by Good et al. [12], and it was assayed by the method of Kemp and Kits [13].

Results and Discussion

There was increase in cholesterol content and some decline of triglyceride levels in blood serum and hepatic tissue of rats on the 15th day of restricted activity. There was a sharp drop in glycogen in the liver. In blood serum, levels of free fatty acids rose and phospholipids declined; there was a tendency toward hypoglycemia (Tables 1 and 2). On the whole these findings coincide with results obtained previously with the same model of hypokinesia [6, 7, 10]. These changes were attributable, to a significant extent to the stress reaction to immobilization [3, 9] and, apparently, were indicative of change from "carbohydrate" type of energy metabolism to predominantly "fat" type [6, 9]. Such a change is inherent in reactions to many extreme factors [8].

Table 1. Blood sugar and blood serum lipid levels in rats, in recovery period following 15-day hypokinesia (M±m)

Parameter	Control	Hypokines. (15 days)	Recovery period		
			7 days	15 days	30 days
Sugar, mmol/ℓ	5,00±0,11 (12)	4,79±0,27 (6)	5,44±0,32 (6)	4,56±0,14 (7)*	4,78±0,21 (6)
Total lipids, g/ℓ	2,44±0,09 (15)	2,35±0,04 (5)	3,34±0,14 (7)*	3,35±0,15 (7)*	2,54±0,04 (5)
Triglycerides, mmol/ℓ	1,24±0,04 (17)	1,06±0,05 (6)*	1,42±0,05 (7)*	1,49±0,05 (7)*	1,24±0,05 (6)
Cholesterol, mmol/ℓ	1,59±0,06 (16)	1,81±0,08 (5)*	2,02±0,15 (7)*	2,13±0,06 (7)*	1,70±0,09 (6)
Phospholipids, mmol/ℓ	1,16±0,05 (15)	0,99±0,02 (5)*	1,73±0,06 (7)*	1,65±0,10 (7)*	1,06±0,08 (5)
Free fatty acids, μeq/ℓ	444±18 (19)	664±88 (6)*	555±51 (7)*	513±20 (7)*	530±35 (6)*

Note: Here and in Table 2, number of animals in group is given in parentheses. *Statistically reliable changes in comparison to control ($P<0.05$).

Table 2. Glycogen and lipid content of rat liver in recovery period following 15-day hypokinesia (M±)

Parameter	Control	Hypokines. (15 days)	Recovery period		
			7 days	15 days	30 days
Glycogen, g%	3,93±0,28 (14)	1,32±0,52 (6)*	5,87±0,57 (7)*	1,40±0,14 (7)*	5,28±0,23 (6)*
Total lipids, g%	5,57±0,18 (10)	4,45±0,18 (6)*	5,06±0,23 (6)	6,83±0,28 (5)*	5,86±0,52 (6)
Triglycerides, μmol/g	21,2±0,5 (10)	17,3±0,9 (6)*	21,2±1,1 (6)	32,5±2,2 (5)*	22,3±2,3 (6)
Cholesterol, μmol/g	6,76±0,23 (10)	7,77±0,26 (6)*	6,61±0,28 (6)	7,23±0,26 (5)	6,11±0,57 (6)

On the 7th day of the recovery period, total lipid, cholesterol and triglyceride levels normalized in the liver, whereas glycogen increased significantly and exceeded the control by 1.5 times. There was drastic increase in total lipids, phospholipids and triglycerides in blood serum, and a high level of free fatty acids persisted. Serum cholesterol level rose, as compared to the 15th day of hypokinesia.

We evaluate the changes on the 7th day of the recovery period as a manifestation of marked anabolic reaction. This reaction is even superfluous with regard to liver glycogen content. The distinct increase in blood serum triglycerides and cholesterol in this period was not associated with their accumulation in the liver. Evidently, hyperlipemia is due to increased lipid synthesis and transport to the site of their utilization. This applies to lipids that perform both structural (phospholipids, cholesterol) and energetic (triglycerides, free fatty acids) functions. In this case, hypercholesterolemia can hardly have adverse consequences, since it was combined with marked increase in serum phospholipid content.

On the 15th day of the recovery period, liver glycogen content again began to decline significantly, with concurrent increase in triglyceride content of this tissue (by 53%, as compared to control; $P<0.01$). Statistically reliable hypoglycemia was demonstrable. In blood serum, all of the assayed lipid fractions remained elevated. The specific mechanism of these changes is still unclear. We believe that the decrease in glycogen and accumulation of triglycerides in the liver on the 15th day of the recovery period should be viewed as an unfavorable sign. These disturbances are possibly due to increased breakdown of carbohydrates due to the return from "fatty" to "carbohydrate" type of energy metabolism.

On the 30th day of the recovery period, most of the parameters studied were close to control levels. Thus, the demonstrated shifts are reversible, even if no rehabilitation measures are instituted. However, it should be noted that, under these conditions, a rather long period of time is required for normalization, while adverse metabolic changes are demonstrable at some stages of the recovery period.

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INFLUENCE OF LIMBORETICULAR COMPLEX ON SOME VESTIBULAR REACTIONS OF RABBITS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (manuscript received 9 Jun 83) pp 88-90

[Article by V. Ye. Koryukin and V. I. Usachev]

[Text] We investigated here the role of the amygdaloid complex of the temporal lobe of the brain, caudate nucleus and dorsomedial nucleus of the thalamus in formation of nystagmic and some autonomic vestibular reactions.

These structures are referable to the limboreticular complex of the brain, the connections of which, in particular with the vestibular system, have already been demonstrated by many authors [1-3, 5, 6, 8, 9]. However, in the cited works studies were pursued of the effect of the hypothalamus, hippocampus, globus pallidus and reticular formation on vestibular reactions. The structures we selected have been virtually unstudied in this aspect.

Methods

Experiments were performed on 89 chinchilla rabbits weighing 2.5-3 kg. We studied the dynamics of heart rate (HR) and respiration rate (RR) while rotating the animals in an isolation chamber for 1 h on a special revolving device simulating angular sign-variable accelerations, by means of pendulum-like rotation of a horizontal platform with the animal to the left and right for 4 s, with maximum angular velocity of 180°/s and 4-s interval between two rotations.

The HR was evaluated from the ECG recorded by means of subcutaneous needle electrodes and the RR from the pneumogram also recorded electrographically by means of an encircling carbon sensor of the rheostat type.

Rotatory nystagmus was studied on electronystagmograms while rotating the rabbits on a trapezoid program, on an electric turn table with programmed control. Positive acceleration constituted $39°/s^2$, duration 5 s, with uniform rotation being continued for 1 min at the rate of 150°/s. The table was stopped at subthreshold acceleration, which did not induce nystagmus. The electronystagmogram was recorded on a Cardiolux-300 electrocardiograph with an alternating current preamplifier, using metal sensors implanted in the zygomatic bones. We determined duration of the nystagmic reaction, mean frequency and amplitude of nystagmus per 10-s interval from the time of termination of positive accelerations.

The selected brain structures were stimulated with square-wave pulses of electric current at frequencies of 10 and 100 Hz, and we also performed electrocoagulation and temporary exclusion of their function with 0.1% dicaine solution prior to rotating the rabbits. To exert an influence on the brain structures, bipolar metal microelectrodes, 100 μm in diameter, in glass insulation or microcannulas 500 μm in diameter were implanted by the stereotactic method. The stereotactic operations were performed after administration of neuroleptic analgesia following a protocol we developed. The position of the electrodes and microcannulae was monitored on frontal sections of the rabbit brain on a freezing microtome upon completion of the experiments.

Results and Discussion

Normally, similar changes in HR were observed in all rabbits under the effect of sign-variable angular accelerations: some increase in rate in the 1st min of rotation (by 2-7%, in comparison to initial level) followed by significant slowing, reaching a maximum by about the 15th min of rotation and constituting 85-91% of base HR. This HR level persisted to the end of rotation. After the table was stopped, HR parameters rapidly reverted to the base level. Such dynamics of this parameter are attributable to stimulation of the vestibular system, since no bradycardia reaction to accelerations developed in the animals after they were submitted to labyrinthectomy [4].

Electric stimulation of the caudate nucleus aggravated the bradycardia reaction, as compared to intact animals, while elimination of the structure with dicaine and its electrocoagulation attenuated development of bradycardia. On the day after electrocoagulation, the level of this reaction came close to the base value. Analogous changes were noted when the amygdaloid complex was treated. However, recovery of the parameter to the base level was observed only on the 5th day after electrocoagulation of this structure. An opposite effect was obtained with the dorsomedial nucleus of the thalamus. While electrostimulation led to attenuation of bradycardia reaction, injection of dicaine into this structure enhanced this reaction. Coagulation of the dorsomedial nucleus of the thalamus not only affected the level of the bradycardia reaction, but change in shape of the curve reflecting HR dynamics. The curve became wavy. Bradycardia progressed slowly and reached maximum values by the 45th min of rotation. Such a reaction persisted to the 5th day after destruction of the structure.

Changes in respiration rate and amplitude are typical findings under the effect of angular accelerations [7], and they are not observed in experiments with labyrintectomied animals [3]. We studied the effect of limbic system structures on difference in RR with dextrorotation and levorotation, and it did not change when tests were repeated.

Such treatment of the caudate nucleus did not affect this parameter.

Electrostimulation of the amygdaloid complex led to prevalence of RR with rotation in the contralateral direction (in relation to the structure), while stimulation of the dorsomedial nucleus of the thalamus did so in the ipsilateral direction. An opposite effect was observed when these structures were eliminated.

Treatment of the limbic structures under study had no effect on frequency of rotatory nystagmus, but there were similar changes in its duration and amplitude.

Electric stimulation of the dorsomedial thalamic nucleus prolonged the nystagmic reaction and increased its amplitude, mainly when turning in the contralateral direction. Elimination of the structure with dicaine shortened the nystagmic reaction and reduced its amplitude, mainly with rotation in the contralateral direction. The opposite effect was observed for the amygdaloid complex and caudate nucleus. Their electrostimulation led to shortening of nystagmus and reduction of its amplitude, while elimination of the structure with dicaine prolonged nystagmus and increased amplitude mainly with rotation in the contralateral direction.

Thus, the amygdaloid complex, caudate nucleus and dorsomedial nucleus of the thalamus are involved in expression of vestibular reactions. Their influence on different components of vestibular reactions are dissimilar and complicated. The impression is gained that these structures do not have a direct effect on autonomic vestibular reactions and nystagmus, but that their influence is transmitted through other structures, for example, the hypothalamus and reticular formation, emerging in the role of a "fine" regulator leading mainly to quantitative, rather than qualitative, changes in these adaptive reactions.

Consequently, as demonstrated in both earlier works and this study, the structures of the limbic system are actively involved in forming the body's adaptive reactions to accelerations.

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BOOK REVIEWS

UDC: 612.014.477-064(049.32)

REVIEW OF BOOK ON PHYSIOLOGICAL STUDIES IN WEIGHTLESSNESS

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (signed to press 13 Aug 84) pp 90-91

[Review by P. V. Vasil'yev of book "Fiziologicheskiye issledovaniya v nevesomosti" (Physiological Studies in Weightlessness), edited by P. V. Simonov and I. I. Kas'yan, Moscow, Meditsina, 1983, 304 pages]

[Text] Among the many problems of space medicine, investigation of the mechanisms of adaptation to weightlessness is of special significance, and it is a prerequisite for developing preventive measures and an optimum system of medical monitoring during long-term spaceflights.

Academician V. V. Parin deserves considerable credit in conducting such studies' one of the first major Soviet works dealing with the problem of weightlessness was written under his guidance, we refer to the collective monograph, "Medico-biologicheskiye issledovaniya v nevesomosti" [Biomedical Research in Weightlessness] (1968). That book summed up the results of the first phase of investigations. The results of subsequent studies of this problem were reflected in the monograph, "Nevesomost'" [Weightlessness] (1974).

The current level of our knowledge and conceptions of the effect of weightlessness on man and steps for preventing adverse effects is represented in the book under review, which is a collective monograph by the leading specialists in the field of space biology and medicine.

This monograph submits essentially new data, which were obtained during long-term manned flights aboard Salyut-type orbital stations and the Salyut-6--Soyuz complex. There is analysis of the results of these investigations and discussion of the possible mechanisms of changes that took place in the cosmonauts.

The vast material in this book is grouped into four sections. Section 1 consists of the summary articles by O. G. Gazenko, N. N. Gurovskiy, A. D. Yegorov and I. I. Kas'yan. On the basis of many facts, future plans for physiological studies of weightlessness are outlined. It is stressed that, during long-term spaceflights, the attention of researchers should be directed not only to the study of questions related to preserving health, but to provide adequate comfort for man's work during space missions. In specifying this thesis, the authors propose on sufficient grounds an entire program of studies that must be conducted during long-term flights and in model laboratory experiments. It addresses itself to the following tasks:

Investigation of changes in function of the main body systems under the influence of flight factors as a function of flight duration.

Experimental investigation of mechanisms of adaptive reactions of the main physiological systems and differentiation between defense-adaptive phenomena and pathological changes.

Quantitative evaluation of the role of different flight factors in the body's responses.

Development of methods of forecasting possible disturbances in man and their severity during long-term spaceflights.

Development of methods of diagnosing, preventing and treating possible deviations of health status or diseases with acute onset.

It must be conceded that the authors' formulation of the above tasks is one of the rather valuable theoretical and practical conclusions of the book, since it is instrumental in scientifically validated medical planning of work aimed at future fulfillment of programs, which are growing increasingly com;licated, of long-term flights.

Section 2 deals with questions of space cardiology. Data are submitted from studies of hemodynamics, phase structure of the cardiac cycle, distinctions of cerebral and peripheral circulation at rest and during functional tests. It is noted that considerable changes in hemodynamics and vasomotor regulation take place during spaceflgihts. Analysis of the results of rheographic examination of cosmonauts inflight revealed rather distinct patterns of changes in parameters of regional hemodynamics. The dynamics of volumes of circulation were less conclusive. A detailed evaluation was made of dynamics of bioelectrical activity of the myocardium before, during and after 96-, 140- and 175-day missions. It is concluded that, on the whole, the changes in bioelectrical activity of the heart were not clinically significant, which is indicative of the absence of pathological changes in health status of crew members.

There too, data are submitted about the results of studies of cosmonauts' energy metabolism and diet.

The attention of readers is drawn to the fact that intensification of reactions to some functional test or other, or manifestation of adverse development of such reactions is most often attributable to nonadherence to work and rest schedule by cosmonauts.

In the light of the foregoing, the questions discussed in Section 3 acquire special significance; there, some basic guidelines and general description of work and rest schedule for cosmonauts during long-term missions are furnished. The significance of biorhythmological patterns is shown; they must be taken into consideration in planning and following the daily schedule aboard an orbital complex. There are some interesting observations of the cyclic alternation of mandatory and facultative work when activities are not strictly regulated. The experience in organizing life and work of cosmonauts could be extended to other areas of human endeavor.

The guidelines for forecasting the health status of cosmonauts are described in the same section, and they have already been justified during long-term missions.

Section 4 of this book contains generalizing material on theoretical and practical aspects of pathogenesis and prophylaxis of adverse effects of weightlessness, data about use of LBNP (lower body negative pressure) and exercise during long-term missions for conditioning purposes.

While the work of these authors is given a high rating as a whole, and we welcome appearance of this book, it should be noted that, in a number of instances, there is repetition of some theses and facts, excessive details are given in describing some experimental data without the required depth of their analysis and theoretical generalization, which shows that the editors were not demanding enough toward the team of authors.

At the same time, there are several original theses in this book, which could serve as the basis for theoretical discussions and experimental work in the quest for truth.

Thus, the book is unquestionably useful, and it should attract the attention of a wide circle of readers.

CURRENT EVENTS AND INFORMATION

UDC: 612.014.477:661.3(100)"1983"

FIFTH INTERNATIONAL SYMPOSIUM ON GRAVITATIONAL PHYSIOLOGY

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (signed to press 13 Aug 84) pp 91-94

[Article by I. B. Kozlovskaya, A. M. Genin, A. I. Grigor'yev and Ye. A. Il'in]

[Text] The session of the 5th International Symposium on Gravitational Physiology convened in Moscow on 26-29 July 1983. Representatives of 15 countries participated in it: USSR, United States, socialist countries--People's Republic of Hungary, GDR, People's Republic of Bulgaria, Polish People's Republic, Socialist Republic of Romania, CSSR--and western Europe--Denmark, West Berlin, Norway, France, FRG, Sweden and Switzerland. A total of 66 papers were delivered at the symposium, which dealt with questions of gravitational physiology and biology.

The symposium program consisted of 3 symposium and 4 section meetings, at which there was discussion of problems such as biological effects of weightlessness and hypergravity, influence of gravity on circulation, respiration, fluid-electrolyte metabolism and musculoskeletal system, gravireception and analyzer functions with changing gravity loads, results of biomedical studies aboard the Salyut-7 station, Columbia and Challenger spacecraft.

There were 23 papers dealing with investigation of the effect of weightlessness on metabolism, in particular fluid-electrolyte metabolism, and condition of bone. One of the central papers in this section was the one delivered by C. LEACH (NASA, United States), which discussed conceptions of mechanisms of control of fluid-electrolyte metabolism and results of studies of hormonal systems during spaceflights of different duration and in simulation of weightlessness by means of antiorthostatic hypokinesia (AOH).

The joint paper of Soviet and Czech researchers--A. I. GRIGOR'YEV, B. LIKHARDUS et al. (Institute of Biomedical Problems, USSR Ministry of Health, and Institute of Experimental Endocrinology, Slovak Academy of Sciences)--was of substantial practical relevance; it dealt with the results of extensive experimental analysis of distribution of blood volumes and distinctions of hormonal regulation of fluid-electrolyte metabolism with the body in horizontal and antiorthostatic positions. The authors proposed a method to correct the fluid-electrolyte changes caused by weightlessness and AOH with administration of adiuretin (SPFA, CSSR) and intake of fluid and salt solutions, combined with LBNP.

The paper of V. N. ORLOV et al. (Medical Stomatological Institute, Moscow) was concerned with investigation of fluid-mineral metabolism in individuals with different degrees of hydration. The results of this study showed that the intensity and duration of increased diuresis and electrolyte excretion induced by immersion increase when the body's hydration status is increased.

A series of papers discussed problems of bone metabolism under hypogravity conditions. The paper of G. P. STUPAKOV (Institute of Biomedical Problems) submitted the results of a wide range of studies of biomechanical properties of the vertebrae and their changes in real or simulated weightlessness.

The obtained data enabled the authors to develop methods of predicting the rate of development of osteodystrophy of bone structures with various forms of hypodynamia.

In a study of the correlation between rate of production and morphology of rat bone tissue before, during and after a spaceflight, M. SPECTOR et al. (Emory University, United States) discovered a reliable decline in rate of osteosynthesis in the tibia during a spaceflight. Using ultrastructural analysis, the authors demonstrated that this decline was localized in regions with weakened influence of muscular forces and did not affect regions (posterior prominence) where internal muscular forces remained high.

T. SZILAGYI et al. (Institute of Pathophysiology, Institute of Anatomy and Medical Faculty of Debrecen University, Hungarian People's Republic) investigated the mechanisms of osteoporosis during immobilization. Their findings indicate that, in this instance, tissue resorption is due to increased activity of osteoplastis and osteolysis of osteocytes which, in turn, is indicative of increased parathyroid hormone activity.

A. S. USHAKOV et al. delivered a paper on a promising direction for correcting calcium-phosphorus metabolism in weightlessness and under hypokinetic conditions with an active metabolite of vitamin D. Problems of the influence of gravity on circulation and respiration were discussed in 16 papers; in addition, there was a special round-table discussion of cardiorespiratory function with exposure to accelerations and weightlessness. The main direction of the papers was investigation of mechanisms of cardiorespiratory homeostasis as related to changes in body position, exposure to accelerations and lower body negative pressure. In this respect, the research of F. BONDE-PETERSEN et al. (A. Krog Institute, Denmark) was interesting; it dealt with determination of the role of baroreceptors of the vascular system in maintaining vascular tonus with postural loads and the combined effect of exercise and LBNP. The results of experiments performed with use of a number of original methods revealed that the vascular system of the muscles of the lower extremities plays the main role in mechanisms of controlling peripheral resistance and, consequently, systemic blood pressure; the vessels of the skin are virtually not involved in these processes.

The paper delivered by F. J. THOMPSON and B. J. JATES (Florida State University, United States), which dealt with mechanisms of activity of the sensory system of walls of lower limb veins, which perceives minor stretching of the venous wall, prompted lively discussion. Using exquisite electrophysiological methods, the authors tracked the arc of the reflex that connects on smooth muscles of the venous wall and striate muscles surrounding venous vessels.

G. BLOMQUIST et al. (Medical Center of Texas State University, United States) delivered a paper with information of clinical relevance, submitting data on comparison of cardiovascular reactions to antiorthostasis [head-down tilt] of people in different age groups. The authors showed that age does not contribute qualitative changes in reaction characteristics; quantitative changes are also minor and amount to slower normalization of central venous pressure in older individuals. The paper of U. J. BALLDIN (Karolinska Institute, Sweden) was concerned with questions of pilot protection against accelerations. The results of his studies are indicative of the beneficial effect of positive pressure breathing on tolerance to Gz-axis accelerations.

The papers of Soviet specialists prompted much interest and discussion: O. G. GAZENKO et al. (Institute of Biomedical Problems, USSR Ministry of Health) concerning results of biomedical studies aboard the Salyut-7 station, I. D. PESTOV and A. M. TENIN (from the same institute) about biophysical aspects of various methods of simulating weightlessness, E. M. NIKOLAYENKO et al. (from the same institute and Institute of Artificial Organ Transplantation, USSR Ministry of Health), who studied the parameters of respiratory function during antiorthostatic hypokinesia. The paper of A. NICOGOSSIAN (NASA, United States) was heard with great interest; it gave a survey of the results of medical studies conducted aboard Columbia and Challenger.

Essentially problems of maintaining man's homeostasis in orthostatic position and with accelerations were the topic of a round-table discussion. Most of those who participated in the discussion held the view that attributes the central place in mechanisms of controlling systemic pressure in erect position to maintenance of resistance in resistive vessels of the lower limbs, which is considered a more significant factor than maintaining cardiac output.

In the symposium program, significant attention was devoted to studies of structure and function of the vestibular system. Questions of vestibular physiology were the subject discussed in two survey papers at the symposium and two special meetings, a section meeting, at which six papers were delivered by USSR and U. S. specialists, and a session in the form of a round-table discussion. The topics of the papers and reports delivered at the symposium clearly dealt with two directions: analytical studies of microstructure of otoconial complexes, which was the topic of the paper of YA. A. VINNIKOV (Institute of Evolutionary Physiology and Biochemistry, USSR Academy of Sciences) and the report by M. D. ROSS (Michigan State University, United States), and physiological studies of mechanisms of sensory interactions. Five papers and reports delivered by USSR, U.S. and FRG specialists dealt with questions of organization of intersensory complexes, their role in organization of motor, autonomic and perceptual functions, real and predicted changes with altered gravity, as well as mechanisms of sensory adaptations.

In this respect, the paper of I. DICHGANS, professor at Tubingen University (FRG), merits attention; he summed up the results of the studies he has pursued for many years of the mechanisms and patterns of oculovestibular interaction, their role in spatial perception, perception of motion and implementation of postural reactions, their place in the genesis of motion sickness. On the basis of the data he obtained, this author concludes that there is an equal share of involvement of visual and vestibular afferentation in organization of all reactions that are usually considered to be vestibular, including aversive autonomic ones that are demonstrable with changes in gravity.

In the light of the data submitted in the paper, it is understandable that a large place was reserved for studies of oculovestibular interactions in the experiment program of Shuttle and Spacelab. According to the paper of J. SOFFEN (NASA, United States), investigation of visual tracking reactions, optokinetic reactions, visual-motor coordination occupy the central place in the program of vestibular research being done at the present time and planned for the next Shuttle flights.

New data pertaining to organization of interaction of otolith and canal afferentation were submitted by A. A. PERACHIO and M. J. CORREIA (Texas State University, United States), who used acute stereotactic and microelectrode techniques in classical neurophysiological studies. The techniques used by the authors made it possible to demonstrate convincingly the involvement of both systems of the vestibular apparatus in perception of linear accelerations and static gravitational stimuli, to build a model of their interaction, which explains the space form of motion sickness from the standpoint of discoordination of otolith-canal interaction.

Serious discussion was prompted by reports of Soviet representatives--I. B. KOZLOVSKAYA and L. N. KORNILOVA (Institute of Biomedical Problems, USSR Ministry of Health), who investigated processes of sensory interaction during real and simulated spaceflights. The material obtained by the authors, which was indicative of development of substantial disturbances in the system of vestibular reactions with change in activity of proprioceptive and visual sensory inputs (I. B. Kozlovskaya et al.) and disturbances of otolith symmetry (L. N. Kornilova et al.), made it possible to validate the hypothesis on the role and mechanisms of involvement of these factors in the genesis of the space form of motion sickness, to outline the routes and approaches to its verification.

A comprehensive and critical examination of the delivered papers and reports, expounded hypotheses and theses was continued at a round-table meeting, at which there was detailed discussion of future development of the problem (I. B. Kozlovskaya, V. S. Gurfinkel', J. Dichgans), possible approaches and routes for solving them (G. I. Gorgiladze, L. N. Kornilova, A. A. Perachio), distinctions of simulating gravitational vestibular effects (M. D. Ross, A. A. Perachio, G. I. Gorgiladze).

An analogous tendency toward intensifying the role of neurophysiological research and broad development of neurophysiological approaches was clearly demonstrable as well in the section of investigations of the skeletomuscular system, represented at the symposium by 6 reports on the muscular system and 4 on bones. Unlike prior symposiums, most of the program of which consisted of morphological, histochemical and biophysical research on muscles and bones, in 50% of the papers delivered at the 5th Symposium, more attention was given to central regulatory mechanisms. These matters were the subject of V. S.

GURFINKEL' et al. in a paper entitled "Investigation of Mechanisms of Holding Pose in Weightlessness," Institute of Problems of Information Transmission, USSR Academy of Sciences, B. A. LAPIN et al., "Effect of Long-Term Hypokinesia on Characteristics of Primate Motor Reactions," Institute of Experimental Pathology and Therapy, USSR Academy of Sciences, D. OLMON and D. DUBUA, "Glycocorticoids and Control of Muscle Mass During Disuse," New York State University, United States, M. TISHLER et al., "Prevention of Metabolic Changes in Muscles ... During Hypokinesia," Arizona State University, United States; the last two papers merit special discussion.

In their study of passive extension of an unloaded muscle on the level of the metabolic processes in it, M. Tishler et al. demonstrated that the rate of atrophic processes is a rigid function of intensity of extension: extended muscles of the leg--soleus and gastrocnemius (confined in a cast in position of dorsal flexion)--failed to demonstrate signs of atrophy when the load was removed. Biochemical data confirmed that passive extension prevents development of changes in protein synthesis and breakdown that are inherent in a hypodynamic muscle. The material submitted by the authors is indicative of the fact that passive extension of muscles during hypokinesia could prevent atrophy, maintaining virtually a normal level of protein metabolism.

The results of research performed by staff members of New York State University, P. Olmon and D. Dubua are of definite interest; according to them, muscular atrophy in absence of a load and with degeneration demonstrates a distinct link with sensitivity of muscle tissue to glucocorticoids. Perhaps the change in sensitivity to this hormonal complex, which determines the level of catabolic processes in muscles, is an important element in expression of influence of loading-unloading on muscle metabolism. However, researchers have only made the first steps on this route.

There were 11 papers at the symposium concerned with biological aspects of gravity. General tasks and prospects of development of gravitational physiology, methodology of experiments in this field and, in particular, experiments involving use of centrifuges were discussed in the report of A. H. SMITH (University of California, United States).

The paper of G. C. PITTS (Virginia State University, United States) submitted data on distribution of fluid in rats exposed to accelerations of 2.76-4.15 G for 35 to 120 days. They observed an increase in fluid content of the skin and gastrointestinal tract under these conditions, with concurrent decline in muscles.

N. PACE, D. RAHLMAN and N. PACE, A. H. SMITH (University of California) reported the results of their studies of metabolic rate in the thermoneutral zone and ratio of body weight to metabolism in mammals differing in weight (hamsters, rats, guinea pigs, rabbits).

Serious discussion on the role of changes in hemopoiesis (and, in particular, erythropoiesis) in the general complexes of reactions to spaceflights accompanied the interesting reports of a team of Czech and Soviet specialists (A. VACEC et al., Institute of Biophysics, CSSR, Institute of Biomedical Problems and Institute of Developmental Biology, USSR) of results of studies of hemopoietic stem cells of mammals, which were conducted in experiments aboard biosatellites, and those of American researchers, S. D. P. DUNN et al., (NASA, United States) who investigated the hematological reactions of rats to "suspension," which simulated AOH effects in these animals.

Several papers were concerned with developmental biology. In particular, the paper delivered by L. V. SEROVA et al. (Institute of Biomedical Problems, USSR) submitted results of an embryological experiment with centrifuging of pregnant rats. V. SABO et al. (Institute of Animal Physiology, CSSR) investigated the effect of 2-20 G accelerations, with exposure for 10 to 120 min, on hatching of Japanese quail eggs.

A significant place was devoted in the program of the symposium to discussion of cellular and molecular mechanisms of perception and expression of a gravitational stimulus in biological systems. These questions were also touched upon in the keynote paper of J. SOFFEN (NASA, United States), who is chief of biomedical research for NASA.

The reports delivered at the symposium are indicative of achievement of some progress in comprehension of subcellular bases of gravireception. The studies of A. SIEVERS (Bonn Botanical Institute, FRG) made a substantial contribution to development of molecular mechanisms of gravireceptors in plants. Some interesting data pertaining to evolutionary and physiological aspects of adaptation of cellular systems to gravity were contained in the paper of G. P. PARFENOV (Institute of Biomedical Problems, USSR). The question of role of gravity in plant ontogenesis was discussed comprehensively in the reports of A. BROWN (Pennsylvania State University, United States) and A. I. MERKIS Lithuanian Institute of Botany, USSR). Methodological bases for investigating the effects of gravity on the cellular level were discussed in the papers of T. H. IVERSEN and S. MYHRE (Tronheim University, Norway) and YE. A. KORDYUM and K. M. SYTNIK (Institute of Botany imeni N. G. Kholodnyy, USSR).

During the symposium, the Commission on Gravitational Physiology held to meetings, at which there was discussion of procedural questions and tentative programs of future symposiums. The commission members were unanimous in praising the scientific and organizational level of the symposium and expressed their appreciation to the USSR Ministry of Health, USSR Academy of Sciences and Institute of Biomedical Problems for their support and efforts in organizing it.

UDC: 612:92 KISLYAKOV

OBITUARY OF VITALIY ANDREYEVICH KISLYAKOV

Moscow KOSMICHESKAYA BIOLOGIYA I AVIAKOSMICHESKAYA MEDITSINA in Russian Vol 18, No 5, Sep-Oct 84 (signed to press 13 Aug 84) p 95

[Article by editorial board]

[Text] The well-known specialist in vestibular physiology and doctor of biological sciences, Vitaliy Andreyevich Kislyakov passed away on 23 February 1984 following a serious illness.

V. A. Kislyakov started his civic life as a soldier. In January 1943, at the age of 18 years, he joined the ranks of the Soviet Army. He fought in Leningrad and Kalinin oblasts, and in Belorussia. In 1944, Vitaliy Andreyevich participated for almost 5 months in tank-borne landing operations in the Baltic region. In September 1945, V. A. Kislyakov was demobilized with the rank of senior sergeant because of an injury. He was then only 20 years old.

The Order of the Patriotic War, second grade, and medal For Victory Over Germany in the Great Patriotic War were bestowed upon V. A. Kislyakov for his valor in combat.

In 1950, Vitaliy Andreyevich graduated from the biological faculty of Petrozavodsk University, and from that time on, to the last days of his life, his fate was linked with the Institute of Physiology imeni I. P. Pavlov, USSR Academy of Sciences, and Koltushi. That is where he traveled the long road from graduate student to laboratory chief. That is where he acquired the title of doctor of sciences, and that is where he joined the ranks of the CPSU.

Vitaliy Andreyevich devoted all of his scientific endeavors to vestibular physiology. In 1962, through his efforts the Laboratory of Physiology of the Vestibular System was organized, which is the only one in the system of the USSR Academy of Sciences and virtually the only one in the nation, and he was its constant chief to the end of his days. This laboratory made a large contribution to development of physiology of sensory systems.

A series of studies dealing with interaction of vestibular and optokinetic nystagmus, hydrodynamic processes in the labyrinth and behavior of caloric nystagmus in a field of centrifugal force was conducted under his guidance and with his participation. Expressly this work brought fame to V. A. Kislyakov and the laboratory as a whole.

The area of his endeavor, which he justifiably called educational, also made a large contribution to physiology. Four foreign monographs, including the classical work of Rudolph Magnus, "Body Schema," were translated into Russian under his editorship.

Vitaliy Andreyevich has more than 80 published works to his credit in the area of physiology of vestibular function, including three collective monographs; he has written sections of a multivolume manual of physiology and a number of surveys. He has trained a number of qualified specialists in his field.

For his achievements in developing Soviet vestibular physiology, Vitaliy Andreyevich was nominated by the USSR Academy of Sciences to the International Astronautics Academy.

This man combined a youthful spirit and mature thinking. He could always discern what was important in everything. His sincerity, benevolence and innate common sense enabled him to make easy contact with people. He had the gift, not only of an orator, but listener. For this reason, people turned to him for help (scientific or any other) and were never refused.

Vitaliy Andreyevich Kislyakov served his country honestly. He was a brave soldier, excellent scientist and citizen. This is how he will be remembered by all who knew him. He was full of creative plans. The laboratory, which he left behind, will continue his work and solve the problems put to it.

ABSTRACTS OF ARTICLES FILED WITH THE ALL-UNION SCIENTIFIC RESEARCH INSTITUTE OF MEDICAL AND MEDICOTECHNICAL INFORMATION

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FORMATION OF PREFERRED STRUCTURAL VARIANTS OF LIFE-SUPPORT SYSTEMS

[Abstract of article by I. V. Gusev, V. N. Danilov, A. M. Karpov, A. N. Mezentseva and V. I. Travkin]

[Text] This deals with the design of systems, formation of alternatives, preferred variant, criteria, lexicographic order, morphology, air-regeneration system, photoreactor and greenhouses.

One of the most important stages in design of life-support systems is formation of possible variants (modifications), which permits the system developer to analyze the numerous possible alternatives and reduce to a minimum the possibility of "losing" the potentially best variant. As a rule, when a system is designed, one has information not only about the basic list of system elements and its morphological structure, but also criteria of quality and efficiency of performance of the different elements and system as a whole. It is desirable to use this information already at the first stage of planning, when forming the possible alternative variants of the future system.

This article discusses a method of forming system variants that is based on the morphological principle of including elements in a variant and the principle of lexicographic classification of alternatives. The morphological principle implies inclusion in the system of variant of one element from each morphological class (subsystem). The lexicographic principle gives the relations of strict lexicographic order for a set of alternatives considered and criteria for evaluating them.

The lexicographic principle of classifying alternatives and criteria was used here due to the qualitative nature of base data utilized to form preferred variants for an air-regeneration system (ARS) based on vital functions of lower and higher plants.

The method in question makes it possible to form a given number (depending on restrictions imposed by the developer) of lexicographically preferred ARS variants, classified on the basis of vector estimates of system variants according to a set of criteria.

The procedure for forming preferable ARS variants consists of defining the basic functions of the system developed, set of requirements imposed on it, ranking of determined criteria according to significance, evaluation of alternative variants within the limits of each subsystem considered on the basis of the set of criteria. All this information is needed when running a computer program of a specially developed algorithm to solve the given problem.

As a result of using such a procedure, 10 lexicographically ordered ARS variants were formed. A structure including the following modes of subsystem realization was found to be best: tubular reactor with external light source ("Wall") for lower plants, a greenhouse of higher plants with axial arrangement of MGL lamps and capillary system of root feeding, recovery of oxygen by using chlorates of alkaline metals and removal of carbon dioxide with gas-separating membranes.

2 References.

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MULTICRITERION CHOICE OF EQUIPMENT FOR LIFE-SUPPORT SYSTEMS

[Abstract of article by B. M. Belov, I. V. Gusev, V. N. Danilov and A. N. Mezentseva]

[Text] This article deals with multicriterion choice, variants, criteria, lexicographic classification, binary ratios, equipment, procedure, air-regeneration systems, microalgae reactor and preferred variants.

The efficiency and quality of equipment operation, including that used for life-support systems, are evaluated according to a number of parameters, which include technical, reliability, economic and other indicators. For this reason, tasks dealing with choice of the preferred variants (or variant) are performed the most efficiently by multicriterion methods, among the many permissible ones.

For example, in choice of type of microalgal reactor discussed in this article, evaluation of reactors according to each of the criteria is a qualitative one, while the criteria are separated into lexicographically classified groups. This made it possible to apply the lexicography principle in selecting the preferred type of microalgal reactor. The procedure for making choices by this method consists of several iterations. At the first iteration, set P_1 of criteria, which are preferable according to the first, most important group of criteria, is selected out of the original set S of variants. At the second iteration, set P_2 of criteria that are preferable in the second group is singled out of the obtained set, etc., until the last, 1st group. As a result, set P_l is obtained, which we shall consider the set of the most preferred variants according to generalized lexicography.

Nine criteria, which were divided into three classified groups, were used to select the preferred type of reactors, while the criteria within the groups were considered equivalent. One of the five types of reactors was selected as the most preferable with use of this procedure.

3 References.

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