KRONIKA I WIADOMOŚCI REDAKCYJNE

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REVIEW OF THE STUDIES ON THE EXPERIMENTAL ANIMALS UNDERGOING ACCELERATION IN THE POLISH CENTRIFUGES IN THE MILITARY INSTITUTE OF AVIATION MEDICINE

BADANIA ZWIERZĄT W POLSKICH WIRÓWKACH PRZECIĄŻENIOWYCH WOJSKOWEGO INSTYTUTU MEDYCYNY LOTNICZEJ

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ABSTRACT: *The authors analyzed the experimental studies on the laboratory animals carried out in the Military Institute of Aviation Medicine. An effect of acceleration on the animal body functioning is the main subject discussed in this paper. Researchers used accelerations of various characteristics. Protocols of the studies included the use of the centrifuge specifically designed for the tested animals, equipped with a device enabling their freezing. Such a procedure enabled to assess pathomorphological and hemodynamic changes in the animal bodies produced by an acceleration. The obtained results showed displacements of both tissues and internal organs and transudation of the body liquids and proteins outside a vascular bed. Results of the studies presented in this paper are a chronological course of the research performed in the Military Institute of Aviation Medicine in the said period of time*
KEY WORDS: *accelerations, animal centrifuge, experimental studies*

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STRESZCZENIE: *Autorzy przeprowadzili analizę badań doświadczalnych przeprowadzonych na zwierzętach laboratoryjnych w Wojskowym Instytucie Medycyny Lotniczej. Podstawowym problemem omówienia był wpływ przyspieszeń na czynność ustroju zwierząt. Badający stosowali przyspieszenia o różnych charakterystykach. W metodyce badań wykorzystali skonstruowaną w Polsce wirówkę zwierzęcą z urządzeniem do zamrażania zwierząt w warunkach działania przyspieszenia, co pozwoliło na ocenę zmian patomorfologicznych i hemodynamicznych. Uzyskane wyniki wykazały przemieszczenia się tkanek i narządów oraz przesiąkanie płynów ustrojowych i białek poza łożysko naczyniowe. Przedstawione wyniki badań stanowią chronologiczny przebieg pionierskich badań prowadzonych w Wojskowym Instytucie Medycyny Lotniczej w omawianym okresie*

SŁOWA KLUCZOWE: *przyspieszenia, wirówka zwierzęca, badania doświadczalne*

Attempts to explain physiological mechanisms acting during accelerations were undertaken already before the World War I. Therefore, various centrifuges were used for this purpose. The first studies on the effect of acceleration on the body were carried out in 1917 – 1920. After the World War II, information on the studies of man examined in the human centrifuges started to reach Poland but an access to the results of such studies was limited. The lack of the human centrifuge in Poland and in the Military Institute of Aviation Medicine unabled to carry out the studies on the effects of acceleration on the body. It resulted in the lack of scientific Polish reports on the problems of the military pilots undergoing an acceleration. Employees of our Institute sporadically participated in the conferences concerning aviation medicine in some other socialist countries.

Use of experimental animals for the studies concerning with pilots' life protection became a necessity. The obtained information had to serve deepening of the knowledge on the human body behavior and its adaptation to the extreme conditions. In the beginning of 1960, pioneer studies concerning the survival of the experimental animals undergoing very high accelerations started to appear all over the world. An effect of mechanical forces on the tissues was examined, cell divisions were analyzed, and various physical cell parameters were defined to get a knowledge on cytoplasm structures. It was found, that mast cells under +41,000 Gz and pressure 913.9 cm^2 are deformed but morphological changes were negligible and a return to the normal shape took 20 to 45 minutes. Other authors, using +40,000 Gz and pressure 8347 atm, showed that cytoplasm is able to survive such a high acceleration and undertake its physiological functions, when an acceleration ceased. [Jendyk, Wojtkowiak, 1962].

Published reports of the foreign researches increased an interest of the Military Institute of Aviation Medicine employees in the investigations of the acceleration effect on the human body. There were the first Polish studies in Poland, started in the Military Institute of Aviation medicine (MIAM) and included animal experiments in the animal laboratory VIVARIUM, existing since 1951.

Up that time, it was known that acceleration produces various hemodynamic disorders. Centrifuges constructed that time did not allow to explain clearly changes in the body produced by acceleration (shift of both blood and body liquid and dislocation of the internal organs in the tested animals), making investigations quite difficult.

In 1962, the first Polish studies were carried out. They concerned the effects of acceleration on biological structures with special reference to the changes of body parameters, which were not investigated, yet. One of the first research carried out in MIAM was an assessment of the respiratory tract functioning, especially a fundamental parameter, i.e. tissular respiratory index, being a very sensitive indicator of the metabolic disorders. Ultracentrifuge used for the organic mixtures fractional separation, being able to generate several thousands rotations per minute, was applied for investigations of the gas exchange in the isolated hepatic tissue under the action of +40 to +8000 Gz. Collected guinea pig liver bioptates were centrifuged at 500, 1000, 3000, 5000, and 7000 rpm. To eliminate an effect of the huge hydrostatic pressure, samples were coated with a thin layer of Singer-Krebs liquid. Tissue respiration was measured with Warburg manometer. The authors noted that tissue respiration index was gradually decreasing with increasing acceleration. No morphological changes were noted in the centrifuged tissues, which preserved remnant respiratory function after an action of the high G-load [13].

The first concepts to design an own, Polish centrifuges (both for men and animals) went back to the sixties of the XX century with participation of both MIAM and technical institutes employees. Construction consent, reached after several unpublished technical assumptions, led to the construction of the first Polish centrifuge. In 1964, the first G-load centrifuge was constructed. It was designed for animal experiments and was manufactured in WSK-PZL Świdnik. This centrifuge was equipped with devices registering liquid and internal organs displacement in dependence of the randomly selected acceleration parameters. Centrifuge had been equipped in a small cabin leaning out according to the Gz vector. Transmission of 6 channels provided information about physiological status of the tested animal.

Year 1965 proved to be favorable for the progress in research, when this animal centrifuge was equipped with a device for the quick freezing of animals during acceleration. These devices for freezing animals in a liquid nitrogen consisted of the part fasten to the centrifuge arm, and a small cabin placed inside a container for poured liquid nitrogen. Specifically designed vessel was placed in the cabin. Its construction enabled to place an animal according to the acceleration vector. The whole device could be used for experiments with an acceleration up to + 20Gz, despite the fact that the strength tests permitted experiments up to +30 Gz. Centrifuge construction allowed safe pouring large amounts of the liquid nitrogen into container and rotations for 150 sec. During that time, the whole animal body and its internal organs became completely frozen and possible pathologies were fixed. Introduction of this centrifuge into the research studies led to several experiments, involving mainly the rats.

Possession of such a animal centrifuge resulted in the scientific investigations aimed at acquiring information about compensatory mechanisms in the body and assessing a degree of the body adaptation to acceleration.

One of the first studies carried out by MIAM employees – hematologist P. Czerski

and physiologist M. Wojtkowiak – was an analysis of the body liquids distribution, labeled with ^{131}Jodoalbumin and ^{22}Na radioisotopes, under accelerations of 3, 5, 7, and 9 Gz. This study enabled to follow changes in both tissues and internal organs, displacing according to the acceleration vector [6]. These investigations were continued. They involved rats, which were rotated at +3 Gz for 3 hours a day for 22 days. Muscle samples collected from the back limb revealed dilated capillaries and precapillaries with hypertrophic walls transuded with serous liquid. Degenerative lesions were seen in the muscular tissue [5,6].

Next years enabled to extend investigations of the hemodynamic disorders. Baseline radioactivity was measured after intravenous injection of the radioactive ^{131}Jodoalbumin and globulin labeled with ^{51}Cr. Then, the rat was centrifuged under prolonged acceleration. Radioactivity extinction in both tissues and internal organs was measured after freezing an animal. Curve of the radioactivity and plasma content in the vascular bed indicated that the acceleration quickened the fluids and protein escape from the vascular bed [4].

Environmental temperature in the cockpit is one of factors playing a significant role in the body acceleration tolerance. This issue was investigated in the guinea pigs by biochemist [12]. The authors analyzed an effect of the following temperatures: +30°C, +40°C, and +50°C as well as accelerations +3, +4, and +5 G on the carbohydrates metabolism. The analyzed these parameters together and separately. The obtained results indicated that the combined higher acceleration and temperature decreased blood glucose levels and muscular glycogen levels, which may lead to the marked reduction of the body carbohydrates reserve. These results suggested that similar changes might been seen in the pilots. Therefore, pilots should be given carbohydrate-rich meals before the flight, to prevent a decrease in the blood glucose.

In 1970 – 1980, MIAM started to participate in the INTERKOSMOS program. Therefore, several studies related mainly to the animal hypokinesis, but some of them were still associated with the action of acceleration.

Studies on the animals in the centrifuge were also subject of the clinical trials. In 1970, a surgeon (Świetlicki, 1970) published the results of his studies in rats undergoing acceleration +5 Gz and +7 Gz. He observed gastric functioning disorders following a meal containing contrast medium and proper diet. An increase in gastric juice and the number of gastric ulcers followed.

In the same year [2], plasma protein displacement in rats under acceleration conditions was investigated. Examined rats were divided into 4 groups and underwent prolonged action of acceleration +5 Gz for 15 minutes, 1 hour, 2 and 3 hours. Animals were frozen at the peak acceleration and radioactivity was scintigraphic radioactivity distribution was measured. Differences in the body liquid displacement were noted. In case of radioisotopes of ^{131}Jodoalbumin and ^{51}Cr globulin escape of the protein from the vascular bed was seen. First escaped low molecular weight proteins.

Numerous studies on the effect of +Gz on the body showed that the direction of blood displacement is head-lower limbs, producing hypertension in both capillaries and precapillaries. It facilitates blood plasma transudation into perivascular space. Extravasation of both protein and electrolytes may disturb osmotic equili-

brium between blood and tissues and lead to blood concentration and decrease in the total volume of the circulating blood. Barański and Wojtkowiak attempted to discover all mechanisms of blood extravasation during prolonged acceleration (1970). This problem remained unclear, especially in reference to the changing acceleration parameters and duration. Novelty introduced by these scientists was the use of scintigraphy and intravenous administration of the radioisotopes as well as randomly chosen degree of freezing the examined animals, which enabled rapid collection of the whole tissues and internal organs. Use of ^{22}NaCl, ^{131}Jodoalbumin, and erythrocytes labeled with ^{51}Cr enabled to substantiate that blood dislocation to the lower limbs during an action of +5 Gz for 15 minutes to 3 hours does not produce blood plasma and protein (even of a low molecular weight) extravasation. It was found that albumin extravasation in the lower limbs muscles begun after 1 hour of acceleration. It means that acceleration of the commonly used maneuver parameters, especially of a prolonged duration, should not produce disorders such as protein extravasation. However, extravasation of liquids in the capillary vessels could be expected.

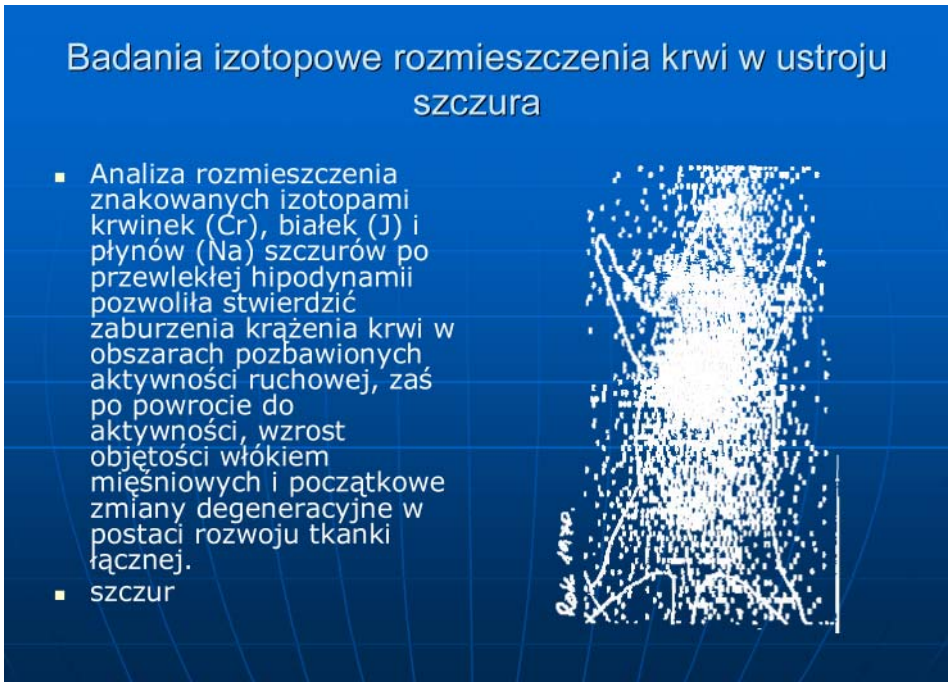

Fig. 1. Scintigram of the blood labeled with ^{131}Jodoalbumin distribution in rat tested in the animal centrifuge (see the text).

Ryc.1. Scyntygram wirowanego szczura po podaniu ^{131}Jodalbuminy.

Next problem, which appeared that time, concerned an effect of the prolonged hypoodynamia on the body. It became a subject of the experiments in rats placed in cases with limited possibility to change body position but with elevated lower limbs at 30°. After prolonged hypodynamia, its dependence on the acceleration

tolerance was investigated. First, radioisotope ^{131}Jodoalbumin was injected. Next, the examined animals were centrifuged at +5 Gz up to development of bradycardia, determining a collapse of the circulatory system. Tested animals in contrast to the control group, not being in hypodynamia, showed low acceleration tolerance and more advanced hemodynamic disorders. This limited their survival during the experiments. In this experiment, marked changes in the blood plasma and large amounts of albumin extravasation. EEM revealed functional changes of the whole neuron, together with motor cells in the in the anterior horns of the spinal cord. The obtained results of experiments might serve to the assessment of the space hypodynamia-produced disturbances.

Protein metabolism disorders produced by various flight factors, being harmful for the pilot, including acceleration, became a subject of scientist's interest concerning changes in transaminases activity in the animals. This problem undertook S. Wróblewski [22]. He found that acceleration +4 Gz acting on the guinea pigs for one hour caused an increase in SGPT and SGOT activities. Moreover, SGOT/SGPT ratio decreased and SGPT markedly increased. It could indicate hepatic disorders.

In 1973, scientific team, including one neurologist, one pathophysiologist, and one physiologist, investigated an effect of extreme acceleration on the bioelectric CNS and heart functioning as well as pathologies in the internal organs in monkeys [10]. The study aimed at defining gradually increasing CNS disorders, heart, and morphological lesions to the examined internal organs. Experimental monkey underwent linearly increasing acceleration at o.1 G/sec. to the critical phase of cardiac cycle expressed as an appearance of single R waves in ECG record. An analysis of sequentially increasing changes in heart functioning in ECG record enabled to define gradation of the disorders, starting from single extrasystoles, features of myocardial hypoxia, and finally critical functional disorders. The obtained results could make a list of cardiac functional disorders with which the physicians examining pilots in the human centrifuge could deal.

Survey of the available studies carried out in the seventieth indicated that the hemodynamic disorders are produced by the acceleration and the experiments in animals could make evaluation of an increase in blood and body liquid circulation more precise. Therefore, the use of animals for the studies on acceleration of increasing values and duration enabled to evaluate susceptibility of the selected organs to the lesions resulting from the dynamic changes of the body liquids pressure. Studies carried out in our Institute with the use of body liquids and erythrocytes labeled with radioisotopes enabled to show substantial variations in hematocrit values during acceleration, indicating local perfusion changes noted in the examined internal organs. Especially valuable was an assessment of the correlation between changes of the total plasma volume in the circulation and changes in some organs, particularly brain, kidneys, and lungs. Fixation of these changes with rapid freezing with liquid nitrogen helped to explain mechanism of these disorders, noted during increasing various body loads.

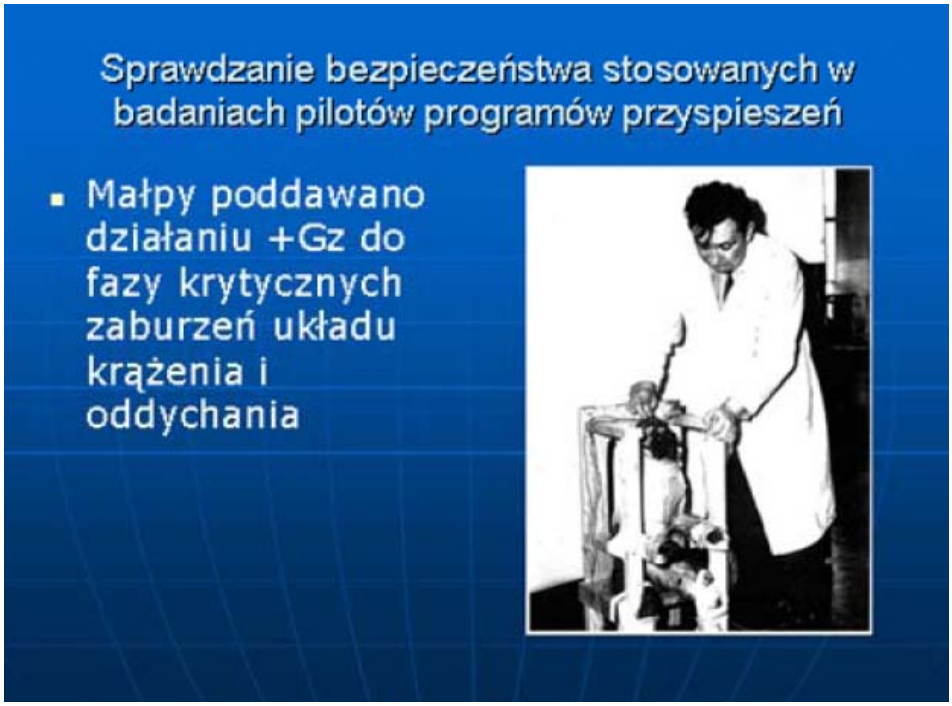

Fig. 2. Professor M. Wojtkowiak carrying experiments in monkeys (see the text).
Ryc. 2. Prof. M.Wojtkowiak podczas prowadzenia badań na małpie.

In 1974, M. Wojtkowiak carried out the studies on the rate of the regression of hemodynamic disorders produced by the tolerated by the animals prolonged acceleration of +5 Gz of various duration. An analysis of a decline of ^{131}Jodoalbumin radioactivity after centrifugation enabled to show its dependence on both duration and acceleration value and was associated with time of the residual blood in the vessels to baseline values.

In the mid-seventies, animal experiments were performed in the human centrifuge. That time emerged the problem of an effect of changes in the flight environment and metabolic disorders on the pilots' feeding. Investigations of these issues were the subjects of animal experiments. Partially completed studies on blood vessels permeability for blood plasma and protein during acceleration of different characteristics were of particular importance. The lack of more detailed evaluation of these disorders, i.e. local histological lesions in the organs and blood vessels needed further studies. The use of a device enabling freezing of the experimental animals proved to be valuable. Complete or partial freezing of animals in the peak acceleration could be applied, depending on the study aims. Partial freezing enabled to rapid collection of the whole muscles and organs. Therefore, dislocation of the body liquids and protein into extravascular space could be investigated. Various time of the tissue sampling partially or completely frozen played an important role for sodium radioisotope of a short physical half-life and allowed to estimate amount of extravascular water.

Next experimental studies concerned an action of combined temperature and acceleration. The authors found unfavorable effect of the elevated environmental temperature on acceleration tolerance. Beside functional disorders, disturbances in carbohydrates metabolism were noted, manifested by a decrease in of blood glucose and muscular glucagon levels. The authors suggested that these disorders result from an intensified carbohydrates metabolism under such conditions. It was known that hypoglycemia in pilots led to earlier fatigue and physical fitness. Such phenomena were also confirmed by the animal studies, which were demonstrated by the decreased acceleration tolerance. Dependence of psychic well-being on blood sugar levels was a subject of the studies by Schreuder et al. [16]. These authors showed that even relative hypoglycemia caused fatigue and decreased psychophysical fitness, threatening flight safety. Carrying out the studies in pilots, the authors proved that a decrease in blood glycemia to 70 mg% produces a sensation of fear, intense sweating, and the loss of situation control. Higher hypoglycemia and decreased glycogen levels were obtained in animals and the produced disorders reached a state of unconsciousness.

In 1974, an effect of acceleration and elevated temperature as well as combined these two factors was assayed in both blood and cerebral tissue, basing on the glucose, glycogen, lactic acid, and pyruvic acid. [20]. The obtained results showed a decrease in glucose and glycogen levels and an increase in lactic and pyruvic acids. It indicated synergic effect of both elevated temperature and acceleration on the brain tissue carbohydrates metabolism. Moreover, the obtained results suggested that giving pilots carbohydrate-reach meals before the flight is justified.

Several pilots' examinations in the human centrifuge showed that the body tolerance depends on several associated factors in which a main role is played by not only acceleration and environmental factors but also body physiological and psychological capabilities.

Continuation of the studies carried out by Domaszuk and Wojtkowiak in 1975, were experiments in guinea pigs in the animal centrifuge. The animals were given intravenously ^{131}Jodoalbumin and centrifuged at +10 Gz up to the development of the circulatory disorders manifested by bradycardia, which meant the point of reaching the threshold of unconsciousness. Then, the animals were frozen after 5, 15, and 30 minutes after stopping centrifuge. Analysis of radioactivity allowed to see that an action of the extreme accelerations has led to a decrease in brain, liver, spleen, and kidneys perfusion. Between 5 and 15 minutes after cessation of acceleration a gradual radioactivity return to the changes normalization was observed. However, these changes did not reach baseline values after 30 minutes. The obtained results suggested that the action of high accelerations accumulates in the body and persisted long time after acceleration declined [7].

Determination of the acceleration tolerance limits (GTP) enables to reach maximum acceptable load assessed with the aid of various criteria. There are no data associated with the body behavior after GTP excess and an increase in disorders parallel with increasing acceleration.

In 1973-1975, the organ of sight was one of the issues examined in the experimental animals in MIAM. Studies aimed at determining whether an acceleration producing circulatory system decompensation affects permeability of the blood-

ocular barrier and what is dynamics of such lesions. This problem was investigated by the team of specialists employed in MIAM, namely Kożuchowska, Wojtkowiak, and Tajchert. Experimental animals were placed in the special containers in the centrifuge situated in the body transverse axis and the direction compatible with acceleration vector. Examined animals were centrifuged up to development of bradycardia signaling blood circulation failure and were immersed in the liquid nitrogen, immediately after stopping centrifuge. Radioactivity of the ocular structures and aqueous humor in the extracted eyeballs. The authors found that acceleration increased radioisotope content in the anterior chamber, suggesting increased permeability of the blood-ocular barrier. Significant increase in radioisotope in the eyeballs indicated also a presence of congestive hyperemia and damage of the blood-ocular barrier. The obtained result might suggest that high acceleration values and rapid centrifuge slowing down may result in the intraocular hypertension. Therefore, a process of centrifuge slowing down should be prolonged to decrease an effect of pressure wave on the blood returning to the head vessels [15].

Histological examination of the previously centrifuged animals was a sequel of the ophthalmologic investigations performed in 1977 [18]. Previous results [15] showed that acceleration produced changes in the blood-ocular permeability for protein and in some cases even its damage. Therefore, M. Wojtkowiak attempted to examine whether such a situation produces pathomorphological lesions to the eyeballs. The study was carried out in the guinea pig eyeballs, frozen after +5Gz acting in the direction head-hindlimbs (direction +Gz) or the opposite (direction –Gz). GTP was defined as the development of bradycardia in ECG record, which meant circulatory failure but guaranteed animal survival after centrifugation. After 5, 15, and 30 minutes as well as 1 and 3 hours the animals were frozen in the liquid nitrogen, and shortly later eyeballs were extracted for histological examination. Marked changes in the eyeball volume, depended on the blood dislocation in acceleration direction, i.e. decreased in case of +Gz and increased in case of –Gz, were found. Histological features of +Gz action manifested by predominated features of eyeballs ischemia. In animals frozen after an action of –Gz, significant hyperemia of the vascular layer was observed. It produced blood vessels walls damage, small hemorrhages adjacent to the optic nerve and ciliary body. Moreover, edema of the optic nerve was noted. Effusion liquid accumulated between retina and choroidea while the retina showed features of the histoarchitectual disorganization and edema. In animals undergoing prolonged centrifugation, lesions during –Gz were increasing and indicated eyeballs structures damage, while lesions produced by +Gz were of transient character and did not produced pathomorphological changes.

It is known from the literature that prolonged acceleration leads to changes in the body liquids distribution, specially blood displacing to the direction compatible with +Gz vector. Moreover, such a situation leads to an increase in blood pressure in the peripheral body areas and overcoming both pre- and capillary vessels resistance. This was investigated in our Institute in 1976 [8]. The authors examined rats after administration of albumin microspheres labeled with ^{131}Jodoalbumin. The obtained scnitigraphs showed that acceleration up to +15 Gz for 5 minutes caused penetration of these microspheres into venous vessels and accumulation in the lung and pelvic areas. It was found that acceleration produced progressive blood

vessel dilation, which diameter became markedly higher than the control values and persisted longer.

Next subject of the studies in experimental animals were physical exercise tests trained to endure acceleration. In 1977, Wojtkowiak, Domaszuk, and Janusewicz carried out an experiment consisting of forcing rats to swim in the water everyday for one month [9]. Rats swam up to achievement of the extreme fatigue manifested by the inability to swim longer. Measurements of time defined the limits of exercise tolerance. After the raining, examined animals underwent an action of acceleration up to bradycardia development. Time of bradycardia development signaled circulatory disorders and constituted a limit of acceleration tolerance. An increase in acceleration tolerance depended on the time of swimming tolerance. The obtained results indicated that the rats being able to swim longer tolerated acceleration better. The authors assumed that an effect of training on the acceleration tolerance depended on the baseline tolerance of the physical exercise in the animals selected from the same species. It is probable that the tolerance of acceleration differentiated rats as regards their resistance to the fatigue.

In 1983, D. Gembicka and Z. Domaszuk examined the animals undergoing acceleration in both linear and interval program in the animal centrifuge [11]. In the linear program an acceleration increased at the rate of 0.2 G/sec. up to the development of circulatory failure. In the interval program, rate of acceleration increase was 0.5 G/sec. to the maximum +10 Gz, continued to the same symptoms of circulatory failure. Rats tolerated acceleration 24.0 ± 3.7 Gz in the linear program, and 32.0 ± 7.5 minutes in the interval program. Development of the circulatory disorders seen in ECG in the form of the sinus rhythm change into ventricular rhythm with sudden bradycardia was a criterion of the acceleration tolerance in both programs. The following biochemical parameters were assayed in the animal blood: glucose, lactic acid, pyruvic acid, fatty acids, urea, Na and Ca, $CO_{2,}$ and blood pH. The authors found that prolonged acceleration produces significantly higher physical effort than that linearly increasing, which leads to the higher degree depletion of the body metabolic reserves. This observation was based on the application of different acceleration parameters in both programs, leading to the extreme tolerance. Metabolic disorders manifested themselves by a significant increase in blood glucose and fatty acids, while an increase in both lactic and pyruvic acids levels indicated anaerobic course of the metabolic reactions. High levels of acid compounds produced a decrease in pH value. However, character of acidosis in both groups of the animals undergoing acceleration differed. PCO_2 values in the animals examined within linear program it was gaseous and resulted from a significantly shallow breathing or respiratory arrest during an action of the high accelerations. In case of the interval program examined animals adapted to the acceleration by more rapid breathing, enabling longer acceleration tolerance. However, in the last phase of centrifugation more intensive disorders were noted. The authors, basing on the obtained results, concluded that the prolonged acceleration was a higher load for the body than the linear one.

Available reports indicated that the course of metabolic processes leading to the energy gain during acceleration is associated with hypoxia. This issue interested Gembicka and Domaszuk in 1983. Their studies involved 6 groups of rats undergo-

ing acceleration of different value and duration. The authors found that an effect of acceleration in the first phase of centrifugation increased glucose levels in all groups of the animals. They assumed that it was caused by stress and high physical load associated with static muscles work. It was interesting that an increase in free fatty acids level appeared after 30 minutes of centrifugation and remained unchanged for 4 to 6 hours. A significant increase in this parameter appeared 2 hours after acceleration cessation. The authors assumed that this increase in free fatty acids level might suggest that at the beginning of +Gz the body uses energy-rich compounds, like glucose and glycogen contained in the muscles, and release free fatty acids in the later phase [11].

Introduction of a new generation aircrafts was associated with an action of high +Gz of variable amplitude and prolonged duration. Cyclic, repeated several times and rapid increase in accelerations and their fading as well as prolonged duration resulted in an accumulation of the haemostatic disorders. In the author's opinion, had to be related to a significant metabolic disturbances. In 1989, team of researchers, using different parameters of acceleration, measured rectal temperature, glucose, lactic and pyruvic acids levels in blood and liver tissue, skeletal muscles and myocardium in all animals undergoing the test in the animal centrifuge. They showed that pulsatory acceleration resulted in the more temperature lowering and liver glycogen. Such disorders suggest an increased demand for oxygen, causing higher metabolism rate arrest in the developing body defense strategy [14].

Summary

Sacrifice of the animal lives to safe human lives is an eternal dilemma of evaluations and deliberations concerning the life. However, animal experiments carried out in the Military Institute of Aviation Medicine enable to achieve several important data, which could not be obtained in case of the humans undergoing acceleration. The obtained scientific knowledge was used for pilots' health and life protection in the extreme conditions and widened the knowledge of aviation medicine.

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