EFFECT OF ARTIFICIAL GRAVITY IN SPACE FLIGHT ON THE CONTENT OF WATER-SOLUBLE PROTEINS IN NERVE TISSUE STRUCTURES

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The content of water-soluble proteins was investigated in the gray and white matter of the spinal cord, the spinal ganglia, and the sensomotor cortex of rats after a space flight lasting 18.5 days. The content of water-soluble proteins in the gray and white matter of the spinal cord and in the spinal ganglia of rats exposed to the action of weightlessness was significantly reduced after 4.5-9.5 h. In rats kept under conditions of artificial gravity during flight the content of water-soluble proteins was reduced in the white matter of the spinal cord. In animals kept previously under conditions of weightlessness 25 days after space flight a significant increase was found in the level of water-soluble proteins in the gray matter of the spinal cord. In the gray matter of the sensomotor cortex of rats kept under conditions of weightlessness or of artificial gravity no changes were found (compared with controls kept in the ordinary animal house) in the content of water-soluble proteins whether 4.5-9.5 or 25 days after the satellite has landed.

KEY WORDS: water-soluble proteins; rat cerebral cortex; spinal cord; spinal ganglia; space flight; weightlessness.

A decrease in the content of water-soluble proteins in the gray and white matter of the spinal cord of rats after a space flight lasting 19.5 days on the Kosmos-782 biosatellite was established previously. However, it remained to be discovered whether these changes were the result of the direct action of weightlessness on the body.

It was decided to analyze the material (functionally and histologically different structures of the spinal cord at the level of the lumbar enlargement, namely the gray matter of the anterior, posterior, and lateral horns, where predominantly nerve cells are grouped, and the white matter consisting of ascending and descending tracts, spinal ganglia, and also the sensomotor cortex of rats) taken after landing of the Kosmos-936 biosatellite, on board which the animals were exposed not only to the factors of space flight, but also to artificial gravitation created by rotation of a centrifuge. Throughout the period of space flight a constant acceleration of 1.0g was produced on the centrifuge (radius 34 cm). The aim of this experiment was to differentiate changes ascribable to the effect of weightlessness from those due to exposure to the other factors of flight.

EXPERIMENTAL METHOD

In rats exposed to weightlessness during flight and those exposed to artificial gravity, 4.5-9.5 h and 25 days after an orbital space flight lasting 18.5 days the following structures were taken for investigation: spinal cord at the level of the lumbar enlargement, the adjacent spinal ganglia, and samples of tissue from the gray matter of the sensomotor cortex. The spinal cord was separated into white and gray matter at 0-4°C under control of the MBS-2 microscope. Weighed samples of tissue were put into special polyethylene centrifuge tubes for homogenization. Each sample of nerve tissue was homogenized in 10 volumes of distilled water at 0-4°C. Water-soluble proteins were extracted for 2 h at 4°C. The extracts were centrifuged at 15,000g (60 min, 0-4°C). The protein concentration in the supernatant was determined by Lowry's method [3]. The results were subjected to statistical analysis by means of Van der Waerden's nonparametric criterion [2]. Rats kept under ordinary animal house con-

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TABLE 1. Content (in μg/mg wet weight of tissue) of Water-Soluble Proteins in Structures of Nerve Tissue

Test object	Animals kept in animal house (control)	Weightlessness										Artificial gravity										
		ground experiment (control)	X_1	5-9 h after flight	X_1	X_2	25 days after ground experiment (control)	X_1	25 days after flight	X_1	X_2	ground experiment (control)	X_1	5-9 h after flight	X_1	X_2	25 days after flight	X_1	spinning on "radiusless" centrif. (contr.)	X_1	25 days after spinning on "radiusless" centrif.	X_1
Gray matter of spinal cord	37	36	0,62	30*	3,32	2,56	35	0,16	42*	2,11	2,56	33	2,10	33	2,10	0,36	34	1,87	35	1,09	34	0
White matter of spinal cord	27	26	0,90	18*	3,32	3,32	26	0,57	29	2,38	1,46	23	0,8	19*	3,32	1,99	22*	3,32	24	1,41	21*	2,56
Spinal ganglia	40	44	2,11	29*	2,56	2,86	43	0,33	43	1,99	0,91	36	2,38	36	0,61	0,36	35	1,41	33	2,14	36	0,91
Gray matter of cerebral cortex	45	37*	3,32*	43	1,06	2,86	42	1,07	42	0,34	1,82	36	2,56	46	1,50	2,28	40	0,78	39	2,14	44	1,7
Number of animals	10	4	—	5	—	—	4	—	4	—	—	5	—	5	—	—	5	—	5	—	4	—
	—	—	2,38	—	2,72	2,38	—	2,38	—	2,38	2,38	—	2,72	—	2,72	2,72	—	2,72	—	2,72	—	2,38

Legend. 1) $X_{1,2}$ and X_0 expressed in conventional units (X_1 — relative to animal house control, X_2 — relative to ground experiment, X_0 — values from tables); calculated as tabular values with level of significance of 5% respectively (differences significant when $X_{1,2} > X_0$). 2) * denotes values differing significantly from control ($X_{1,3} > X_0$).

ditions and rats taking part in a model experiment on the ground, in which all factors of space flight except weightlessness were simulated, served as the control. The ground control experiments also included another two groups of animals. The rats of one group were spun for the duration of the experiment on a centrifuge (radius 24 cm) with an acceleration of 1.4g, and the animals of the other group were spun on a centrifuge with the smallest possible radius ("radiusless centrifuge"), in order to assess the role of the rotation factor (acceleration 1.1g).

EXPERIMENTAL RESULTS

The experimental results are given in Table 1. They show that 4.5-9.5 h after a space flight lasting 18.5 days, just as 9-11 h after a space flight lasting 19.5 days [1], the content of water-soluble proteins (expressed per milligram of weight of tissue) was significantly reduced in the white and gray matter from the spinal cord and in the spinal ganglia of rats exposed to the action of weightlessness. The level of water-soluble proteins in the gray matter of the spinal cord and in the spinal ganglia of rats kept during the experiment under conditions of artificial gravity did not differ from the control (control rats kept in the animal house and rats taking part in a model experiment on the ground), whereas their content in the white matter was significantly lower than in the rats kept in the animal house, but indistinguishable from the concentration of water-soluble proteins in the white matter of the spinal cord of rats taking part in the ground experiments.

In animals kept previously under conditions of weightlessness a significant decrease in the content of water-soluble proteins was found in the gray matter of the spinal cord 25 days after space flight compared to the control. The content of water-soluble proteins in the white matter of the spinal cord and in the spinal ganglia was increased up to the control value. In rats exposed during flight to an artificial force of gravity, the content of water-soluble proteins in the gray and white matter of the spinal cord and in the spinal ganglia 25 days after the flight did not differ from that in the control.

In the gray matter of the sensomotor cortex of the cerebral hemisphere of rats kept under conditions of weightlessness and artificial gravity no change was found (compared with the animal house control) in the content of water-soluble proteins either 4.5-9.5 h or 25 days after landing of the biosatellite (Table 1).

The results showed once again that a long space flight leads to a decrease in the content of water-soluble proteins in the gray and white matter of the spinal cord and spinal ganglia of rats. Since no such changes were observed in animals exposed to an artificial force of gravity it can be concluded that the decrease observed in the content of water-soluble proteins in the structures investigated was evidently the result of the action of weightlessness on the body. One of the factors determining these changes in the peripheral (afferent and efferent) structures of the motor system may perhaps be a decrease in the flow of information transmitted by intero- and proprioceptive impulses from the skeletal muscles and bones, in consequence of the reduced functional load and relaxation of the antigravity muscles. These changes can be regarded as responsible for adaptation of the animal to the new conditions of existence in a state of weightlessness, connected with removal of the static load from the locomotor apparatus. The fact that there was no change in the content of water-soluble proteins in the gray matter of the sensomotor cortex suggests that adaptation takes place mainly at the level of the spinal reflex arc. This hypothesis appears likely to be true, for we know that the antigravity muscles are connected with the reflex mechanisms of the spinal cord mainly through a myotatic bineuronal reflex arc [4].

Readaptation to ground conditions 25 days after the end of space flight in animals exposed to a state of weightlessness was manifested as an increase in the content of water-soluble proteins in the gray matter of the spinal cord. The level of water-soluble proteins in the white matter of the spinal cord and in the spinal ganglia reached the control. This hypercompensation was probably functionally necessary, for it was a response to an increase in the functional load connected with the switch from weightlessness to the conditions of the earth's gravitational force. The presence of an artificial force of gravity on the biosatellite in all probability made readaptation of the animals to the conditions of existence on the ground unnecessary. It must be assumed that this may explain the absence of changes in animals kept during flight under conditions of artificial gravity in the content of water-soluble proteins in the gray matter of their spinal cord and spinal ganglia, whether during the first few hours or 25 days after the end of the flight. In these experiments the action of artificial gravity on the animals was perhaps not completely equivalent to the action of the earth's force of gravity, for a decrease in the content of water-soluble proteins was observed in the white matter of the spinal cord of animals exposed to an artificial force of gravity during the flight. It can tentatively be suggested that under the conditions of flight the character of transport of metabolites in the system of nerve fibers of the spinal cord was modified (retarded).

The results of these investigations thus show that the decrease in the content of water-soluble proteins in the gray and white matter of the spinal cord and spinal ganglia of rats kept during flight in a state of weightlessness, observed a few hours after the end of the flight, is evidently attributable to removal of the static load from the locomotor apparatus.

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BIOCHEMICAL CHARACTERISTICS OF SYNAPTOSOMES AND MITOCHONDRIA OF THE MOTOR CORTEX AFTER SENSORY DEPRIVATION

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Changes in cytochrome oxidase, monoamine oxidase, acetylcholinesterase, and Na,K-ATPase activity following early light deprivation were found in fractions of heavy and light synaptosomes and mitochondria isolated from the bodies of neurons of the rat motor cortex by gradient centrifugation. These changes differed in direction for different metabolic cycles and were specific in individual ultrastructures of the cell. The effect of sensory impulsation on functional activity of neurons in the various cortical projection areas is discussed.

KEY WORDS: enzyme activity of synaptosomes and mitochondria; motor cortex; light deprivation.

The writer showed previously that absence of visual afferentation in the early stages of ontogeny leads to depression of cytochrome oxidase (CO), Na,K-ATPase, and acetylcholinesterase (AChE) activity in the subcellular fractions of the visual cortex in rabbits [6]. These changes were regarded as the result of morphological and functional underdevelopment of specific neurons and their synaptic structures. Activation of monoamine oxidase (MAO) in the structures studied, which evidently reflected compensatory changes in particular metabolic cycles maintaining growth and development of the animal under changed external environmental conditions, was observed under these same conditions.

Considering the data in the literature showing an increase in the functions of other analyzer systems of the brain in visually deprived animals [7], the investigation described below was carried out in order to study the same enzymes in the synaptosomes and free mitochondria of the motor cortex under conditions of light deprivation.

EXPERIMENTAL METHOD

The brains of 20 control and 20 experimental rabbits were used. From birth the experimental animals were kept in a dark room for ten weeks, and then used in the experiment. The fractions of synaptosomes and mitochondria were isolated from the motor cortex by the method

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