MORPHOLOGICAL CHANGES PRODUCED IN ANIMAL ORGANS BY PROLONGED HYPODYNAMIA AND SUBSEQUENT PHYSICAL EXERTION

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Restriction of mobility of rats for 15 days leads to atrophy of skeletal muscles, an increase in weight of the adrenals, a decrease in the glycogen reserves of the body and an increase in succinate dehydrogenase activity and a decrease in alkaline phosphatase activity in the liver. The resistance of animals to physical exertion (swimming, radial acceleration) is lowered in animals after hypodynamia, and more marked morphological changes are found in the myocardium, lungs and liver than in animals under normal conditions.

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Prolonged limitation of movement gives rise to a variety of disturbances of function in man. The danger arises that during a prolonged stay under hypodynamic conditions the body may become adapted to minimal expenditure of energy, and in that state would be unable to compensate for disturbances of function arising on the change from hypodynamia to physical exertion [1, 4, 7, 9]. This problem is particularly important during space flights when man may spend a long time under conditons of weightlessness and hypodynamia [2, 3, 5, 8].

In this investigation the early structural changes developing in the organs and tissues of rats during hypodynamia were studied.

EXPERIMENTAL METHOD

Morphological investigations were carried out on 30 albino rats kept for 15 days in plaster casts (6 of the animals were subsequently exposed to physical exertion). The effect of a prolonged stay (more than 100 days) in small cages on ability of the animals to tolerate radial acceleration was studied on 12 rats and 2 dogs. After the end of the experiment the animals were sacrificed and the relative weights of the organs and muscles determined. Pieces of the organs were cut into sections in a cryostat and fixed in various solutions. Sections were stained with hematoxylin-eosin.

The content of lipids (with Sudan black), cholesterol (using the polarization microscope), ribonucleoproteins (by Kurnicke's method), glycogen (by Shabadash's method), and the succinate dehydrogenase activity (by Nachlas's nitro-BT method) and alkaline phosphatase activity (by Gomori's method) were determined in the heart, skeletal muscles, liver, and adrenals. Fuchsinophilic degeneration of the muscle fibers of the myocardium was detected by Selye's method. The thickness of the skeletal muscle fibers was measured and historadiography carried out after injection of C^{14}-labeled amino acids, and the dry residue of the skeletal muscles was determined after drying in vacuo to constant weight.

EXPERIMENTAL RESULTS

After hypodynamia for 15 days the weight of the animals fell on the average by 20 g compared with its initial value. Fatty tissue disappeared almost completely. The glycogen content in the sarcoplasm of the muscle cells was considerably reduced. In the liver the succinate dehydrogenase activity was increased and the alkaline phosphatase activity decreased (Fig. 1). On autoradiographs of liver sections of the experimental animals there were fewer silver granules than in sections from control animals kept under normal conditions.

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Fig. 1. Succinate dehydrogenase (I) and alkaline phosphatase (II) activity in liver cells of rats after hypodynamia for 15 days (a) and of control rats (b). I) nitro-BT by Nachals's method, 90×; II) Gomori's method, 90×.

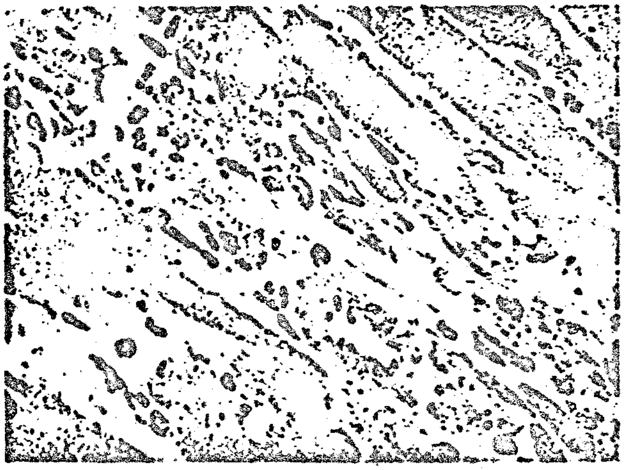

Fig. 2. Myocardium of a rat sacrificed 3 days after overloading, having spent the previous 100 days under hypodynamic conditions (hematoxylin-eosin, 425 ×).

The weight of the adrenals was increased (36.1±1.27 mg; control 29.6±1.04 mg; $P<0.001$). The content of lipids and cholesterol in the cytoplasm of cells of the zona fasciculata was reduced. The content of ribonucleoproteins and succinate dehydrogenase activity were slightly increased.

The spinal muscles and muscles of the lower limbs were redder in color than in the controls. The weight of the groups of lower limb muscles relative to the initial weight of the animal was reduced (experiment 1.16±0.025 g, control 1.68±0.061 mg; $P<0.001$). The muscle fibers showed well marked cross striations. However, they were reduced in thickness (25.7 ± 1.44 in the experimental and 28.8 ± 1.23 in the control rats; $P<0.001$). The dry residue of the skeletal muscles was essentially unchanged (experiment 26.3%, control 24%). The glycogen and uptake of labeled amino acids into the muscle fibers were less than in the controls.

In the 6 albino rats exposed to a swimming test for 30 min after hypodynamia for 15 days, besides the changes described above, fuchsinophilia of individual fragments of heart muscle fibers was found. After the animals had been kept for 100 days in confined cages their mean weight was approximately 53-61% of the weight of control animals kept under normal conditions.

All the experimental and control animals ([illegible] dogs and 13 rats) at the end of the experiment were exposed to radial accelerations. The magnitude of the acceleration did not exceed that increasing the duration of the cardiac cycle by 50-60% compared with its initial value. Whereas in the control rats this increase in duration of the cardiac cycle took place with acceleration of 23–40 units, in the case of animals kept in confined cages the corresponding figure was 20–35 units.

These overloads caused slight morphological changes in the control rats, consisting mainly of redistribution of blood in the lungs, a slight decrease in the glycogen content of the liver, and lowering of the cholesterol and lipid levels in the zona fasciculata of the adrenal cortex. No hemorrhages were found in the lungs or degenerative changes in the liver, myocardium, or brain.

The overloads caused considerable structural changes in rats kept in confined cages. Of the 9 rats sacrificed before the 3rd day after exposure to radial acceleration, petechial subpleural hemorrhages in the lungs were found in 6, and foci of pneumonia combined with hemorrhages and usually developing 24 h or later after the experiment were found in 5 animals. Vacuolation or perinuclear edema of individual groups of muscle fibers and fuchsinophilic degeneration of their fragments were present in the heart of all experimental animals sacrificed during the first three days after overloading. Three animals showed signs of cloudy swelling, sometimes with a slight cellular reaction (Fig. 2). Cells of the zona fasciculata of the adrenals in the experimental animals contained more ribonucleoproteins and less cholesterol and lipids than in the control animals sacrificed at the same time after exposure to overloading.

Particularly marked differences were found in the glycogen content in the liver of animals sacrificed 30 min after overloading. In rats with restricted mobility a few glycogen granules were present only in individual liver cells, while in the control rats glycogen had disappeared only from the cells of the peripheral parts of the lobule. After 24 h and later the glycogen content was restored in both the experimental and the control animals. The structural changes in the brain and kidneys were identical. Precisely the same results were obtained with dogs.

The changes described are in agreement with our earlier discovery of the depression of synthesis in animals subjected to hypodynamia [6].

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