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B. M. Fedorov, V. P. Krotov, Ye. N. Zhuravleva

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# CHANGES IN SOME BLOOD INDICES AND MYOCARDIAL ELECTROLYTE CONTENT DURING HYPOKINESIA

by

B. M. Fedorov, V. P. Krotov and Ye. N. Zhuravleva

The authors investigated experimentally the volume changes of circulating blood, its hematocrit and protein content, volume ratios between extra- and intracellular liquids in the body, as well as electrolyte content in the blood and myocardium during hypokinesia. Investigations were conducted on 112 rabbits (64 test and 48 control animals) placed as long as 62 days in special hypokinetic cages. Electrolyte (K, Na, Ca and Mg) concentration and water content in the serum, hematocrit index, and hemoglobin count were determined initially and every 7 days; the other indices were measured after the animals were killed. The measurement technique is described. Results obtained are displayed in three tables. Pronounced changes in the water-electrolyte metabolism occurred in the test animals: the amount of extracellular fluid was reduced, while the amount of intracellular fluid was increased; and sodium ion concentration decreased in the serum and increased in the myocardial cells. Blood plasma volume and its albumin content, which decreased duirng the first month of experiments, were restored during the second month. However, the hematocrit index, which decreased by the end of the first month, remained unchanged to the end of the experiments.

At present hypokinesia is one of the basic problems of the pathological physiology of extreme states. Prolonged reduction in motor activity is noted in the most diverse situations-- /27*

*Numbers in margin indicate pagination in original text.

during a stay in small-sized pressurized chambers, under conditions of a strict bed-confinement pattern in the clinic, etc.

It has been shown on healthy people that under the influence of a lengthy reduction in motor activity with strict immobilization in a plaster cast or in a strict bed-confinement pattern a number of pronounced changes emerge on the part of the osteomuscular system (intensified breakdown of proteins in the muscles and atrophic changes in them), cardiovascular system (detraining of blood circulation system, reduction in orthostatic stability), nervous system (dystonia of the autonomic nervous system and asthenia of the central nervous system), and pronounced shifts develop in the water-saline metabolism [1-6, 8, 10, 14, 19].

The question of changes in the volume of the circulating blood and erythrocyte mass during hypodynamia has been ambiguously covered in the literature, which is linked to a considerable measure with the duration and conditions of experiments [13, 22, 24]. In experiments on animals the effect of hypokinesia is closely linked to the degree of immobilization and species peculiarities of the organism. On rats it was established that under the influence of hypokinesia a stress reaction emerges, protein breakdown increases [18], oxygen consumption by the tissues rises [7], and a certain group of muscles atrophies [15]. Strict immobilization of rabbits produces serious damages to the cardiovascular system and death of the test animals in the space of several weeks [16]. In the experiments with less strict fixing of the rabbits in special hypokinetic cages a pronounced stress reaction does not develop in the animals, and under conditions of thorough care they undergo 2-month hypokinesia without serious damage of the internal organs. Here there is a clear change in the functional state of the higher autonomic centers of the brain, the hormonal and mediator metabolism of the organism is disrupted, and the content of water and Na in the skeletal muscles rises [9-12, 17].

It is generally acknowledged that during hypokinesia the blood circulation system is one of the most vulnerable. Here in the mechanisms of circulatory disorders of primary importance in addition to the changes in vascular tone are the changes in cardiac activity, volume of circulating blood and water-saline balance of the organism.

We studied the changes in the volume of circulating blood, its hematocrit and protein composition, correlation of volumes of extracellular and intracellular fluid of the organism, as well as the content of electrolytes in the blood and myocardium during hypokinesia.

Technique /28

Experiments were conducted on 112 male chinchilla rabbits (64 test and 48 control) weighing 3300-4000 g. All the animals received the same food.

To limit the motor activity the rabbits were placed in special hypokinetic cages whose walls were moved as the animals lost weight.

In the initial state and further every 7 days the concentration of electrolytes (K, Na, Ca and Mg) and water in the serum, the hematocrit index and the hemoglobin quantity were determined in the experimental and control rabbits.

Determination of the sizes of the fluid spaces in the organism was based on the principle of dilution of the indicator. Simultaneous intravenous administration of a certain quantity of indicator mixture T-1824, sucrose and antipyrine, made it possible to measure the volumes of plasma, extracellular fluid and the total water in the body during the experiment several times in the same animals.

The animals were killed with an electric current. In the cardiac muscle the water, K, Na and Cl contents were analyzed. The electrolyte concentration in the serum and tissues of the myocardium was determined by the method of flame photometry (K and Na--on a flame photometer of the Zeiss firm, Ca and Mg--on an atomic-absorption flame spectrophotometer). The Cl content in the serum and tissues was determined by the method of mercurimetric and amperometric titration. The protein quantity in the serum was determined by refractometric method, and its fraction--by the method of electrophoresis on paper. The intracellular concentration of electrolytes in the myocardium was analyzed by the computation method according to the Cl content [21].

## Results

In the experiments with hypokinesia the weight of the rabbits was reduced by the 15th day on the average by 11%, by the 30th day--by 21%, and by the 60th --by 27% of the initial amount.

Reduction in the weight of the test rabbits could be linked to dehydration of the organism or to changes in the plastic metabolism towards dominance of the catabolic processes.

The total quantity of body water was reduced by the 30th day of hypokinesia on the average by 545 ml, and by the 45th--by 495 ml. However, in conversion of the fluid quantity per unit of weight the amounts did not significantly differ from that established for the same animals before the start of the experiment and in the control animals. Thus, before the experiment the quantity of water was $677 \pm 21$ ml/kg, after 30 days of hypokinesia--$669 \pm 10$ ml/kg, after 45 days of hypokinesia--$653 \pm 3$ ml/kg.

In the same experiments with hypokinesia the quantity of extracellular fluid was reliably reduced from $179.9 \pm 4.6$ to $153.8 \pm 8.1$ ml/kg during 30-day hypokinesia, and from $177.3 \pm 1.9$ to

166.3±1.9 ml/kg in 45-day hypokinesia. The quantity of intracellular fluid in the organism determined by computation in these periods was increased.

The total volume of plasma after 30 days of hypokinesia was reduced by 23%, in computation per unit of weight--by 15%. In 45-day hypokinesia the total volume of plasma was reduced by 20%, but its volume per unit of weight did not differ from the initial value. After two months of hypokinesia the total volume of plasma remained reduced, but in conversion per unit of body weight was not reduced, and even was increased as compared with the initial amount (table 1).

Hypokinesia produced changes in the content of total protein and the correlation of its fractions in the serum. The protein concentration in serum was reduced from 7.01±0.14 to 6.34±0.17g% (D∠0.01) after three-week hypokinesia, and even more (to 6.08 ±0.18g%) (D∠0.001)--by the end of the first month; by the seventh week of the experiment it approached the initial level (6.84±0.13 g%), and by the 62nd day corresponded to it (7.08±0.17 g%).

The concentration of albumins in the serum by the end of the first week of hypokinesia was reduced from 3.65±0.18 to 2.93± 0.19 g% (D∠0.005), staying on this level to the end of the third week; by the end of the first month it was reduced even more (to 2.41±0.06 g%; D∠0.001), however during the second month of the experiment it was restored, reaching by the 45th day 3.51±0.28 g% and by the 62nd day--3.96±0.25 g%. The globulin concentration in the serum, on the contrary, increased during the first 30 days of hypokinesia and was reduced during the second month. Here the albumin-globulin coeffficient from 1.08 in the initial state /29 was reduced to 0.66 by the end of the first month of the experiment and increased to 1.26 by the end of the second month.

## TABLE 1

CHANGE IN VOLUME OF CIRCULATING BLOOD AND PLASMA IN DIFFERENT PERIODS OF HYPOKINESIA (M±m)

| Duration of experiment (in days) | Volume of plasma | | Volume of circulating blood | |
|---|---|---|---|---|
| Initial data | ml | ml/kg | ml | ml/kg |
| (30) | 164.6+6.5 | 43.1+1.8 | 268+14.1 | 70.9+3.8 |
| 30(8) | 110.1±3.7*** | 36.7±1.3** | 177.9+5.8*** | 59.3±2.1* |
| 45(8) | 132.4±2.1*** | 41.5±0.26 | 201.0±4.6*** | 63.0±1.4 |
| 62(14) | 141.4±4.4** | 50.5±1.7** | 201.3±8.5*** | 71.9±3.1 |

*D < 0.05
**D < 0.01
***D < 0.001

Note: Here and in the remaining tables D is computed as compared to the initial data. In parentheses--number of animals.

## TABLE 2

CHANGE IN HEMATOCRIT AND HEMOGLOBIN CONTENT OF BLOOD IN DIFFERENT PERIODS OF HYPOKINESIA (M±m)

| Duration of experiment(in days) | Hematocrit(in %) | | Hemoglobin(in %) | |
|---|---|---|---|---|
| | control | experiment | control | experiment |
| Initial data | 42+0.8 | 42+0.4 | 13.9+0.15 | 13.7+0.09 |
| 1 | 43±1.5 | 41±1.2 | 14.0±0.21 | 14.0±0.18 |
| 7-8 | 43±1.7 | 43±1.3 | 13.8±0.26 | 14.2±0.29 |
| 14-15 | 43±1.3 | 44±1.2 | 13.9±0.18 | 14.3±0.17* |
| 21-22 | 41±1.5 | 41±0.9 | 14.1±0.36 | 14.1 +0.27 |
| 28-29 | 41±1.4 | 38±1.2* | 14.2±0.23 | 13.3 ±0.21 |
| 35-36 | 41±1.7 | 34±1.1** | 13.9±0.20 | 12.6 ±0.24* |
| 42-43 | 42±1.5 | 35±1.3* | 13.8±0.28 | 11.4 ±0.30** |
| 47-48 | 42±2.0 | 33±1.5** | 13.8±0.30 | 10.9 ±0.27*** |
| 60-62 | 42±1.8 | 30±1.1*** | 13.9±0.25 | 9.7 ±0.33*** |

*D < 0.05
**D < 0.01
***D < 0.001

Under the influence of hypokinesia the hematocrit number was gradually reduced--by the end of the second month of the experiment by 29% (table 2). Similar changes were observed also in the ratio of hemoglobin, whose content on the 62nd day of hypokinesia was reduced by 30% (see table 2).

The volume of circulating blood relative to a unit of weight was reduced on the 30th and 45th day of hypokinesia, but within 2 months was normalized. This normalization was linked to the increase in the volume of plasma while the erythrocytic mass remained reduced by 20% as compared to the initial amount.

With 2 month hypokinesia no reliable changes in the K and Mg concentration in the serum were noted as compared to the initial amounts and control data. The Ca concentration was reduced for a short time in the fourth week of hypokinesia from 6.5±0.18 to 5.6±0.17 mequiv/l (D∠0.05).

The Na concentration in the serum was reduced by the end of the first month of the experiment from 147±1.6 to 141±1.8 mequiv/l (D∠0.05). This reduction was maintained until the end of the experiment (by the 62nd day of the experiment it was equal to 138±1.9 mequiv/l; D∠0.01).

TABLE 3 /30

INTRACELLULAR CONCENTRATION OF Na AND K IONS IN DIFFERENT SECTIONS OF THE MYOCARDIUM DURING 2 MONTH HYPOKINESIA (M±m)

| Electrolyte | Group of animals | Right ventricle | Left ventricle | Interventricular septum |
|---|---|---|---|---|
| Sodium | Control | 39.9±2.3 | 21.7±3.4 | 23.9±2.8 |
| | Experimental | 47.5±2.1* | 33.5±2.7* | 32.2±3.3* |
| Potassium | Control | 126±11 | 128.8±9 | 130.5±12 |
| | Experimental | 134.8±8 | 133.9±10 | 128.8±6 |

*D ∠0.05

The intracellular concentration of Na and K ions was determined in different sections of the ventricular muscle of the heart in experiments with 2-month hypokinesia. By this period the intracellular concentration of K ions was practically unchanged, while that of the Na ions was increased in all sections of the cardiac ventricles, especially in the tissues of the left ventricle (table 3).

## Discussion

In discussing the mechanisms of the changes occurring under the influence of hypokinesia in the water-electrolyte metabolism it is possible to explain the redistribution of fluid in the organism by intensification in the catabolic processes that govern an increase in the content in the cell of the quantity of endogenous water and that retain the water of osmotically active molecules.

An increase in the later stages of hypokinesia in the intracellular concentration of Na ions can have several causes, among which serious attention should be given to the reduction in the energy supply to the work of the sodium-potassium pump of the cellular membrane. This is indicated by a number of indirect data, in particular the sharp reduction in hypokinesia in the content in the myocardial tissues of the mediators that stimulate the cardiac muscle [11, 12], decrease in the quantity of cristae in the mitochondria [10], and disruption in the processes of oxidizing phosphorylation [7]. It should be noted that an increase in the intracellular concentration of Na ions has significance for the change in excitability of the cardiac muscles, and affects the amount of transmembrane potential and heterochronicity in the myocardial fibers.

The cited data make it possible to propose the presence of a causal link between the increase in the quantity of albumins and the increase in the volume of plasma at the later stages of hypokinesia. This agrees with the known assumptions on the important role of plasma proteins, especially albumins, in the regulation of water metabolism.

A clear reduction in the hematocrit in the dynamics of hypokinesia we explain first of all by the changes in the apparatus of regulation for the autonomic functions of the organism [11, 12, 17]. This assumption agrees with the data on the stimulating effect of the sympathetic sections of the nervous system on the erythropoiesis [20,23] and sharp reduction in the function of these sections of the nervous system during hypokinesia [11, 12, 17].

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