SOME MORPHOLOGICAL MANIFESTATIONS OF EXPERIMENTAL HYPODYNAMIA

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Experimental hypodynamia for a period of 4-75 days led to vascular disturbances in rabbits accompanied by changes in the content of chromatophilic substance in the cells of the central nervous system, varying in character in different parts of the brain and spinal cord.

Considerable attention is being paid at the present time to the problem of hypodynamia, especially by physiologists and clinicians. In the investigation described below the morphological manifestations of hypodynamia were studied.

EXPERIMENTAL METHOD

The investigation was carried out on 29 rabbits. The animals' movements were restricted by keeping them in metal cages of about the same size and shape as their body. Movements of the limbs and trunk were therefore virtually excluded, but the head remained outside the cage. Suitable holes were drilled in the lower part of the cage for removal of excreta. The rabbits were fed on a special stand; the quantity of food given was the same as for the remaining rabbits in the experimental unit. The periods of hypodynamia were 4-8, 30, 45, 60, and 75 days. Regular observations were made on the animals. Periodically they were allowed to mix in order to study their behavior outside the cage and for chronaximetry and electromyography. Pieces

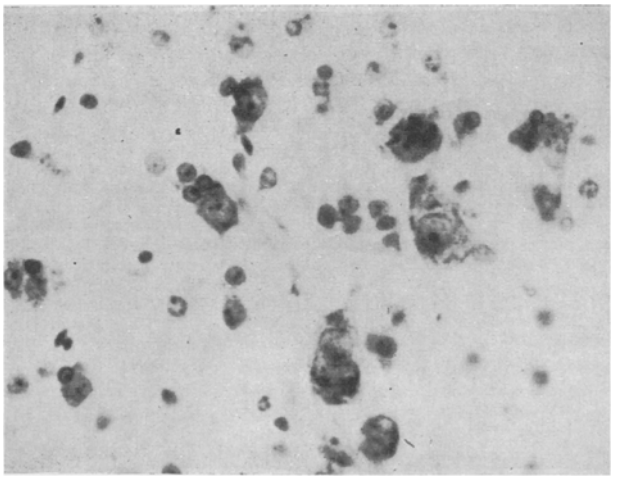

Fig. 1. Chromatolysis and redistribution of Nissl substance in neurons of layers IV-V of the parietal cortex (period of hypodynamia 1.5 months). Here and in Fig. 2, staining by Nissl's method, 300×.

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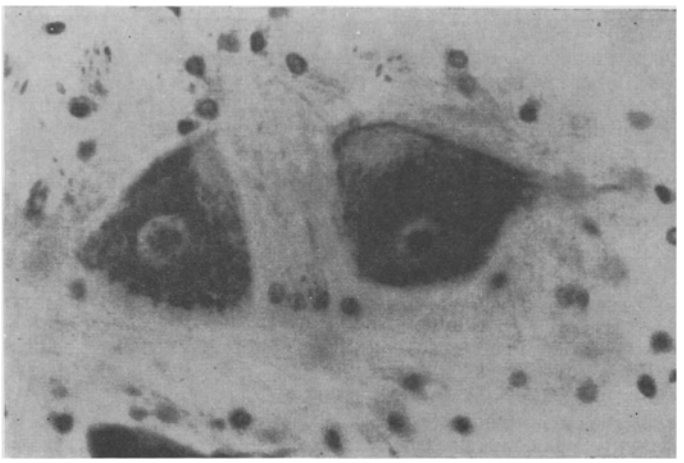

Fig. 2. Increase in size of granules of chromatophilic substance and in size of nucleoli, with appearance of paranucleolar bodies in anterior horn motoneurons in the lumbar division of the spinal cord (duration of hypodynamia 1 month).

of brain (parieto-temporal lobes), the brain stem at the level of the corpora quadrigemina, the cerebellum, segments of the spinal cord (the cervical and lumbar enlargements, the mid-thoracic region), the sciatic nerve, and femoral muscles were removed for histological investigation. The material was stained by the methods of Nissl, Van Gieson, Weigert–Pal, and Cajal in Favorskii's modification, and also with hematoxylin and eosin.

EXPERIMENTAL RESULTS

Microscopic examination revealed two principal groups of changes in the central nervous system of the experimental animals: 1) vascular disturbances, and 2) changes in the content of chromatophilic substance in the cells of the brain and spinal cord.

Restriction of movement for a short time (4-8 days) produced no appreciable changes in the blood vessels. With an increase in the duration of hypodynamia, a decrease in the lumen and thickening of the walls were observed in the arteries of the cortex, brain stem, and cerebellum; features of perivascular edema and cloudy swelling were visible.

After hypodynamia for 1-1.5 months, as a rule the cortical cells showed a decrease in the quantity of Nissl substance, or even its total disappearance. Frequently the chromatolysis was partial: virtually complete absence of chromatophilic granules at one pole of the cell was associated with its relative integrity at the other pole (Fig. 1). No significant changes affected the configuration and size of the nuclei, although the nuclear membrane under these circumstances was often thickened.

A picture of pseudoneuronophagy was frequently observed, with the concentration of glial elements at the pole where the chromatophilic substance remained intact or even increased in amount. With an increase in the duration of hypodynamia, the features of chromatolysis usually progressed, but their progress was no longer regular.

Similar changes were found in the cells of the subcortical structures and reticular formation of the brain stem and in the Purkinje cells. Redistribution of the Nissl substance with an increase in size of the granules at one pole and chromatolysis at the other was found in the hippocampal cells. An increase in size of the granules of chromatophilic substance was a regular feature in the red nuclei.

Features of hyperchromatosis were most clearly seen in the anterior horn cells of the spinal cord (Fig. 2). The degree of hyperchromatosis was directly connected with the duration of hypodynamia: with an increase in its duration the degree of hyperchromatosis also increased. Frequently the nucleoli were increased in size, and paranucleolar bodies appeared. In the cells of the intermediate zone and the posterior horns, as a rule changes of chromatolysis were observed. In the cells of the spinal ganglia the granules were increased in size but decreased in total number. The changes described above were most char-

acteristic of cells in the lumbar division, and less characteristic of the cervical enlargement. Most cells in the thoracic part of the spinal cord were normal in appearance, but less frequently they showed the initial signs of redistribution of the chromatophilic substance. In sections stained by the Cajal–Favorskii and Weigert–Pal methods, in a few cases deformation of the nerve fibers, tortuosity of their course, and irregularity of their diameter were observed. Structural disturbances of a similar character were also found in the sciatic nerve. Deformation of the nerve endings in the muscles, with foci of thickening and hyperimpregnation, was a regular feature.

Some workers [5, 8, 11] associate the appearance of changes in many systems of the body in animals whose movements are restricted artificially with an acute response to stress, and they specify its duration in periods not exceeding a few days. To investigate the relationship between the structural responses discovered by this investigation and the behavior of the animals during the first few days, the same parts of the nervous system were investigated in rabbits kept under experimental conditions for the first 4-8 days. However, initial changes of the same intensity as during prolonged immobilization were observed only in single cells: the absolute majority of neurons retained their usual structure.

Prolonged hypodynamia in animals is thus accompanied by definite morphological changes in various parts of the central and peripheral nervous system.

Besides the reversible, functional nature of these changes, their polymorphic character is noteworthy. Since too little attention has been paid to the study of the morphological manifestations of hypodynamia, it is difficult to explain the disturbances found. Meanwhile, the opposite condition – motor hyperfunction – has been fairly widely discussed in the literature [2, 4, 6, 7, 9, 10, 12-21]. There are also reports of observations made during experiments in which a decrease in the functional load has been created on other systems (usually exclusion of the visual system) [1, 20], or the brain in a state of inhibition has been studied [3]. The results of these investigations can be used, with some justification, as an aid to the interpretation of the present findings.

It is now generally considered that rest promotes the accumulation of Nissl substance, while active function leads to its disappearance. If states of rest and hypodynamia are identical, the above conclusion is valid in the present observations only for cells of the anterior horns of the spinal cord, the region most closely connected with direct motor effects. Changes in higher levels of the motor system and sensory pathways are opposite in character. The explanation of these facts must evidently be sought in the different roles of ordinary rest and hypodynamia where animals are concerned. To some extent this could be predicted, having regard to the well-developed "freedom reflex" in the animal world (there are many examples of this, such as death of animals when kept in confinement). In addition, the morphological picture of artificial hypodynamia reflects the end result of action of a cumulative stimulus. It must evidently be borne in mind that maintenance of a uniform posture for a long period of time must increase the activity of certain groups of toxic muscle fibers. At the same time, the activity of other systems was not essentially restricted, nor were movements of the neck excluded. These factors may perhaps be related to the predominance of changes in the cells of the lumbar enlargement. Brazovskaya [1] points out that many impulses of other modalities, capable of maintaining a certain level of unit activity even after exclusion of one sensory system, reach the cerebral cortex. In other cases, the level of this activity in certain regions of the brain evidently must have been higher than normal.

Consequently, histological changes in the central nervous system are not only the result of direct effects of hypokinesia, but may also be associated with the action of many other factors. This is of considerable importance both to the formation of general conclusions and also for the interpretation of facts observed in experiments on man.

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