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METABOLISM DURING HYPODYNAMIA

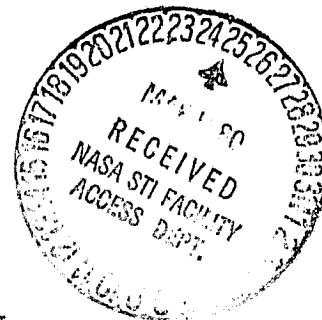
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METABOLISM DURING HYPODYNAMIA

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In this survey, the author reviews the published data and his own observations of changes in protein, carbohydrate, fatty, and aqueous-saline metabolism, the activity of enzymes, and hormone production during hypodynamia. Possible mechanisms for the changes manifested and the consequences of their activity on the human organism are discussed. /24*

Scientific and technical progress brings mankind priceless good, but it also presents medicine with new and complicated problems. One of these problems is the progressive diminution of the amount of muscular activity in man's everyday life -- hypodynamia [23, 24, 26, 42, 78]. Hypodynamia weakens the organism and itself causes various impairments of a healthy condition. In certain population groups -- operators, dispatchers, submarine and surface-ship crew members, aviators and astronauts, and others -- hypodynamia is, in a way, an occupational hazard. Another category of persons must, for a prolonged time, be partially or completely immobilized because of illness (from a myocardial infarct, impaired cerebral circulation, illnesses of the locomotor system). In the overwhelming majority of cases, hypodynamia acts on the organism in combination with other factors. It is quite important to evaluate its influence in the course of various physiological and metabolic processes in the organism.

In this survey we have attempted to give a general picture of hypodynamia's influence on metabolism, based on published data and our own studies.

*Numbers in the margin indicate pagination in the foreign text.

In an experiment, the state of hypodynamia has been modelled by placing the experimental subjects in bed; in this manner, a horizontal position of the body has been combined with immobility. Confinement in a chair, in a small-sized chamber, or submergence in water (water immersion) have also been used. Experiments for hypodynamia with animals are done by placing them in special cages with sliding tops and of limited volume. Changes in practically all types of metabolism are undergone during hypodynamia, but the greatest shifts are manifested in protein and aqueous-saline metabolism.

Body Weight

Decreased body weight and arrested growth are an integral indicator which is characteristic of the state of metabolism in the organism. During a seventy-day hypodynamia, the weight of the experimental subjects decreased 2 to 6.4 kilograms [46], during 120 days, it lessened, on the average, 2.4 kilograms by the eightieth day, and then normalized [36]. During a two- to seven-week confinement in bed of healthy young men, their weight fluctuated within limits of ± 0.5 to 2.5 kilograms [12, 63, 65]. It has been shown [13, 34], that some stabilization or increase of body weight takes place because of the progressive increase in the quantity of fat in the organism. On the average, on the second day of hypodynamia, the quantity of fat increases by 250 grams; after seven days, by 1030 grams; and, after ten days, by 1440 grams. In the first few days, dehydration of the organism simultaneously with an increase in fat content is observed, and, after five days, the muscular mass decreases, reaching 1200-1550 grams on the tenth day. /25

Limitation of the motor activity of monkeys [43] was not accompanied by a decrease in body weight; in rabbits [10], dogs [61], and mice [39], body weight most frequently dropped. The most detailed study of changes in body weight was done with rats [55]. After three days of dehydration, the majority of the rats decreased in weight because of diminished food excitability [52] and, probably, from an increase in the adrenal cortex's activity, since, at that period, hypodynamia acts as a stress factor [23, 39]. Later, the food

excitability of the rats increased, and they adapted to conditions of hypodynamia. However, after fifteen days of dehydration, the general deviation in weight, compared with the control group was, on the average, 34%, and after sixty days it was 48%. According to other data [31], the weight of all the rats during dehydration decreased, by the fifteenth day, by an average of 36%; by the thirtieth day, by 40%. The decrease in body weight was basically connected with a decrease in the skeletal muscles' absolute weight by, respectively, 23% and 46%, after fifteen and sixty days of dehydration [55, 56]. The absolute weight of the internal organs (liver, kidneys, heart) also decreased, but at the same time their relative weight increased somewhat [21, 55, 56].

It may be supposed that the decrease in animals' body weight during hypodynamia is connected to an increase in the intensity of tissue decomposition, first of all protein decomposition, or, contrarily, with a decrease in their synthesis. A decreased rate of protein synthesis may be combined with an acceleration or with a decreased rate of their decomposition.

Protein Metabolism

Excretion of the Products of Protein Synthesis in the Urine

An impairment of protein metabolism is one of the characteristic and necessary manifestations of hypodynamia. In healthy experimental subjects, after two to three days' stay in bed with a constant level of protein intake from food, the total nitrogen excreted in the urine grows significantly. Parallel with the growth of the urine's total nitrogen content is an increased quantity of urea, and the quantity of ammonia somewhat increases. Here and later, changes in the excretion of various components in the urine is given in comparison with the average level of their excretion for six to ten days preceding hypodynamia.

Most carefully done methodologically were the experiments of Dietrick, Whedon, and Shorr [65]: over six to seven weeks of

strict bed confinement, each of the four experimental subjects lost, above the initial control level, from thirty to eighty-four grams of nitrogen, which corresponds to 937 to 2625 grams of muscular mass. Under less severe conditions of dehydration [61], each of eight experimental subjects over twenty-eight days excreted in the urine, on average, 39.7 grams of nitrogen; that is, the same as the amount excreted during the same period by the subjects in the experiments of Deitrick and his coworkers [65]. According to Heilskov and Schonheyder's data [76], three experimental subjects each lost, during sixteen days, an average of 62 grams of nitrogen, and in Iu.K. Syzrantsev's experiments [49], twelve subjects, during twelve days in bed confinement, lost 37 grams of nitrogen each, or, correspondingly, 1160 grams of muscular tissue.

We found manifestations of increased excretion of general nitrogen in the urine and impairment of the nitrogen equilibrium in three healthy young people who were in bed for ninety days. Over ten days until the experiment, the average nitrogen balance for the group was positive (+0.12 grams of nitrogen in 24 hours). During dehydration, the nitrogen balance became negative. The quantity of nitrogen excreted grew when the period in bed increased. It was, for the tenth to seventeenth, twenty-seventh to thirty-fourth, fifty-fourth to sixty-first, and eightieth to eighty-ninth days, respectively, -1.7, -3.6, -3.2, and -4.1 grams of nitrogen daily. A persistent negative nitrogen balance developed in people and animals in almost all cases, with any model of dehydration [46, 49, 52, 63, 65, 67, 81]. According to some observations [46], a sharp decrease in protein intake from the food was the reason for the negative nitrogen balance, and it was not accompanied by an increase in the excretion of total nitrogen and urea in the urine. Under similar conditions, while using a diet rich in calories and lightly assimilating proteins, Cuthbertson [64] succeeded in restoring the nitrogen equilibrium. However, other authors [47, 69, 90] utilizing such diets were unable to achieve a positive effect.

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During water immersion, the excretion of nitrogen increases three to four times from the first hours of the stay in water and reaches a maximum on the third day [71-73]. As shown by a ten-day observation [38], the relative decrease in mobility during a stay in a small-sized chamber did not cause azoturia. Our trials with four experimental subjects, conducted in the course of a month, revealed a persistent increase in the urine's general nitrogen content. The greatest increase in nitrogen was in the first week of the experiment.

All the authors point out that during any form of limitation of mobility the nitrogen content in the urine increases; the nitrogen content in the feces remains unchanged.

During the dehydration of animals the same tendency in nitrogen excretion was revealed as with human dehydration. The content of total nitrogen and urea in rats' urine increased by 1.5 to 2 times after one to two days of dehydration and remained at that level in the course of the whole period of observations (22 to 24 days). Similarly, growth in the general nitrogen and urea content was noted in dogs' urine during dehydration.

The quantity of inorganic sulfur in the urine increased proportionately to the growth of the general nitrogen content, and sometimes even somewhat exceeded its increase; the content of ether-bonded and neutral sulfur remained unchanged [63, 65]. The relation between sulfur and total nitrogen in the control period, during the immobilization, and during the recovery period, remained at an almost constant level, from 1:14 to 1:15.8; that is, in general, it corresponded to the sulfur content in the muscular tissue's proteins.

During hypodynamia the creatinine content in the urine did not change substantially. The majority of the authors [25, 63, 65, 76] note a surprising constancy of the creatinine content in the experimental subjects' urine. Moreover, some experimenters observed a small decrease [46] and increase [49] in the creatinine content of humans' urine during dehydration. Some growth in the quantity

of creatinine in the urine was discovered in dehydrated rats [52].

The authors are almost unanimous regarding creatine content. Creatinuria is a characteristic sign of hypodynamia. The most careful studies of creatine metabolism were in the experiments of Heilskov and Schonheyder [76]. They found that three experimental subjects' daily excretion of creatine, beginning with the fifth day of dehydration, equalled 600 to 800 milligrams. According to Iu.K. Syzrantsev's observations [49], on the average, the experimental subjects daily excreted 80 to 170 milligrams of creatine. Deitrick and his coworkers [65] did not find creatinuria in the experimental subjects, but established a sharp lessening in the retention of creatine in the organism during dehydration. In the control period, after a determinate quantity of creatine (1.32 grams per person) was introduced from food, more than 80% of it was assimilated, but during dehydration assimilation fell to an average of 29% (11% to 70%). In rats, during the time of immobilization the creatine content in the urine increased four times over [52].

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In the majority of cases, the urine's uric acid content did not substantially change [63, 65]. Iu.K. Syzrantsev [49] and N.D. Popov [38] observed in people, as we did in rats [52], a small, statistically insignificant growth in the uric acid content in the daily urine.

The general amino acid content in the urine increased by 18% to 40% during dehydration in humans [38, 45, 49]. During aminoaciduria in dehydrated dogs a more significant increase in the content of replaceable amino acids -- glycine, alanine, tyrosine -- was observed [49].

Changes in the Composition of the Blood which are Characteristic of Protein Metabolism

The content of proteins and proteinless nitrogenous compounds in humans in a state of hypodynamia has not been systematically studied; only isolated information exists. The general content of serum

proteins and their fractional compositions in humans during hypodynamia which was prolonged for two to four weeks did not change [18, 65]. On the twentieth or thirtieth day of dehydration in rats, a significant decline in the quantity of serum proteins was found [6]. According to some data [8, 15], the urea content in the blood did not change; according to others [35], it increased. According to our observations of four experimental subjects who were in a small-sized chamber, the urea content in the blood increased by 20% to 30%. During confinement in bed for ten to twelve days, an increase in the general level of amino acids in the blood by 15% to 25% was discovered [49]; the residual nitrogen content in the same experimental subjects did not materially change, however.

Changes in the Tissues

We evaluated the synthesis of tissue proteins by the intensity of inclusion of radioactive amino acids in the tissue proteins of rats over two hours. Various experimental series were conducted employing methionine or tryptophan, and also mixtures of tryptophan with methionine and glycine, alanine, and phenylalanine with methionine. All the amino acids contained carbon-14 except the methionine, which contained carbon-14 or sulfur-35. By introducing radioactive amino acids, it was established [54-56] that the intensity of the marker's inclusion in the tissue proteins of the kidneys, liver, small intestine, spleen, heart, and skeletal muscles, dropped as early as the third day of dehydration. This drop was expressed even more sharply on the tenth day, and on the fifteenth day, on the average, it was lower than in the controls by 21% to 40% (the data are statistically significant for all except the muscular tissues studied).

After sixty days of dehydration, the intensity of inclusion of the marker remained practically on the same level as it had been after fifteen days, but for muscular tissue it was halved. On the sixtieth day, the decrease in radioactivity of all tissues in relation to the control was statistically very substantial ($\underline{P} < 0.002$).

During hypodynamia, the marker's maximum inclusion was displaced to a later time. So, in healthy mice, the maximum of inclusion for all proteins of the small intestine was found to be two hours after the introduction of the radioactive amino acids; but after fifteen days of hypodynamia it shifted by four hours. Similarly, for liver-tissue proteins, the maximum shifted from the first to the fourth hour; for spleen proteins, it moved from the first to the second hour. A decrease in the inclusion of glycine (carbon-14) in the protein part of the bones of the jaw and lower extremities in rats was also found [41].

Both the decrease in the marker's inclusion which is found soon after its introduction, and the displacement of the maximum of inclusion to a later time, are quite significant evidence of decreased 28 protein synthesis in the tissues studied.

On the fifteenth, twenty-second, thirtieth, and sixtieth days of general dehydration, the general nitrogen content in one gram of raw muscular tissue in the control and in the experimental rats was identical [29, 30, 56]. During local immobilization [68], during denervation or tenotomy [16], a significant decrease in the general nitrogen content of the operating extremities' muscles was observed. During a study of the fractional protein content of the skeletal musculature of animals in a state of hypodynamia [29, 31], it was established that the quantity of general nitrogen in the miofibrillary proteins did not change. However, the quantity of nitrogen in the proteins of the actomyosin complex statistically-significantly lessened, with an increase in the content of proteins of the T-fraction and proteins of the stroma. In the skeletal muscles of rats who were in less strict conditions of hypodynamia, according to M.S. Gaevskaya's data [7], the summary protein content (by Lorne's* method) decreased, on the thirtieth and sixtieth days, respectively, by 5% and 13%. The quantity of sarcoplasmic proteins also decreased; the miofibrillary protein content had increased by

*Name retransliterated from the Russian. -- translator

the thirtieth day of dehydration (+22%), but by the sixtieth day had decreased substantially (-25%). The increase in the quantity of miofibrillary proteins is connected to [7] some increase in the rats' muscular activity in the first month of their confinement in crowded cages.

What is the tendency of change in protein metabolism during hypodynamia? Analogies are often drawn between changes in metabolism during hypodynamia and changes during trauma, between hypodynamia and fever, and between hypodynamia and the muscular atrophy which is connected with denervation and tenotomy. Actually, if changes in metabolism during hypodynamia and the indicated states [4, 16, 59] are compared, then it is clear that they have some features in common. So, during trauma, fever, and hypodynamia, increases in the excretion of nitrogen, urea, and sulfur in the urine are observed; aminoaciduria, creatinuria, and the development of a negative nitrogen balance are seen. The differences are, first of all, qualitative. During trauma and fever, all the metabolic disruptions are more clearly expressed, and are two to three times higher in absolute numbers than in those disruptions during hypodynamia. During trauma and fever the changes are observed from the first hours of the injury; however, during hypodynamia they are seen, as a rule, only from the second to the fifth day of dehydration. It is known that a negative nitrogen balance, an increased excretion in the urine of general nitrogen, urea, sulfur, etc., may develop when there is an increased intensity of tissue degeneration and a constant level of their synthesis, or because of a decrease in the synthetic processes with a constant speed of degeneration, and sometimes with the latter somewhat lessened.

During fever and especially trauma, two phases of a general metabolic reaction are distinguished [59, 64]. The first phase, which lasts for ten to fifteen days, is catabolic, when the process of degeneration clearly dominates in almost all of the organism's organs and tissues. The second phase is anabolic. During this period the intensity of the degenerative processes is normalized, and

synthetic processes prevail in the focus of the injury and throughout the organism.

During hypodynamia, the catabolic phase in classic form is not manifested, or is very short. The factors which give rise to it, such as multiple negative impulses from the focus of the injury to the central nervous system, pain, and the degeneration of damaged tissues, are absent. More characteristic for hypodynamia is an earlier and progressive decrease in the synthetic processes, manifested first of all in a decline in the formation of new tissue proteins.

Cuthbertson [63] stated the assumption that nitrogen, sulfur, phosphorus, and potassium are excreted in increased quantities in the urine because they are used in smaller quantities for synthetic processes, especially in the muscles and the bones. This position is 29 now confirmed by much experimental data.

During hypodynamia the excretion of creatinine and uric acid does not substantially change, which indicates the constancy of the catabolic index. During a massive degeneration of tissue, such as during trauma, an increased excretion of these components of the urine is usually observed. Creatine, which is produced in the liver, is completely utilized in the muscular tissue during hypodynamia, and its wastes are excreted in the urine. Experiments with creatine-C¹⁴ [70] have shown that the same kind of changes are observed with E-avitaminosis, during which the synthesis of muscular proteins decreases.

Under the action of radiation [1, 14] or general starvation [27], the summary content of DNA in the tissues decreases because of cellular degeneration. During hypodynamia in animals, the DNA content in the tissues does not decrease, but, on the contrary, increases. During an expression of tissue degeneration, for example in cases of denervation and tenotomy, the nitrogen content in the muscular tissues does not change. During denervation, tenotomy [16], and general starvation [27], the tissues' content of residual

nitrogen increases, and the intensity of proteolysis grows. During hypodynamia, proteolysis grows substantially only in later periods.

Schonbeyder et al. [88] studied the excretion of nitrogen-15 in healthy humans and in humans during hypodynamia, when, after receiving glycine-N¹⁵ from food, a negative nitrogen balance was manifested. A sharp growth in the speed of nitrogen-15's excretion in the urine in the first hours after the preparation was given, and a unique angle of inclination of the curves for healthy and hypodynamic humans, allowed the authors to assume that the intensity of synthesis had been affected, but not protein degeneration. A determination of the intensity of the inclusion of radio-amino acids in the protein of rats' tissues during hypodynamia [54-56] shows the decrease in the synthesis of many tissue proteins which progresses as the period of hypodynamia increases.

Aqueous-Saline Metabolism

From the first days of hypodynamia, aqueous-saline metabolism is substantially changed, and its disturbance is as characteristic for these states as changes in protein metabolism.

As a rule, in experiments with dehydration, increased diuresis is observed in the subjects. Under the conditions of a strict bed-rest regimen which lasts two to seven weeks, diuresis, on average, increased by 200 to 300 milliliters per day [49, 64, 65]. In the majority of observations, the use of liquid by the subjects was not limited, and not considered; in those cases where such observations were made, it was established that the increased diuresis was not related to an increase in the use of liquids. In isolated observations [25], a decreased diuresis was noted in the fourth and fifth week of hypodynamia. Diuresis increased four to sixfold during immersion in water for six to twenty-four hours. With a more extended water immersion (seven days), diuresis exceeded the initial level three to six times in the first three days and then somewhat declined; it did not regain the initial value, however [71-73]. An extended stay in a chamber of small volume also made for somewhat increased

diuresis.

In rats, diuresis grew by 1.5 to 2 times from the first day of dehydration, and maintained that level in the course of three weeks [52]. In a few experiments on dehydrated dogs, increased diuresis was not observed, possibly because of the constant diarrhea which was noted in all the animals.

Increased diuresis during hypodynamia is ordinarily related to a redistribution of blood in the organism, to an increase in its basic volume in the pulmonary circulation [20, 69], which causes an excitation of the volume receptors in the region of the auricles and the major vessels of the thoracic cavity, and, through the hypothalamus and the pituitary body, leads to suppression of the antidiuretic hormone. Because of the latter's insufficiency, the reabsorption of water and salts in the small canals of the kidneys is lessened, and the excretion of water and salts in the urine increases proportionally. Moreover, the changes in diuresis may depend on increased blood circulation in the kidneys and an intensification of glomerular filtration [9], on an excess of tissue-degeneration products in the organism, and on an increase in the oxidation processes' intensity. During dehydration a redistribution of the fluid in the organism takes place, and its quantity in the intervascular phase somewhat increases.

It has been established [89] that, after a three-week stay in bed, the evidence of hemocrit increases from 45.7 to 49.5 millimeters, the volume of the plasma decreases by 518 milliliters, and that of the blood decreases by 582 milliliters. The decrease in the plasma volume was noted as early as the second day of bed confinement, and after two to three weeks it reached 1800 milliliters in individual subjects [83]. A four-day chair confinement led to a decrease in the mass of the circulating blood by 522 milliliters. With a fourteen to sixteen-hour stay in water, the quantity of plasma decreased by 370 to 630 milliliters [79]. In the final analysis, some concentrated salts were observed in the blood, which caused an irritation of the

osmoceptors and reflexively influenced the production of the corresponding hormones, especially aldosterone.

As with dehydration in bed, so also with immersion in water noticeably more sodium and potassium than the norm are excreted in the urine. A six-day stay in water made for a threefold increase in the sodium excreted in the urine, and almost a twofold increase in potassium [71]. During a longer stay in water, the sodium and potassium excretion levels decreased, but were still higher than the initial value [72]. During dehydration in bed, increased quantities of sodium were excreted in the urine, chiefly in the first few days of the experiment [49]. From the seventh to the tenth days of the experiment, the excretion of sodium grew. By the eighth day of dehydration, the K:Na relation was 1:1; the norm is 1:2. Over six to seven weeks of dehydration, sodium loss in the urine exceeded its excretion in healthy subjects by 4.2 to 14.2 grams. In Iu.K. Syzrantsev's experiments [49] with eight subjects, the average loss of potassium was 5.4 to 8.0 grams over eight to twelve days of dehydration; according to other data, in experiments with subjects [81] for twenty-eight days, it was 2.15 grams. Naturally, a negative potassium balance developed in all the subjects. The sodium balance remained positive, but declined by three to eight times in absolute numbers [81].

From the second or third day of a stay in bed, the excretion of phosphorus in the feces, and especially in the urine, rose. The maximum quantity of phosphorus in the subjects' urine appeared in the second and third weeks of dehydration; a secondary increase in the phosphorus content was noted in the seventh week. The losses of phosphorus over six to seven weeks of dehydration [65] equalled 5.6 to 11.6 grams, and over twenty-eight days [81] they were 4.24 grams. During dehydration, a negative phosphorus balance developed.

In rats [52], the phosphorus content in the urine during hypodynamia increased by 25% to 82%; an especially sharp increase was noted in the second week of the experiment. The phosphorus content

decreased [6] in the rats' blood and was more poorly utilized in bone tissue [41].

Simultaneously with an increase in the phosphorus and nitrogen content in the urine, the quantity of calcium grew. Its maximum value was reached on the fourth or fifth weeks of dehydration. Hyperealeiuria was noted in all subjects during hypodynamia [36, 46, 58, 65, 66, 77, 81], and also in astronauts after eighteen days in space [3]. During hypodynamia, the calcium concentration in the urine exceeded the initial level by 1.7 to 2.5 times [36, 65]; over four weeks, its general losses were, on average, 4.75 to 5.26 grams [66, 81]; over seven weeks they reached 23.9 grams in individual subjects, which led to a negative calcium balance [75]. The calcium content in the blood of humans often rose or did not change [36], but in rats and rabbits it even decreased [6, 51]. X-ray photometry discovered a decrease in the mineral saturation of the bones [34, 58, 75].

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The decrease in the muscles' motor activity related to the pressing, squeezing action on the bones, and, in the horizontal position, the complete cessation of the action of the masses of muscular tissue which is directed along the longitudinal axis of the large tubular bones, led to the degeneration of the bony tissue and a decrease in the assimilation of calcium from food. These are the basic factors which lead to hyperealemia and hyperealeiuria during hypodynamia in humans.

During rats' dehydration, in the course of 30 to 100 days, the intensity of inclusion of calcium-45 in the bone tissues declined [21, 28, 41], and the thickness of cross-sectional layers of the tibia lessened [2]. The totality of experiments with general and local immobilization [80] shows that osteoporosis is caused by the decreased formation of new bony tissue and by an increase in its degeneration. According to clinicians' observations, patients' extended confinement in bed leads, in many cases, to osteoporosis and the atrophy of the bony tissue [87]. The fear has been expressed

that during the prolonged action of hypodynamia and weightlessness on astronauts, the strength of the bones may significantly decrease, so that, under the action of a load, fractures may occur, and the coagulation of the blood and neuromuscular excitability may be impaired [20, 62, 77, 85, 86]. These problems require further study.

Carbohydrate and Fatty Metabolism

Information about the impairment of carbohydrate and fatty metabolism during hypodynamia is very scanty. Hypodynamia makes for a decrease in the absorption of the products of the digestion of food, including the absorption of glucose [32].

According to some experimenters' data, the sugar content in the subjects' blood during a twelve-day stay in bed [18] and a six-hour water immersion [74] did not change. In other authors' experiments [49, 72], under the same conditions, a small hyperglycemia was found. Later on, the sugar level in these subjects' blood returned to the initial one or even less. According to our observations [54] of rats, on the first day of dehydration a significant, though short-term, hyperglycemia was manifested. After fifteen and sixty days, hypoglycemia was found in the rats in every case.

When the rats floated, after two to three weeks of hypodynamia the sugar level in the blood declined more noticeably, and more slowly recovered, than under the same circumstances for the control animals. During hypodynamia in dogs, after centrifuging, a hyperglycemic reaction was more weakly expressed.

A lessened glycogen content was found in the rats' livers and skeletal muscles. After fifteen days of dehydration, lyofraction of the glycogen had almost completely disappeared, and the general glycogen content had decreased, on average, by 89%. Some strengthening of the intensity of glyconeogenesis simultaneously with the diminution of the glycogen stock was demonstrated in experiments with alanine- $1-C^{14}$. In rabbits, the sugar level in the blood increased during hypodynamia

[50].

The state of fatty metabolism during hypodynamia is most frequently judged according to the change in the fat content of the organism. Obesity has been noted in older persons who lead a sedentary life [26]. In experimental subjects, a one to seventy-day stay in bed caused an increase of from one to five kilograms in the body's fat content [12, 13, 25, 45]. During a six-month local immobilization of puppies' paws, the fat content in the muscular tissue increased from 23.5 to 84.8 milligrams/gram [68]. In rats, under strict conditions of hypodynamia, the supply of fat in the subcutaneous fat, in the region of the omentum, and around the internal organs almost completely disappeared [52, 55]. During short-term hypodynamia (ten to fifteen days), no changes in the content of general fat, cholesterol, and lipid phosphorous were found in the subjects' blood [18]. During extended hypodynamia (120 days) the content of general lipids, cholesterol, and beta-lipoproteins in the blood increased [36].

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We have established that there is a significant increase in the level of cholesterol and beta-lipoproteins in the blood of hypodynamic rats and rabbits. With physical conditioning of the rats, the cholesterol content in the muscles decreases [84], and the glycogen and creatine phosphate content increases [44].

During hypodynamia, the utilization of carbohydrates and fats as energy materials is impaired because of the substantial change in the oxidizing processes. In humans and dogs the basic metabolism is decreased; in rats, it does not change for the first two to three months, and then it increases [21, 22]. The level of the tissues' respiration changes. In the liver, the intensity of tissue respiration increases; in the heart and the skeletal muscles it decreases [11, 21, 37]. A disconnection of the phosphorylation and oxidation processes occurs, and the production of macroergic compounds declines [11, 17]. All these things, along with other reasons, lead to a lessening of the ability to perform static and dynamic work.

Conclusion

Muscular activity, movement, is the strongest factor of control of vital processes, of the regulation of physiological systems and the maintenance of homeostasis [57]. During inactivity, the biological value of any physiological system declines. However, muscular activity is not only a means of conditioning the neuromuscular apparatus itself, but also a powerful lever for affecting the cardiovascular, respiratory, and nervous systems and the endocrine glands. During hypodynamia, hormonal production decreases [21, 53], which leads to the discoordination of the enzymes' activity.

While studying the influence of hypodynamia on humans and in experiments on animals, changes in the distribution and the activity of many tissue enzymes were found [5, 8, 29, 30, 47-49, 56]. Impairment of the neuro-hormonal regulation of all the vegetative processes, and the changes, which are related to those processes, in enzymes' activity, lead to that substantial impairment of the metabolism of proteins, water and mineral salts, carbohydrates, fats, and the production of energy, of which we spoke above.

Cardiovascular ailments, kidney stones, frequent pneumonia, high susceptibility to various kinds of colds, and much else, and in the final analysis, premature ageing and senility -- this is far from a complete list of the harmful consequences of hypodynamia. No medications are able to replace muscular activity. Complete rest is not the organism's optimal state [33]. A certain minimum of muscular activity is necessary for all groups of the population and even for the seriously ill [19, 60]. Without a certain amount of physical labor and physical culture the creation of well-rounded, more mature individuals for the future communist society is inconceivable.

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*Milov's second initial is different in item 55 than in items 54 and 56 in the original text. -- translator

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