The Space Congress® Proceedings

1973 (10th) Technology Today and Tomorrow

Apr 1st, 8:00 AM

Skylab Medical Experiments Program

Rufus R. Hessberg

*Director, Space Medicine, NASA Office of Life Sciences, Headquarters National Aeronautics & Space Administration, Washington, DC 205*16*

Scholarly Commons Citation

Hessberg, Rufus R., "Skylab Medical Experiments Program" (1973). *The Space Congress® Proceedings*. 1.
https://commons.erau.edu/space-congress-proceedings/proceedings-1973-10th/session-1/1

SKYLAB MEDICAL EXPERIMENTS PROGRAM

Rufus R. Hessberg, M.D.
Director, Space Medicine
NASA Office of Life Sciences
Headquarters National Aeronautics &
Space Administration
Washington, DC 20546

ABSTRACT

With the completion of the historic Apollo Program, the significant medical findings will be reviewed and the medical results summarized. The medical objectives of Skylab will be presented. The medical experiments which will be conducted and their relationship to the Apollo medical findings and Skylab objectives will be discussed. The interrelationship of the Skylab medical experiments will be described and the anticipated information to be obtained will be postulated.

INTRODUCTION

Today we stand on the threshold of a new era in the United States Manned Space Flight Program. Mercury, Gemini and Apollo led the way by establishing unequivocably that man can effectively perform operational and applied missions in space flight. The new era in which we are about to embark next month will capitalize on all that we have learned and will, for the first time, emphasize scientific investigations rather than operations and applications. The Skylab Program has maintained throughout its design and development, its basic objective to provide an orbiting laboratory capability and my remarks will be devoted to the importance of this program to the Life Sciences. The contribution the medical experiments will provide to the further understanding of some of the physiological adaptative processes and mechanisms involved in the observed changes in our manned space flights to date will be discussed. Time will not permit covering the entire Life Sciences Experiments Program in Skylab. This paper will be limited to the medical experiments.

AREAS OF MAJOR MEDICAL OBSERVATIONS

As a result of the Mercury, Gemini and Apollo manned space flights, certain findings have resulted and can be described in six major areas of human systems (Figure 1).

I will briefly describe the findings associated with each of these areas, of the hardware developed to support the experiments associated, and describe the procedures and significance of the medical investigations associated with each. It is important to recognize that all of the findings on observed changes in manned space flight to date have been reversible and have returned to the preflight values for each individual during the postflight observation period.

METABOLISM (Figure 2)

This is more specifically referred to as nutritional and musculoskeletal function because we are interested in the basic metabolic processes of man as they are influenced by the space flight environment. The most significant finding, to date, has been the consistent weight loss experienced by every astronaut during a mission. We have had one exception; Al Shepard in Apollo 14. Most of the weight loss has been attributed to loss of body fluid although a small percent has been lean body mass. There has been indirect evidence of either loss or shift of body calcium or perhaps both. Attempts to determine changes in bone density from pre- to postflight have not been consistent in verifying total loss of body calcium as opposed to the alternate theory of calcium shift. It may be that the manned space flights to date have been too short to establish the true picture associated with calcium metabolism and the musculoskeletal system. Electrolyte changes have occurred and are most likely associated with the loss of body fluid.

An example of the difficulty in establishing specific and consistent findings is the potassium studies associated with Apollo 15 and 16. In Apollo 15, we used K^{42} which is a method for determining total body exchangeable potassium. At the postflight determination, it was found that the two astronauts who had been to the lunar surface had a 15% decrement from their preflight value obtained at F minus 5. The Command Module Pilot had a 10% decrement. During the interval between Apollo 15 and 16, changes to the diet by selecting foods high in potassium and fortifying some of the beverages using a potassium supplement were instituted. In addition, special attention was paid to the timeline with emphasis on adequate rest periods and planning no excessive work days. The Apollo 16 crew showed no significant change in their potassium levels postflight. One cannot attribute this result just to the change in potassium intake but it certainly points up the relationship of the nutritional aspect in terms of maintaining an adequate balance of basic constituents associated with metabolic activities. Generally speaking, the changes observed in this area returned to preflight control levels from three to five days after recovery.

In Skylab, we plan a comprehensive controlled metabolic balance study which will provide data on the inflight status of fluid, electrolyte and hormonal changes coupled with pre- and postflight data on skeletal and muscle mass changes. The Skylab crews will commence this experiment 21 days preflight by going on the Skylab diet exclusively, to insure a nutritionally stabilized situation at launch. They will stay on this for 18 days after recovery while the postflight investigations are completed. Precise measurement of the nutritional constituents will be maintained throughout the entire period from 21 days preflight through 18 days postflight. All food and fluid intake and output will be measured during this entire period. Unconsumed portions of food inflight will be measured by the Small Mass Measurement Device (Figure 3).

Inflight, we will be obtaining a 120 cc sample of urine from each crewman each day from their 24 hour output. This along with all feces, which will be dried and returned with the urine, will be analyzed postflight (Figure 4). Daily mass measurement will be obtained inflight using the Whole Body Mass Measurement Device pictured in Figure 5. This inflight capability will permit the first indepth study of the metabolic functions associated with man and his activities in the space flight environment. It is anticipated that we will have a better understanding of fluid balance mechanisms as a function of time inflight with the associated electrolyte and hormonal data. It is anticipated that more definitive information on calcium, bone and muscle mass changes will be obtained.

HEMATOLOGY AND IMMUNOLOGY (Figure 6)

In Gemini and Apollo, we have measured the loss of red cell mass in those flights where oxygen partial pressures have predominated. In those Apollo missions which had no cabin decompression for EVA or where it was postulated that a small percentage of nitrogen remained in the Command Module atmosphere, we saw no loss of red cell mass. This poses a very interesting and intriguing physiological question which remains unanswered to date, namely; is it the high oxygen environment that causes the loss of red cell mass or is it the presence of nitrogen that prevents the loss of red cell mass? In addition to the above, decreased plasma volumes have been consistently observed postflight and are most likely associated with the fluid balance changes and loss of total body water. We have found immunological changes whose magnitude is in keeping with the changes associated with those observed in ground-based studies and cannot be attributed exclusively to space flight. Specifically, we have seen changes in immune globulins A and G but these increases were associated with pre- and inflight illness and were within the ranges associated with such conditions. The increase in haptoglobin and ceruloplasmin postflight can be attributed to the stresses of reentry, splashdown and recovery.

In addition to the pre- and postflight Hematology and Immunology Studies, blood will be drawn inflight for the first time in the U.S. Manned Space Flight Program and will be preserved and returned for postflight analysis for comparison with the pre- and postflight studies (Figure 7). The information obtained will augment the body fluid shift studies, supplement the electrolyte investigations and provide cross-checks for the metabolic and cardiovascular experiments.

CARDIOVASCULAR (Figure 8)

We have consistently observed throughout Mercury, Gemini and Apollo, a decreased orthostatic tolerance postflight. This is a finding which is readily explained by the fact that inflight, the cardiovascular system does not have to work against a gravitational workload represented by a column of blood between the feet and heart and between the heart and the head. Because there are receptors or sensors in the cardiovascular system called gravi-receptors, they respond to the weightless environment resulting in a new physiological level of activity as a normal adaptative response. The orthostatic intolerance observed postflight is a reflection of the changes that occur in space and are normal for the weightless environment, but are not adequate for the 1-G environment until a readaptation back to the preflight 1-G status occurs. In all but Apollo 15, the return to preflight values have occurred in three to five days.

The assessment of the cardiovascular system is accomplished by imposing an externally imposed workload or stress on the system. In the early days of Mercury and Gemini, we used the tilt table as the stressor but with subsequent development, the Lower Body Negative Pressure Device (LBNP) has been cross-calibrated with the tilt table and has been used pre- and postflight in Apollo with the exception of the quarantine missions (Figure 9). This device will be used inflight in Skylab and its development was specifically in anticipation of the inflight ability to stresses in the cardiovascular system since it is obvious that the tilt table could only be used in a gravitational field. By applying controlled negative pressure to the lower half of the body at 30, 40 and 50 mm Hg negative pressure, the resultant effect is that of providing an external force which tends to "pool" the blood in the lower extremities, thereby, creating a provocative stress on the cardiovascular system. By using the vectorcardiogram in conjunction with this experiment, we will obtain both changes in heart rate and changes if they occur in the three dimensional electrical characterization of the heart. In addition, blood pressure is obtained every 30 seconds during the use of the LBNP. This inflight information will be of inestimable value not only for the determination and understanding of the cardiovascular changes as a time course inflight but will contribute to the operational medical assessment of the Skylab crew as a function of mission duration. This is considered to be the earliest observable physiological system to change in man since it was observed even in the short duration of the Mercury missions. However, the changes in the cardiovascular system cannot be disassociated from blood volume and body fluid changes.

PULMONARY FUNCTION AND ENERGY METABOLISM (Figure 10)

There has been, in most instances in Apollo, a reduced work capacity postflight compared to preflight values. This has usually returned to preflight levels in two days and is based on the oxygen consumption required for a calibrated workload on a bicycle ergometer. When it has occurred, it has averaged a 25% reduction from the preflight level. It is interesting to note that the energy expenditure for lunar surface EVA's has been less than predicted. In spite of the fact that we anticipated a reduced energy requirement in the 1/6 G environment and we had obtained metabolic data during 1/6 G simulations, the total expenditure on all lunar surface EVA's still fell under the predicted values.

In Skylab, we will use the bicycle ergometer and its supporting equipment inflight in the same configuration as that used pre- and postflight (Figure 11). Inflight, the ergometer will be used at 25, 50 and 75% of the preflight control value. During this experiment, blood pressure, vectorcardiography and metabolic rates will be obtained. This will be the first attempt to obtain inflight data on pulmonary function (minute volume and vital capacity). In addition, this will provide a significant increase in the level of sophistication in our assessment of work capacity during manned space flight.

NEUROPHYSIOLOGICAL FUNCTION - VESTIBULAR AND SLEEP (Figure 12)

Although not reported by all the Apollo crewmen, many have indicated postflight that early in the mission, they experienced what has been commonly referred to as "stomach awareness." This has usually disappeared within the first 48 hours of the mission with no reoccurrence. Interestingly enough, Mercury and Gemini were free of any reports or instances of this nature including Gemini 5 and 7 where specific head movements were programmed as an experiment to see if any of the symptoms of motion sickness could be induced. In Apollo, we have had, early in the flight program, one or two instances that could be termed "motion sickness." In Apollo 15, we had our one and only instance of a postflight vestibular finding. One of the crewmen experienced "stomach awareness" during trans-lunar coast which disappeared with lunar orbit and landing and did not reoccur during trans-Earth coast. However, following recovery, he experienced what was described as a feeling of being about 20-30 degrees head-down when lying horizontally in bed. This condition completely disappeared after about one week.

In the area of sleep, we have mainly subjective reporting wherein early in the Gemini Program, the attempt to have one man awake and on duty while the other one slept proved to be disturbing to the one trying to sleep. This culminated in the change to both crewmen sleeping at the same time to avoid the noise and activity which occurred with one crewman awake and active. In Gemini 7, inflight electroencephalograms were obtained and no abnormalities whatsoever were found on the returned records.

In Skylab, we will have our first opportunity to investigate the question of whether there is a threshold shift in sensitivity of the vestibular apparatus in weightlessness. This will be done by using a rotating chair, electrically driven, and so designed that all rotations of the chair including starting and stopping are below the threshold of perception in a 1-G environment (Figure 13). The chair will be used in two modes: (1) in the dynamic (rotating) mode which will assess the sensitivity of the semi-circular canals in the weightless environment; and (2) the static mode which will assess the sensitivity of the otoliths in the weightless environment.

In addition to the above, EEG's will be obtained on one of the crewmen during sleep about every other night (15 times in the 28 day SL-2 mission and 21 times in the 56 day SL-3 and 4 mission) - (Figure 14). This EEG is designed with an automatic onboard analyzer and associated magnetic tapes for storing and returning the data which will permit the subsequent analyses of the amount of each of the four stages of sleep. Some of the fatigue which has been consistently observed in the crewmen postflight might possibly be associated with changes in sleep quality. It is most important to keep in mind that there is great individual variability both between individuals and in the same individual in the vestibular and sleep areas.

TIME AND MOTION - BEHAVIORAL (Figure 15)

If you recall in Figure 1, I listed this as "Behavioral - Lunar Surface" since we have observed no psychological or performance changes in our manned space flight activities to date. We have looked at data from many flight activities such as rendezvous and docking, lunar orbit insertion, LEM descent and landing and other inflight activities and, in each instance, the flight performance can be superimposed upon the simulation and training data with no significant differences. The only area in which we have determined a change has been in the translation of the training and simulation for EVA from the 1-G environment to the 1/6 G on the lunar surface. Our studies have indicated that it has taken longer in the 1/6 G than we had planned in the timeline for many of the lunar surface activities. We have also noted that there is a rapid learning experience on the lunar surface with shortening of the time required for certain activities with each subsequent EVA.

In Skylab, we will assess the translation of 1-G and water immersion training to the actual inflight situation (Figure 16). We will use the data acquisition camera to film already scheduled activities, primarily experiments but some operational activities as well. Postflight analyses of the returned films will be compared to films of the same functions taken during preflight training and simulation (Figure 17).

EXPERIMENT INTERRELATIONSHIPS (Figure 18)

I am sure it has become evident that as I have described these medical experiments that they are interrelated and that the results of one will have a bearing on another. For example, if stomach awareness should occur early in the Skylab mission as it has on the Apollo flights, this would have an understandable effect on eating. If the intake of food and fluid is reduced, then, there will be a resultant effect on the nutritional and electrolyte data. The electrolyte changes can, in turn, effect fluid shifts and fluid loss from the body which, in turn, would be reflected in the cardiovascular system changes. With changes in the cardiovascular system, it would be natural to expect a change in exercise response and, of course, nutrition is directly related to energy metabolism. Any of these foregoing features could influence the quality and quantity of sleep which could result in fatigue and could be reflected in performance changes. The point here is not that any or all of these things will occur but it establishes the fact that there is this close interrelationship in all of these experiments and not one of them stands alone nor can it be evaluated without complete knowledge of the results of the other. A very important element of this Skylab Medical Experiments Program is the fact that Medical Experiment Principal Investigators are working together as a team. The medical evaluations and decisions will be based on the integration by this team of the total data analysis process. This insures that no isolated data point will be misconstrued and insures a cross-check which will preclude erroneous judgment.

SUMMARY

Virtually all of our medical information from manned space flights to date has been derived from pre- and postflight data or observations made by the crewmen and reported at the postflight debriefings. Skylab presents the first opportunity to investigate inflight, the time course of the physiological parameters of prime importance to manned space flight.

The medical experiments in Skylab are unique in that they are not only experiments but will provide operational and medical information for mission continuation decisions and equally as important; the basis for the go/no go decision for SL-3 after SL-2.

It is only reasonable to expect that many new questions will arise from the Skylab Medical Experiments Program. Conversely, it would be overly optimistic to assume that we will obtain answers to all the questions concerning the observed changes we have seen in manned space flights to date. However, the Skylab Medical Experiments Program is a tremendous stride forward in that direction. It will be an important contribution to the future of manned space flight.

AREAS OF MAJOR MEDICAL OBSERVATIONS

- METABOLISM
- HEMATOLOGY
- CARDIOVASCULAR
- PULMONARY
- VESTIBULAR
- BEHAVIORAL - LUNAR SURFACE

Figure 1. Areas of Major Medical Observations.

NUTRITIONAL AND MUSCULOSKELETAL FUNCTION

(METABOLISM)

PURPOSE: DETERMINE EXTENT OF SKELETAL AND MUSCULAR ALTERATIONS; EVALUATE MINERAL, WATER, ELECTROLYTE AND HORMONAL CHANGES; ASSESS NUTRITIVE REQUIREMENTS

Figure 2. Metabolism.

Figure 3. Small Mass Measurement Device.

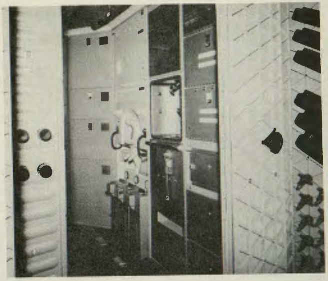

Figure 4. Waste Management System.

Figure 5. Body Mass Measurement Device.

HEMATOLOGY AND IMMUNOLOGY

PURPOSE: DETERMINE SPACE FLIGHT EFFECTS ON PHYSIOLOGY OF FORMED BLOOD ELEMENTS, BODY FLUID COMPARTMENTS, AND SELECTED ASPECTS OF IMMUNITY

Figure 6. Hematology and Immunology.

Figure 7. Automatic Sample Processor.

CARDIOVASCULAR FUNCTION

PURPOSE: ASSESS EFFECTS OF SPACE FLIGHT
ON CIRCULATORY SYSTEM
(HEART AND BLOOD VESSELS)

Figure 8. Cardiovascular Function.

Figure 9. Lower Body Negative Pressure Device (LBNP).

PULMONARY FUNCTION AND ENERGY METABOLISM

PURPOSE: ASSESS EFFECTS OF SPACECRAFT ENVIRONMENT ON
CREW'S RESPIRATION, BODY MASS AND COMPOSITION,
AND ENERGY COSTS OF PHYSICAL ACTIVITY

Figure 10. Pulmonary Function and Energy Metabolism.

Figure 11. Bicycle Ergometer and Metabolic Analyzer.

NEUROPHYSIOLOGICAL FUNCTION
(VESTIBULAR AND SLEEP)

PURPOSE: EVALUATE EFFECTS OF THE SPACE
ENVIRONMENT UPON THE CENTRAL
NERVOUS SYSTEM OF MAN

Figure 12. Neurophysiological Function - Vestibular and Sleep.

Figure 13. Rotating Litter Chair.

TIME AND MOTION

(BEHAVIORAL)

PURPOSE: ASSESS MAN'S FUNCTIONAL EFFICIENCY IN COMPLETING OPERATIONAL AND SCIENTIFIC WORK DURING LONG DURATION SPACE FLIGHT

Figure 15. Time and Motion - Behavioral.

Figure 16. Orbital Workshop - Work Area.

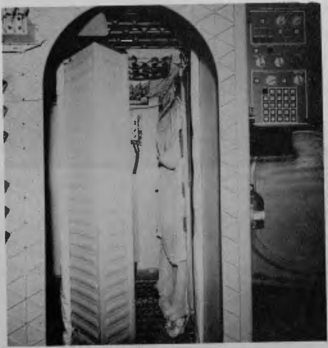

Figure 14. Sleep Station.

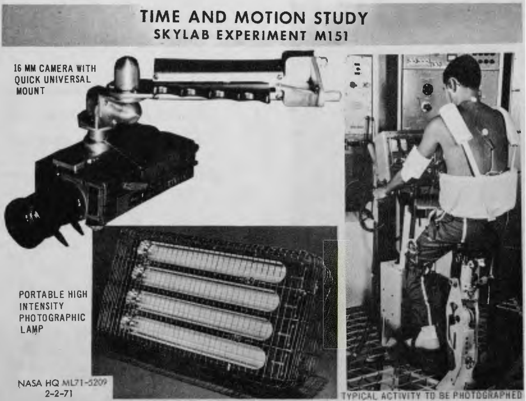

Figure 17. Time and Motion Hardware.

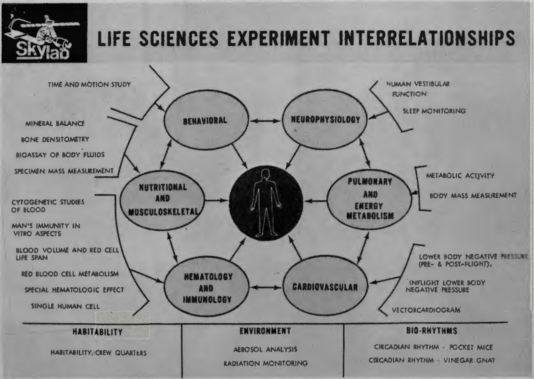

Figure 18. Medical Experiments Interrelationships.