ASSESSMENT OF THE REACTION OF THE CARDIOVASCULAR AND RESPIRATORY SYSTEMS OF ASTRONAUTS TO PHYSICAL WORK

In selecting methods for conducting functional tests with physical loads, suitable for assessing the state of the astronauts' organism, we proceed from the following basic position: comparative data should be obtained during pre- and postflight examinations. This is possible only in the case when the output of the work being performed, rather than the value of any one of the recorded parameters (for example, lung ventilation, pulse frequency, etc.), is taken as the criterion of the load "weight". In other words, the amount of work performed during a given period of a functional test, depending on the examination, should be constant for a given astronaut, if only his physiological parameters do not exceed previously extablished limits. /1*

If we proceed on the requirement for a constancy of any one parameter, even pulse frequency, comparison of the data obtained with different amounts of work becomes difficult. It is well known, for example, that the same work (according to amount) induces considerably greater recovery of pulse frequency after experiments on simulation of weightlessness with the aid of prolonged bedrest than during the initial period. In this case, oxygen consumption in the "stable state" increases only slightly or does not change at all. Consequently, some previously established value of pulse frequency is taken as the criterion of the "heaviness" of work, in the case of deterioration of the functional state of the astronauts' organism, and changes in the postflight amount of work, such important indicators as oxygen consumption, carbon dioxide excretion and lung

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

ventilation, we feel, fall out of the analysis.

The second main requirement on physical work is the receipt of a maximum amount of information in the absence of feelings of the "excessiveness" of work among astronauts, especially immediately after flights. Hence the suggestion of permitting the astronauts to rest for 10-15 minutes after completing work in each of the "stages" (25, 50 and 75% of the maximum). This will make it possible to obtain data on the oxygen, carbon dioxide, pulse, etc. after operations of different intensity, without which the "metabolic cost" may not be determined which, as we know, increases to a considerable extent due to the "debt" rather than due to the stable state. If we assume that the astronauts' condition deteriorates considerably and work during the postflight examination will be interrupted at any minute of the second or third stage (50 or 75%), in case there are no breaks, the data on recovery processes will be irretrievably lost. And, on the other hand, the presence of breaks between work "plateaus" will make it possible to interrupt the work, while retaining data on the recovery processes after the preceding work.

It is suggested that the length of each of the work plateaus be extended up to 7 minutes for reaching the best stable state. In this case, we proceed from available experimental experience, which indicates retardation of the "response" processes after prolonged bedrest, when the stable state is achieved considerably later rather than within 3-4 minutes. The possibility is not excluded that a similar phenomenon will also be observed after prolonged spaceflight. Moreover, an increase /3
in the length of work will make it possible to record such important parameters of hemodynamics as cardiac ejection and the systolic volume of the heart in the stable state with the aid of Fick's indirect method (recurrent respiration of CO_2).

Taking into account that the pulse frequency in a number of completely healthy subjects is equal to or exceeds 150 beats/min after completing 7 minutes of work, the amount of which reaches 75% (judging by the ratio of oxygen consumption during the given work to its maximum level), the test should be stopped when the pulse frequency is 160 beats/min, rather than 150, as indicated in the proposals of the American party.

The periods of conducting investigations to determine the "maximum possible load" and the percentages (25, 50 and 75%) should be especially mentioned. In physiology and sports medicine, the criterion of "work load" is taken as that amount of it at which O_2 consumption comprises a specific percentage of the maximum (in our case, 25, 50 and 75%). It was desirable to follow this principle, but specific difficulties arise in determination of the level of the work load, at the 5th-7th minutes of which oxygen consumption would reach a specific value.

With regard to the intense activity of astronauts prior to alunch, physical load tests on the bicycle ergometer should not be carried out within three days prior to the flight.

In order to assess the specific role of orthostatic instability (observed to one or another extent after almost all flights) in reducing physical work capacity, it is suggested that physical loads of 25% capacity be carried out after a number of flights both in the "sitting" and "reclining" positions. This modification of the test is not compulsory for all flights, but is quite feasible in some of them.

We should also agree on the procedures for conducting tests of the "maximum possible load", which is not outlined in the materials from the Americans which we have received, and about the position of the test subjects' body when taking

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"background" data prior to the test and during the rest periods between the individual work stages. We feel that rest and taking of "background" data are best carried out in a position with the upper half of the body raised 30°, and the legs raised 10° higher than the level of the pelvis. In this regard, as the nature of the load changes, a somewhat different procedure is required from investigations which differs from that previously outlined in the materials submitted by the American party.

INVESTIGATION PROCEDURE

a) Compulsory Test

1. The astronaut rests not less than 10 minutes, part of this time being used to apply the sensors. This should be followed by recurrent respiration (or prolonged expiration) to determine cardiac ejection and the systolic volume of the heart. The indicators indicated below are then recorded for 7-10 minutes.

2. The astronaut sits on a bicycle ergometer for one minute, after which he performs physical work of 25% of capacity of the maximum for 7 minutes, recurrent repiration (RR) or single expiration being carried out during the 6th minute.

3. Rest in the same position as when taking "background data" for 9 minutes.

4. The astronaut again sits down on the bicycle ergometer at the 10th minute, and beginning from the 11th minute, performs work equal to 50% of capacity for 7 minutes, and carries out RR during the 6th minute.

5. Rest for 10-14 minutes.

6. Changes to the bicycle ergometer at the 15th minute and, beginning with the 16th minute, performs work of 75% of capacity with RR during the 6th minute.

7. Rest for 15 minutes.

A total of 90-100 minutes is required for each astronaut to complete the test. The speed of rotation of the pedals during all work should be constant (60 ± 5 rpm).

b) Facultative Test

Work at 25% of maximum is carried out, but in the "reclining" position.

RECORDED PARAMETERS

a) Compulsory

- Oxygen consumption
- Elimination of carbon dioxide
- Minute volume of respiration
- Respiration frequency
- Pulse frequency
- Amount of work

b) Facultative

- Pressure of CO_2 in the alveolar gas
- Sphygmograms of the carotid, femoral and radial arteries
- Electrocardiogram by nebu taps
- Phonocardiogram and similar parameters as desired by one of the parties.

It would be desirable to conduct pre- and postflight examinations of bicycle ergometers of the same types and calibrated identically (the distance from the center of rotation to the pedals should be especially mentioned).

Besides the data on temperature, barometric pressure, etc. /6
mentioned in the documents of the aprties, the height of the seat and of the handle of the bicycle ergometer, which should be constant for a given astronaut in all examination stages,

must be fixed.

PROCEDURES FOR PRESENTATION OF DATA

The values of the recorded parameters should be presented in the form of tables for each individual astronaut (average data for each minute of recording).

CRITERIA FOR ASSESSMENT

The reaction of the cardiorespiratory system for each of the three physical load is assessed:

- by the value fo the different parameters under stable state condition;
- by the total value of O_2 consumption, elimination of CO_2, lung ventilation and pulse frequency throughout the period of work and recovery;
- by their increase above the level of rest during the same periods.