EFFECT OF SPACE FLIGHT ON COMPOSITION OF SOLUBLE PROTEINS OF THE SPINAL CORD AND SPINAL GANGLIA OF RATS

A. V. Gorbunova and V. V. Portugalov*

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The content of individual protein fractions extracted from the spinal cord, at the level of the lumbar enlargement, and the spinal ganglia of rats consecutively with distilled water, 0.85% NaCl solution, and 0.1 N NaOH solution was investigated. A significant decrease in the content of water-soluble proteins was found in the white and gray matter of the spinal cord 12 h after space flight. The content of salt-soluble and alkali-soluble proteins in the structures of the spinal cord and spinal ganglia per milligram wet weight of tissue was not significantly altered. A significant increase in the content of water-soluble proteins compared with the control was found in the gray matter of the spinal cord 25 days after space flight. The content of water-soluble proteins in the white matter of the spinal cord was increased to the control level. A significant increase also was observed in the content of alkali-soluble proteins in the spinal ganglia.

KEY WORDS: space flight; spinal cord; spinal ganglia; water-soluble proteins.

A previous investigation [2] showed a decrease in the content of cytoplasmic proteins in the motoneurons of the anterior horns of the spinal cord and in neurons of the spinal ganglia innervating the muscles of the hind limbs in rats kept under conditions of weightlessness. In the investigation described below individual protein fractions were studied in functionally and histologically different regions of the lumbar enlargement of the spinal cord, as follows: in the gray matter of the anterior, lateral, and posterior horns where mainly neurons of the motor centers of the spinal reflexes of the hind limbs and sensory interneurons are grouped, in the white matter formed by ascending and descending tracts, and also in the spinal ganglia of rats completing a 19.5-day space flight on the satellite Kosmos-782.

EXPERIMENTAL METHOD

The spinal cord was removed at the level of the lumbar enlargement, together with the adjacent spinal ganglia, from the experimental animals 10-12 h and 25 days after space flight. The spinal cord was separated at 0-4°C into white and gray matter under visual control by the MBS-2 microscope. Weighed samples of the spinal cord were placed in special polyethylene centrifuge tubes for homogenization. Each sample of spinal cord was homogenized in 10 volumes of distilled water at 0-4°C. The content of individual protein fractions extracted from the spinal cord by distilled water (for 2 h), 0.85% NaCl solution (for 24 h), and 0.1 N NaOH solution (for 2 h) consecutively was investigated. Homogenates were centrifuged at 15,000g (60 min, 0-4°C). The protein content was determined by Lowry's method [6]. The numerical results were subjected to statistical analysis by the van der Waerden nonparametric criterion [1]. Rats kept under animal house conditions or taking part in a model experiment on the ground, in which all the factors of space flight were simulated but weightlessness, served as the control.

*Corresponding Member, Academy of Medical Sciences of the USSR.

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TABLE 1. Concentration of Water-Soluble Proteins in Spinal Cord at Level of Lumbar Enlargement and in Spinal Ganglia

Test object	Protein concentration, μg/mg wet weight of tissue								
	control (animal house) (8)	10 h after flight (6)	X	25 days after flight (5)	X	control (model experiment (6)	X	25 days after model experiment (5)	X
Gray matter	37	30*	3,59	43*	3,1	35,5	2,44	39	0,74
White matter	28	20*	3,59	27,5	0,2	26	2,15	30	2,25
Spinal ganglia	43	37	1,76	47	1,87	41	1,36	57	1,20
X_0	—	—	2,96	—	2,72	—	2,96	—	2,38

Legend. (Tables 1-3): 1. X and X_0) Conventional units calculated values and values obtained from tables for a level of significance of 5%, respectively (differences significant when $X > X_0$). 2. Number of animals in parentheses. 3. Values differing significantly ($P < 0.05$) from control marked by asterisk.

TABLE 2. Concentration of Salt-Soluble Proteins in Spinal Cord at Level of Lumbar Enlargement and in Spinal Ganglia

Test object	Protein concentration, μg/mg wet weight of tissue				
	control (animal house) (8)	10 h after flight (6)	25 days after flight (5)	control (model experiment)(6)	25 days after model experiment (5)
Gray matter	6	7	6	7	8
White matter	6	7	5	6	6
Spinal ganglia	8	9	7	9	10

TABLE 3. Content of Alkali-Soluble Proteins in Spinal Cord at Level of Lumbar Enlargement and in Spinal Ganglia

Test object	Protein concentration, μg/mg wet weight of tissue								
	control (animal house) (8)	10 h after flight (6)	X	25 days after flight (4)	X	control (model experiment) (6)	X	25 days after model experiment (4)	X
Gray matter	47	46	0,38	54	1,07	49	1,67	57	0,63
White matter	38	39	0,12	45	1,02	37	0,35	48	0,57
Spinal ganglia	21	30	1,17	37	2,53*	29	0,61	47	1,07
X_0			2,96		2,38		2,96		2,38

EXPERIMENTAL RESULTS

The investigation showed differences in proteins of the aqueous fraction in the gray and white matter of the spinal cord of the control rats: The content of water-soluble proteins in the gray matter was greater than in the white, whereas in the spinal ganglia the protein content expressed per milligram wet weight of tissue was greater than in the gray matter of the spinal cord (Table 1). The content of proteins extractable by NaCl solution was almost identical in the white and gray matter of the spinal cord and in the spinal ganglia (Table 2). The content of proteins of the alkali-soluble fraction was a little higher in the gray matter of the spinal cord than in the white matter, and the content of alkali-soluble proteins per milligram wet weight of tissue was lower in the spinal ganglia than in the white matter of the spinal cord (Table 3).

A significant decrease in the content of water-soluble proteins was found in the white and gray matter of the spinal cord of the experimental rats 12 h after space flight; in the spinal ganglia a decrease also was observed in this fraction of proteins but it was not significant (Table 1). The content of salt-soluble and alkali-soluble proteins in the structures of the spinal cord and spinal ganglia, expressed per milligram wet weight of

tissue, showed no significant change (Tables 2 and 3). A significant increase in the content of water-soluble proteins in the gray matter of the spinal cord was observed compared with the control 25 days after space flight. The content of water-soluble proteins rose in the white matter of the spinal cord up to the control level (Table 1). A tendency also was observed for the content of alkali-soluble proteins in the structures of the spinal cord to rise, and the level of this protein fraction in the spinal ganglia was significantly increased (Table 3).

Disturbances of motor functions arise in weightlessness during space flight. One possible factor responsible for these disturbances is a reduction in proprioception from the skeletal muscles, arising through hypokinesia and as a result of relaxation of the antigravity muscles. The level of proprioception modulates metabolism in the structures of the motor analyzer, adapting it to the new conditions of existence of the body. Nervous structures which, for some reason or other, are deprived of their normal inflow of afferent information from the proprioceptors, undergo partial or complete atrophy. Ten hours after a 19.5-day space flight a decrease in the concentration of water-soluble proteins was found in the structures of the spinal cord and in the spinal ganglia, possibly as a result of a deficiency of proprioceptive impulses. This decrease can evidently be regarded as a change leading to adaptation to new conditions – to a lowered level of motor function.

On the other hand, it must not be forgotten that, on the return to terrestrial gravity conditions, which becomes a stronger stimulus of the gravity receptor system of the muscles after adaptation to weightlessness, the flow of afferent impulses may increase and this may also lead to an increase in the level of functional activity of the structures of the motor analyzer. In this case the increase in function may bring about a mobilization of energy formation and mobilization of the activity of the genetic apparatus of the cell [3], but this does not mean that these two processes take place simultaneously [3]. Protein synthesis has been observed to be inhibited at a time of intensive hyperfunction [4]. The authors cited explained the result on the grounds that under certain conditions competition for energy may develop between function and biosynthetic processes, for during adaptive reactions energy for functions must be supplied much more rapidly than energy for plastic processes. Evidence of the utilization of the cell proteins of the brain under certain conditions as a source of energy has also been obtained [5]. These could be the possible causes of the observed decrease in the content of water-soluble proteins in neuronal structures.

Changes observed in protein metabolism in the spinal cord and spinal ganglia 10 h after flight may in all probability be associated not only with the level of their function, but also with humoral influences accompanying this function, i.e., the action of stressor agents, which evidently occurred while the satellite was landing.

The accumulation of water-soluble proteins in the gray matter of the spinal cord on the 26th day after the flight is attributable to the increase in protein synthesis and can be regarded as a compensatory reaction of the biosynthetic apparatus of the nerve cells to a decrease in the neuronal protein concentration.

The results of these experiments thus show the existence of metabolic shifts in the structures of the afferent and efferent components of the spinal reflex arc of animals after space flight.

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