THE EFFECT OF CENTRIPETAL ACCELERATION ON THE CONTENT OF ACETYLCHOLINE, ADRENALIN, ADRENALIN-LIKE SUBSTANCES, POTASSIUM AND SODIUM IN THE BLOOD OF ANIMALS

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In spite of the large number of papers dealing with the effect of acceleration on the body, the mechanisms of regulation of function during the action of acceleration remains far from clear. Accordingly, the aim of our investigation was to study certain aspects of the neuro-humoral mechanisms of regulation.

EXPERIMENTAL METHOD

The work was carried out on white rats (over 300) and five dogs. The animals were exposed to centripetal acceleration of magnitude 4-10 g for varying exposures and in varying directions.* For the rats we used a centrifuge of radius 1.25 m and for the dogs one with radius 3.6 m. Estimations were made of the acetylcholine, adrenalin-like substances, and potassium and sodium ion contents of the blood of the animals. Blood was taken from the rats by decapitation, and from the dogs – from the femoral vein.

The adrenalin-like substances in the blood were determined by the adsorption-calorimetric method [5] as modified by A. M. Utevskii [3]. As the main indicator of the changes in the proportions of adrenalin and adrenalin-like substances we took the coefficient of specificity.

Where the coefficient of specificity is equal to unity or less only adrenalin-like substances are present. Where the coefficient of specificity is equal to 2 or more only adrenalin is present.

Acetylcholine was determined by a biological method using the eserinized dorsal muscle of the leech. Determination of the potassium and sodium ions was carried out with a model 3 Zeiss flame photometer.

EXPERIMENTAL RESULTS

The results of the influence of centripetal acceleration acting in the caudal (head – pelvis) direction are shown in Table 1.

As it can be seen, with increase in the magnitude of the acceleration, starting from 4 g/30 sec, there is a significant rise in the content of adrenalin-like substances with complete disappearance of free adrenalin when the magnitude of the acceleration was 7-10 g/1 min. If, for instance, in the normal animal the content of adrenalin-like substances is 10.31 γ% and the coefficient of specificity 1.17, then after the action of acceleration of 10g/1 min the content of adrenalin-like substances was 12.5 γ% and the coefficient of specificity 0.85.

The acetylcholine content was slightly raised at an acceleration of 4g/15-30 sec; with an increase in the acceleration to 10 g the acetylcholine content fell. Thus, in the normal animal the acetylcholine content is 1.4 γ% and after the action of acceleration of 10 g/1 min it was 0.61 γ%.

* The accepted definition in aviation medicine of the direction of action of centripetal acceleration is in fact the direction of the opposing forces.

At the same time changes were observed in the content of potassium and sodium in the blood. After the action of acceleration of 10 g/ 1 min the sodium content fell slightly (from a normal value of 322.1 mg% to 310.6 mg%) while the potassium content rose (from a normal value of 25.6 mg% to 27.6 mg%). After the conclusion of the action of acceleration the acetylcholine and adrenalin-like substances in the blood were approximately at their initial level within 15-30 minutes.

TABLE 1

Results of the Action of Centripetal Acceleration in a Caudal Direction

Experimental conditions and direction of action of acceleration	Adrenalin-like substances		Acetylcholine (in γ%)
	in γ%	coefficient of specificity	
Control	10.31	1.17	1.40
Head – pelvis 4 g/ 15 sec*	8.30	1.20	1.60
" " 4 g/ 30 sec	9.80	1.00	1.51
" " 7 g/ 1 min	9.00	0.73	1.16
" " 10 g/ 1 min	12.50	0.85	0.61

*The fraction indicates that the acceleration acted for the time indicated in the denominator.

In a second series of experiments the effect of acceleration in a cranial (pelvis – head) direction was studied (Table 2).

TABLE 2

Results of the Action of Centripetal Acceleration in a Cranial Direction

Experimental conditions and direction of action of acceleration	Adrenalin-like substances		Acetylcholine (in γ%)
	in γ%	coefficient of specificity	
Control	10.31	1.17	1.40
Pelvis – head 4 g/15 sec	12.60	0.96	1.60
" " 4 g/30 sec	12.50	0.91	2.00
" " 7 g/1 min	12.90	0.84	1.30
" " 10 g/ 1 min	13.56	0.78	0.53

As can be seen in Table 2, the changes in the content of adrenalin-like substances and acetylcholine are somewhat more pronounced but are in the same direction as when the acceleration was applied in the caudal direction.

It must be pointed out that after the action of acceleration of a magnitude of 10 g/ 1 min in this direction the animals sometimes were in a comatose condition.

When acceleration was applied in a transverse direction (spine – sternum) in a magnitude of 10 g/ 1 min the acetylcholine content of the blood of the animals was practically unchanged and was at the upper limit of normal (1.52 γ%).

The changes in the content of acetylcholine and adrenalin-like substances and of electrolytes are due not only to the magnitude of the acceleration but also to the duration of its action. Thus, a study of the effect of acceleration acting in the caudal direction and of magnitude 4 g/ 5 min showed that in this case the acetylcholine content rose to 1.7 γ%, the sodium fell to 318.4 mg% and the potassium rose to 28.5 mg%.

In the final series of experiments which took into account the possibility of the cumulative effect of acceleration [2], we tried to ascertain the character of the changes in the content of the test drugs in the blood during repeated exposures to acceleration, deliberately making the experimental conditions severe.

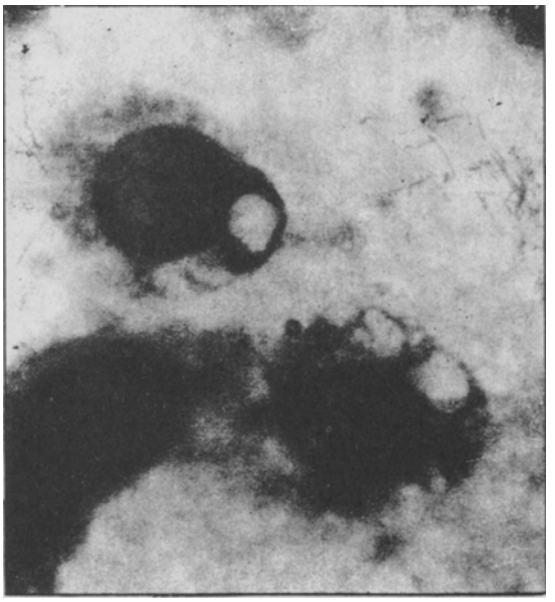

Fig. 1. Vacuolar degeneration of nerve cells in the brain of the rat after 120 acceleration procedures. Nissl's stain. Immersion.

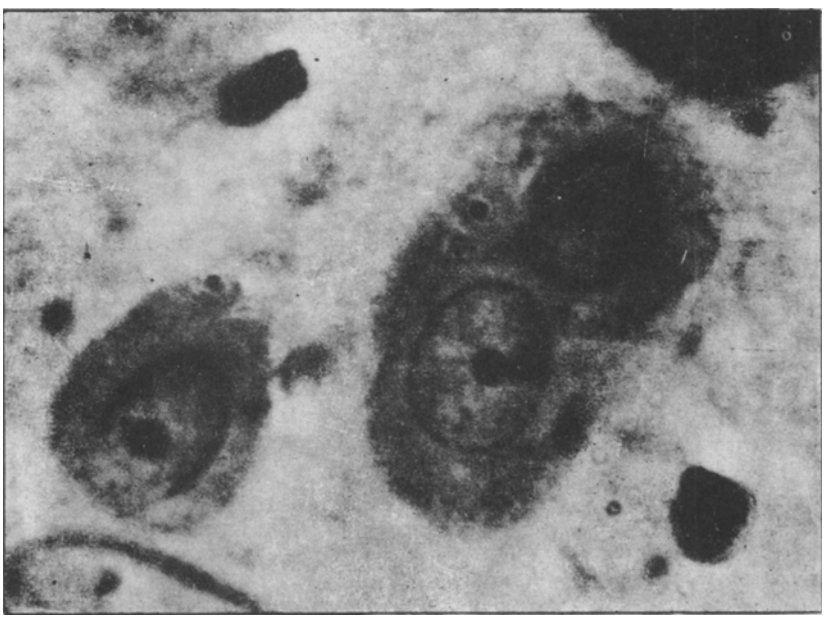

Fig. 2. Amitosis in a nerve cell in the brain of a rat after 120 acceleration procedures. Nissl's stain. Immersion.

The animals were subjected daily to four acceleration procedures in the head – pelvis direction and with a magnitude of 10 g/min. The intervals between the procedures was 30 minutes (Table 3).

TABLE 3

Results of the Repeated Action of Centripetal Acceleration in a Caudal Direction

Experimental conditions and direction of action of acceleration	Adrenalin-like substances		Acetyl-choline (in γ%)	Sodium (in mg%)	Potassium (in mg%)
	in γ%	coefficient of specificity			
Control	10.31	1.17	1.40	322.10	25.60
Head – pelvis 10 g/1 min.	12.50	0.85	0.61	310.60	27.60
The same, after 32 procedures . . .	5.60	1.10	1.70	325.4	25.7
The same, after 120 procedures . .	4.80	2.60	1.38	309.00	26.50

As can be seen from Table 3, increase in the number of procedures to 120 leads to a considerable fall in the content of adrenalin-like substances (to 4.8γ %) and to a sharp rise in the coefficient of specificity (to 2.6). A fall in the sodium content (to 309 mg%) and a slight rise in the potassium content (to 26.5 mg%) are also observed. The acetylcholine content remains within normal limits.

In the experiments where 120 procedures were applied, morphological changes were found in different tissues of the body. In particular, cells with vacuolar degeneration and a considerable number of amitoses were found in the brain. Thickening of the vascular walls was also found in various organs (Figs. 1, 2 and 3).

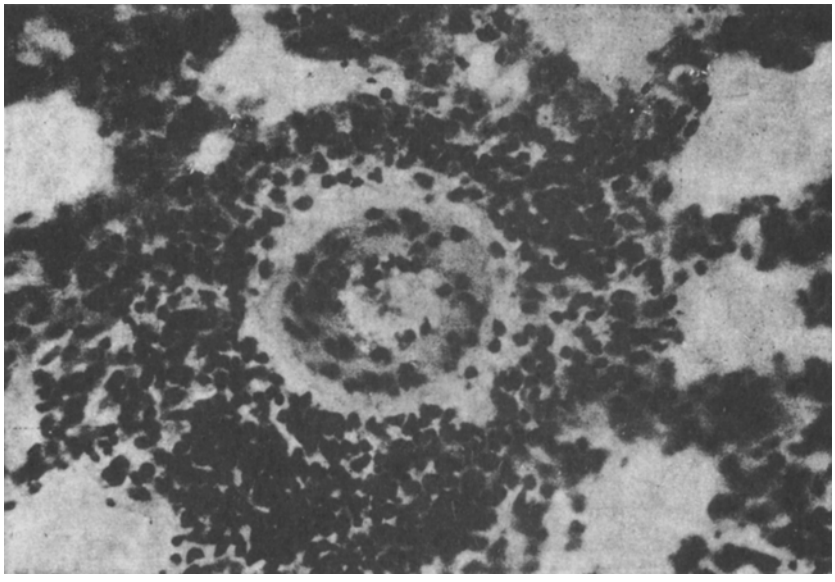

Fig. 3. Blood vessel with thickened walls in the lung of a rat after 120 acceleration procedures. Stained by hematoxylin-eosin. Magnification: ocular 10 ×, objective 40 ×.

The results of the experiments shown in this paper permit the role of the sympathetico-adrenal system in the mechanism of regulation of function during the action of acceleration on the body to be judged. Considerable importance here is attached evidently to noradrenalin which is one of the main pressor substances [4].

Changes in the acetylcholine content reflect not only changes in the excitability of the parasympathetic nervous system but also changes in the tone of the skeletal musculature. These findings are in agreement with observations made earlier by P. K. Isakov [1] and others who studied the bioelectric changes in skeletal muscle during the action of acceleration.

The occurrence of the most pronounced rise in the acetylcholine content with centripetal acceleration acting for a considerable length of time (5 minutes) and with a magnitude of 4 g suggests that under these conditions the compensatory tone of the muscle has reached its full development.

In our experimental conditions the changes in the contents of acetylcholine and adrenalin-like substances after single procedures are adaptive in character. After repeated procedures (32) a fall is observed in the content of adrenalin-like substances with a slight increase in the content of acetylcholine. After 120 procedures even more significant changes were found, demonstrating that the sympathetico-adrenal system is in a state of severe strain or even overstrain.

The morphological changes also indicate the presence of profound disturbances in the general condition of the animal arising after repeated acceleration procedures.

SUMMARY

The changes in blood content of adrenalin, acetylcholine, adrenalin-like substances, potassium and sodium were studied in animals after the action of centripetal acceleration. A definite dependance of changes in the content of these substances was noted on the value, direction and the time of action of accelerations. The morphological changes were also noted in various tissues of the body following numerous actions, of centripetal accelerations.

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