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EFFECTS OF WEIGHTLESSNESS ON THE HUMAN ORGANISM

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/Article by I. Pestov, doctor of medical sciences, State Prize laureate: "Through the Weightlessness Barrier"/

/Text/ The Soviet Union has begun to operate orbital stations. Multimonth watches on the part of cosmonauts have become a commonplace phenomenon and are having a huge scientific and economic effect.

The specialists in space medicine, who have done everything possible so that the cosmonauts can work long and fruitfully in orbit, deserve a great deal of credit for the achievements gained in manned cosmonautics. For its development of methods and equipment preventing protracted weightlessness from having a deleterious effect on the human body, a group of Soviet scientists has been awarded the USSR State Prize.

This article is concerned with what is now known about the effect of weightlessness on the human organism.

In making an orbital flight, man is not simply lifted several hundred kilometers above his native planet -- he breaks away from the conditions under which he was formed and lives permanently. The new medium into which he penetrated 20 years ago is unique and foreign to his nature. The uniqueness is due to its lack of gravity, a factor which is very important for every living and growing thing on Earth. Man began to conquer space, a world without gravity, very cautiously. The first scouts in orbit were various biological objects, including our four-legged friends.

The first real obstacle cosmonauts encountered in space was vestibular malfunction accompanied by seasickness and spatial disorientation. In the initial phase of spaceflight, it turned out that every third cosmonaut suffered such disorders.

It is important to mention a curious fact here: there proved to be no reliable correlation between a person's susceptibility to seasickness on Earth and the probability of the appearance of vestibular malfunction in him during spaceflight. A person can be seasick on Earth and feel fine in space, and vice versa.

In order to overcome this malfunction, at the present time we are using -- with a certain degree of success -- a system of preflight training of the vestibular apparatus, as well as training for an "antiorthostatic" position of the body (that is, a position in which the head is below the feet).

Fortunately, vestibular malfunction during spaceflight is of a temporary nature and lasts, as a rule, only 2-3 days, rarely longer, before it passes away.

As the length of spaceflights increased, so did the number of problems arising before the specialists. As it turned out, vestibular malfunction is only part of the organism's reaction to the unusual conditions of a world without gravity.

Right now, 20 years after Yu.A. Gagarin's flight, the mechanism of the effect of weightlessness on the basic systems of the human organism is quite clear. However, questions concerning weightlessness's possible effect on cells, the reproductive organs and the intimate processes of vital activity require further study.

In popular scientific articles one can find the expression, "Weightlessness -- Enemy Number One." In space, man has more than enough enemies: radiation, vacuum, huge temperature gradients. However, this expression is true in the sense that in comparison with the other flight factors, weightlessness causes living organisms the most trouble and, at the same time, creates serious complications in the overcoming of its unfavorable consequences.

One would think that in space the body is freed from all the difficulties that are related to terrestrial gravity. However, not just any lightening is a blessing. Weightlessness means a reduction in the load on the muscles, a lessening of the load on the skeleton, and the absence of hydrostatic blood pressure. As a result of the relieving of the hydrostatic blood pressure, overfilling of the vessels in the upper part of the body takes place. This is accompanied by a feeling of heaviness in the head, a headache, and a spinning sensation in the head. The congested blood contributes to seasickness and activates vestibular malfunction. If this went on all the time, man would not be able to make flights into space. However, in response to unusual conditions the body engages its adaptive mechanisms.

As a designer, nature is a genius. In the human body she has provided reserves, taken the trouble to duplicate a series of functions, and installed in it the ability to substitute for lost properties and increase reserves and reliability by means of training. However, nature is not wasteful and does not manifest any striving toward redundant solutions.

As soon as the load on the skeleton is reduced, calcium starts to wash out of the bones and they lose their strength. If there is no load on the muscles, such as when the force of gravity is being counteracted, they decrease in volume. Since the cardiovascular system is not charged with assignments related to the constant supplying of the body's energetics with oxygen and nutritive substances for opposing terrestrial gravitation, poor conditioning of the heart develops and its productivity decreases. There are also changes in metabolic processes. It is obvious that we could put up with this if man did not, sooner or later, have to return to Earth and the readjustments in his body do not go too far and threaten his health. The encounter with overloads during landing and with terrestrial gravity does not promise anything good to a weakened body. Man in space needs some kind of equivalent of those loads to which his body is accustomed on Earth. This is the only way to combat weightlessness. But how do we do this, since nothing weighs anything in space and a man floats freely in the compartments of an orbital station?

K.E. Tsiolkovskiy thought about this a long time ago. He suggested artificial gravity. If spin is imparted to a spacecraft, then because of the radial acceleration there appears an overload that is close, in its content and effect on the body, to the force of gravity.

True, we run into serious difficulties in connection with this. For instance, in order that the artificial gravity not cause vestibular malfunction, the space system must have a large radius of rotation on the order of tens and hundreds of meters. This complicates the design of the system substantially. Besides this, life in a constantly rotating station involves large complications related to the onset of Coriolis accelerations when people move. In this case, it would be impossible to conduct research, experiments and observations under weightless conditions.

Since the complex of facilities for prophylaxis against the unfavorable effect of weightlessness that has now been developed satisfies the practical needs of cosmonautics, the question of creating artificial gravity in spacecraft has been asked prematurely. The existing complex of prophylactic means is based on an effort to create in weightlessness the equivalent of the weight load on the bone and muscle system and to eliminate the consequences of the abnormal distribution of blood in the body that is related to a lack of weight and hydrostatic pressure.

It is possible to create a constant, static load on the muscles and skeleton with the help of rubber braces that run along the body. The load suits that cosmonauts now use during flights operate on this principle.

A complex trainer with a "running track" makes it possible to obtain a dynamic physical load in a station. A cosmonaut dressed in a load suit stands on the "running track" and is held on it by a tightening system. As a result, the suit distributes the forces on the waistband and the shoulders, while the legs are pressed to the track. This makes it possible to walk, run and jump with a great expenditure of physical effort, thereby maintaining the coordination of the important motor skills.

A space trainer of another type is the veloergometer, with the help of which it is possible to dose out a wide range of physical loads, thereby preventing the development of deconditioning, including that of the cardiovascular system.

In order to simulate intravascular hydrostatic blood pressure, we use devices that produce lowered pressure in the lower half of the body and facilitate the movement of blood to the legs.

Our arsenal of prophylactic measures also includes instruments for electrostimulation of the muscles, water-salt loading and pharmacological preparations.

The rational organization of the cosmonauts' labor, rest and daily life has an important role in prophylaxis of the unfavorable consequences of protracted spaceflight.

Large groups of scientists, designers and engineers have taken aim at overcoming the barrier of weightlessness. Cosmonauts have been active participants in this work.

All of this, as a whole, made it possible to enlarge the framework of the permissible duration of spaceflight and gradually reach the periods we see today. As is well known, they are now numbered in months, and not just a few of them.

For the future, the amount of time that has been achieved will probably prove to be inadequate. Manned flights for the investigation of the planets can last for years. The work of crews in stations in orbit around the Moon, Venus, Mars and Jupiter can last for just as long.

What are the predictions relative to flights of such duration? They can be based on a generalization of our preceding experience, an analysis of tendencies, the investigation of analogs. Our experience in manned flights lasting up to half a year that have already been made indicates that apart from the well known manifestations of fine adaptation to weightlessness and the development of asthenization processes related to the phenomena of "disuse" or "atrophy from inaction," no unexpected or qualitatively new changes take place in the human body. It goes without saying that if corrective, controlling measures are not used with respect to these changes, they can reach levels that are dangerous to health and cause serious complications, in particular, in the process of readaptation or adaptation to terrestrial conditions after the end of a flight into space. However, if the stipulated volume of prophylactic measures is carried out properly and the work and rest regimes are observed, extended flights can be borne as easily as those of shorter duration.

According to most indicators of the functioning of the cardiovascular system, blood formation, the metabolism and the muscle support system, a stable equilibrium state is achieved that gives no grounds for assuming the appearance of unexpected and unfavorable tendencies in relation to a subsequent extension of the duration of flights into space. Psychological difficulties will apparently be of the most substantial importance, although even they do not appear to be insurmountable.

Apart from this, factors limiting the duration of spaceflight can be illnesses, which on a long flight can increase the effect of asthenization and the lowering of the body's resistance and demineralization of the bone tissue that is related to the slow but steady loss of calcium.

Unfortunately, it is not possible to establish temporal limits for the appearance of these limitations on spaceflight on the basis of the factual data available at the present time.

Considering that an active motor regime is an important factor in longevity, it can be assumed that the hypodynamia that constantly and invariably accompanies weightlessness serves as a prerequisite for the development of premature aging. However, this hypothesis has not yet been confirmed by experimental observations.

With due consideration for these stipulations, it can be said that flights ranging in duration from a year to several years are possible in principle, but require the presence in the crew of medical personnel, and on the ship of special equipment for diagnostic and medical-prophylactic assistance. It is also necessary to utilize an extensive complex of measures that facilitate the readaptation of the body to terrestrial conditions after the completion of such flights.

Judging by the results of spaceflights that have already been completed, for the body of a grown man the recuperation of the structure and functions is successful, although it does take some time. Less clear is the answer to the question of how reversible would be the losses caused by weightlessness in a young, developing body in which the formative role of gravity would not be able to be manifested to the same degree as in those of the same age on Earth. It can be assumed that in this case the development process would proceed with deviations in comparison with terrestrial standards that might be consolidated in features of the body's structure and functions that would complicate the subsequent process of adaptation of a young body to terrestrial conditions. Although this question is only of theoretical significance for the future development of cosmonautics at the present time, it probably should be studied on the basis of experiments with animals.

In the 20 years that have passed since Yu.A. Gagarin's historic flight, Soviet space medicine has accumulated a great deal of experience, enriched science with important factual data and theoretical propositions, and made a notable contribution to the development of Soviet cosmonautics. Engendered by the demands of scientific and technical progress, in the future it will continue to carry out its high and humanistic mission, assisting with great success man's conquest of outer space.

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