APOLLO 15

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APOLLO SUMMARY REPORT

ABSTRACT

CARDIOVASCULAR FINDINGS

G. W. Hoffler, M.D., R. L. Johnson, M.D., and
R. A. Wolthuis, Ph. D.

USA/USSR JOINT WORKING
GROUP ON BIOLOGY AND SPACE MEDICINE
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APOLLO SUMMARY REPORT

CARDIOVASCULAR FINDINGS

ABSTRACT

A brief historical resume of American manned space missions has emphasized the importance of alterations in the cardiovascular system affecting human orthostatic tolerance. Decreased orthostatic tolerance has been observed clinically after Mercury flights, measured by tilt table stress testing during Gemini, and elaborated upon primarily with the use of incrementally applied lower body negative pressure (LBNP) testing in Apollo missions. Correlation with multiple other measurement data from other investigators has gradually produced some clarification of the total physiological picture.

Of 9 Apollo missions to date, LBNP has been used in four (12 cremembers), abbreviated orthostatic stand tests were performed in three missions; and both tests were used in one mission. Apollo missions have been earth and lunar orbital with four lunar landings (8 crewmembers); mission durations have ranged from 143 hours to 295 hours and lunar stays from 22¼ to 67 hours.

Results have been categorized by measurement. Post-flight values have been compared with preflight baseline determinations (3 each) on individual crewmen.

Heart rate from an electrocardiographic lead has been the single most useful measurement. Of 21 crewmen tested,

12 have shown statistically significant postflight elevations in their supine resting heart rates. Eighteen of this 21 had significantly elevated heart rates during postflight orthostatic stress tests. Heart rate elevations are directly correlated with weight loss (averaging 6 pounds for the total 27 crewmen), which also correlates with fluid volume deficits.

Maximal calf circumference decrement postflight averaged nearly 0.4 inch, indicative of muscle mass loss. Calf volume changes during LBNP have not revealed a significant postflight pattern.

Blood pressure, taken only every 30 seconds, has revealed decreased pulse pressure during supine, resting and orthostatic stress states postflight in the majority of crewmen. There also appears to be increased lability of blood pressure postflight.

Five crewmembers experienced presyncopal episodes during postflight stress testing, a response not observed during preflight tests.

The cardio-thoracic ratio determined on both pre- and postflight chest films for nearly all astronauts has revealed a highly significant decrement postflight (approximately -.02). This decrement appears, however, to be directly, but non-linearly, related to mission duration. Further differences are indicated by an apparent "protective" effect for those crewmen who spent time on the lunar surface.

The influence of other environmental conditions, including possible circadian effects, on test results have been critiqued. With essentially identical tests performed on ground control subjects, the results from space crewmen appear to be authentic.

The addition of the precordial vibrocardiogram and the vectorcardiogram to Apollo 15 crew evaluations has provided baseline data, not yet fully analyzed, for additional interpretations and for support of the Skylab M090 series inflight experiments.

SUMMARY OF NASA/MSC BONE MINERAL STUDIES

October 1971

A. Continual bed rest for 30-36 weeks without treatment leads to:

1. a loss of total body calcium of about 0.5%/month,

2. a loss of mineral from the central calcaneus of about 5%/month, suggesting that mineral loss during bed rest occurs preferentially from bones which are normally weight-bearing, and

3. a reversible disease. All subjects regained all of their calcaneus mineral within a few months of reambulating.

B. Assuming that bed rest is analogous to weightlessness (since in both situations the mechanical forces to which the skeleton is normally subject during ambulation in a one G environment are absent), we would predict that astronauts undergoing space flight of more than several months duration will develop a serious degree of demineralization. This demineralization is expected to place them at risk for the development of traumatic fractures, particularly of bones which are normally weight-bearing. In addition, the increased urinary calcium excretion places them at risk for the development of kidney stones.

C. Several treatment programs have been studied in an attempt to prevent mineral loss during bed rest and by implication reduce the hazard to future long range astronauts:

1. A horizontal exercise program employing the Exer Genie apparatus for 80 min/day had no effect on mineral loss during bed rest.

2. Longitudinal compression administered by a GASS suit for 5 hours/day at 80% of body weight may have reduced the mineral losses but did not totally prevent them.

3. Intermittent longitudinal compression at a cycle of 45/min with full body weight being applied for 6 hours/day also did not prevent the mineral loss, although some attenuation may have occurred. Both forms of compression are probably impractical since the suits are tedious and uncomfortable to wear.

4. Calcitonin injections failed to have a favorable influence on the mineral loss.

5. Oral phosphate supplements, 1.3 gm P/day as the neutral potassium salt, prevented the increased urinary calcium during bed rest but did not change overall calcium balance or mineral loss from the calcaneus. We believe that phosphate supplements would be useful for preventing kidney stones but not for preventing demineralization.

6. Calcium and phosphorus supplements (1.3 gm Ca/day as the lactate and 1.3 gm P/day) prevented the negative calcium and phosphorus balances during the first 10 weeks of bed rest but subsequently there was an apparent escape from this effect and negative balances developed. Loss of mineral from the calcaneus may have been attenuated but was not prevented in all subjects.

APOLLO SUMMARY REPORT

ABSTRACT

BONE MINERAL MEASUREMENT

J. M. Vogel, M.D.

USA/USSR JOINT WORKING

GROUP ON BIOLOGY AND SPACE MEDICINE

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APOLLO SUMMARY REPORT

BONE MINERAL MEASUREMENT

ABSTRACT

Loss of mineral from bone during periods of immobilization, recumbency or weightlessness have been observed. These losses are more apparent in the lower extremity than the upper and have been observed to exceed 30% in the case of the central os calcis during 36 weeks of bed rest. No mineral losses were seen in the upper extremity during this same period of time.

In early Gemini studies using X-ray densitometry, large losses of bone mineral were observed in the radius and ulna. This observation was not validated in the Apollo XIV and XV crewmen when a more precise technique, gamma ray absorptiometry, was used. Mineral losses from the central os calcis have been variable. Again, the large losses reported for the early Gemini missions were not seen when this newer measuring technique was employed. Indeed, 4 of the 6 crewmen studied lost no mineral during the 10 and 12 day missions. Since two crewmen did lose mineral from the os calcis, it is clear that losses can occur even in these short periods of time, even though losses are not seen in 14 days of bed rest. If these losses were allowed to continue unabated for a prolonged period of time, the consequences might be severe, since the losses observed are probably not confined to the os calcis.

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APOLLO SUMMARY REPORT

ABSTRACT

FLUID AND ELECTROLYTE BALANCE

(ENDOCRINE HOMEOSTASIS)

C. Leach, Ph. D. and W. C. Alexander, Ph. D.

USA/USSR JOINT WORKING
GROUP ON BIOLOGY AND SPACE MEDICINE
MOSCOW, OCTOBER 1971

APOLLO SUMMARY REPORT

FLUID AND ELECTROLYTE BALANCE

(ENDOCRINE HOMEOSTASIS)

ABSTRACT

Spaceflight produces complex physiological changes due to the individual or summating stresses of the environment. These stresses which include weightlessness, acceleration, confinement, restraint, and exposure to radiation constitute the major challenge to the discipline of space medicine. It has been the purpose of our investigations to study the effect of spaceflight upon man's ability to adapt to the environmental changes to which he is exposed.

Upon transition from earth's gravity into the weightlessness state, a series of changes are postulated which, when effected, depict the adaptive processes characteristic of exposure to the space flight environment. Although to date, inflight sample collection has, at best, been severely limited and essentially unrewarding, a thorough evaluation of pre and postflight body functions has yielded information upon which a hypothesis for space adaptation has been formulated. Plasma and urinary excretion values of selected endocrine and biochemical parameters have been recorded in space crews prior to and following varying exposures to weightlessness in the Projects Gemini and Apollo series of urine and plasma electrolytes; urinary antidiuretic hormone, aldosterone and catecholamines; and in plasma angiotensin suggest an adaptation to the weighless environment with values significantly different from those considered normal in the one g state. These adaptive changes are

characterized by an absolute decrease in total body water, a total body potassium deficit, and a predicted compensated intracellular acidosis. While deemed adequate for the null gravity environment, this homeostatic "set" is not without physiological cost, and could reduce the functional reserve of exposed individuals. The hypothesis and supportive data describing this adaptive process is presented and its relevance to long duration exposure to the weightless environment is discussed.

APOLLO SUMMARY REPORT

ABSTRACT

HEMATOLOGY AND IMMUNOLOGY

S. L. Kimzey, Ph. D. and C. L. Fischer, M.D.

USA/USSR JOINT WORKING
GROUP ON BIOLOGY AND SPACE MEDICINE

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APOLLO SUMMARY REPORT
HEMATOLOGY/IMMUNOLOGY

ABSTRACT

Laboratory analyses of blood performed in support of the Apollo Program were designed to evaluate the biochemical responses of man to the spaceflight environment. The measurements of red cell mass were of particular interest due to the significant decreases in red cell mass observed during the Gemini flights.

The red cell mass losses measured in the Apollo mission were variable and correlated closely with the length of exposure to a high oxygen atmosphere. These data seemed to confirm the hypothesized toxic effect of oxygen on the circulating red blood cells. The initial hypothesis predicted an intravascular hemolysis of the cells due to failure to maintain osmotic balance. However, based upon additional data collected, this hypothesis may have to be modified. It now seems more likely that alterations of red cell membrane lipids and/or sulfhydryl bonds causing membrane structural changes would lead to fragmentation of the red blood cells and their subsequent destruction by the reticuloendothelial system.

No significant changes attributable to the spaceflight conditions were noted in routine hematological parameters. The exception to this being a postflight observation of a transient leucocytosis associated with an absolute neutrophilia and lymphopenia of small but significant magnitude.

Serum chemistry and protein value have shown only minor changes. Haptoglobin shows a marked elevation (70%) in all flights with only a gradual

(> 2 weeks) return to the normal values. The significance of increased serum haptoglobin has not been determined, but as mentioned above, the concept of intravascular hemolysis is not consistent with elevated levels of this protein. There have been cases of increases in immune globulins G and A and ceruloplasmin, but only in selected crewmen. These increases in the immunoglobulins are probably related to the reported episodes of clinical illnesses reported during some flights, and the moderate acute phase response might well be the result of the nonspecific stresses encountered during the spacecraft's reentry.

In summary, it might be stated that there are no data to suggest that man's humoral or cellular immune systems were compromised or stressed significantly as a result of the Apollo flights, except in cases of reported clinical illnesses attributable to causes not unique to the spaceflight environment.

APOLLO SUMMARY REPORT

CENTRAL NERVOUS SYSTEM - SLEEP

ABSTRACT

Sleep during the Apollo missions has proven to be as variable as it is on Earth when factors known to influence it are encountered. Elements such as time of attempted sleep, duration between sleep periods, previous sleep deprivation, sleep wakefulness schedules which do not coincide with usual Earth routines, disturbances caused by non-simultaneous sleeping of the crew, excess noise, uncomfortable temperature, sleep facility comfort, anxiety, and excitement, all have been reported to influence sleep in the spacecraft environment.

During Apollo flights it was necessary for man to accommodate to specific mission requirements. Factors which influence sleep could not always be sufficiently controlled to insure that the astronaut obtained adequate sleep. This was demonstrated in Apollo missions 7 - 15. The stress of sleep loss was not of sufficient magnitude to induce gross changes in performance. At times the crewman was sufficiently aware of sleep need to utilize the assistance of a hypnotic to bring about sleep onset.

Sleep aspects of the Apollo flights to date may be summarized as follows:

1. Preflight and postflight baseline sleep profiles were not obtained in Apollo 7 - 15 missions.

2. There exists a discrepancy between the astronaut's subjective evaluation of sleep duration and quality and that estimated on the basis of limited EKG and respiratory data available to the medical monitor on Earth.

3. Based on information obtained to date, it is not possible to draw conclusions regarding the effect of 0 g on man's sleep.

4. There is no central nervous system data available on which the quality or quantity of astronaut's sleep may be described during Apollo flights.

5. Conditions of the environment, assigned work/sleep periods, etc., were sufficiently different for the various Apollo series that a meaningful comparison for sleep function cannot be obtained.

6. Information is not at hand to allow the influence of individual factors affecting sleep to be evaluated.

7. The evidence is strong that erratic departure of assigned sleep periods from the customary sleep time on Earth is a consideration that bears close attention in mission planning.

The measure of sleep adequacy or inadequacy largely depends upon the degree of deviation from the individual's normal sleep pattern. Secondary importance is placed upon deviation from sleep patterns of the general population.

An objective measure of sleep quality and quantity can be obtained only by monitoring nervous system activity by means of the electroencephalogram and the electro-oculogram. Use of heart rate and respiratory function to estimate sleep quality and quantity is recognized as being less than perfect; however, these factors are utilized to monitor sleep during flight in lieu of nervous system information which is not available.

A first step toward obtaining objective information on the effect of space flight upon sleep would be to record nervous system activity and heart rate during sleep, both pre- and postflight. With a proper baseline record it will be possible to quantify any alteration of sleep upon return to Earth. The heart rate pattern obtained during baseline sleep recording may be referred to when attempting to assess the inflight sleep.

If a hypnotic is included in the medical kit during flight, it is desirable that the selected drug be administered to the crew preflight and its effect upon their sleep monitored.

As a result of NASA, MSC, fundamental research support, technical developments that permit optimum evaluation of sleep in the space flight environment are coming into fruition.

APOLLO SUMMARY REPORT

ABSTRACT

STATOKINESIS

M. R. DeLucchi, Ph. D.

USA/USSR JOINT WORKING
GROUP ON BIOLOGY AND SPACE MEDICINE
MOSCOW, OCTOBER 1971

APOLLO SUMMARY REPORT

STATOKINESIS

ABSTRACT

Statokinesis may be defined as the adjustment made by the body in motion to maintain stable equilibrium. Neuromuscular function is a prime element in efficient statokinetic adjustments. The vestibular system and visual apparatus is significantly implicated. Any factor which affects the function of the sensory, coordinating, or motor aspects of the reflex cycle will impinge upon the response of the statokinetic mechanism.

During the Apollo series specific neuromuscular examinations with the objective of assessing statokinetic alterations were not conducted either preflight, postflight, or during the mission. However, careful observation was made of the astronauts upon their return to Earth, their overall physical appearance, and their ability to walk about immediately postflight. Comments made during the postflight physical regarding equilibrium, walking, postural adjustment, etc. were noted. In addition, the pre- and postflight physical examination included clinical evaluation of nervous system function.

There has been little comment which might relate to statokinesis other than casual remarks concerning "sea legs" when first walking on the recovery vessel.

Modification of lean body mass, loss or change in the size of particular muscle groups, electromyograph evidence of muscle function, and modification of neuromuscular reflex, are aspects of physiology which may in the future require investigation. Long duration flights may involve statokinetic mechanisms to a degree not apparent in present missions.

APOLLO SUMMARY REPORT

ABSTRACT

EXERCISE RESPONSE TESTS

J. A. Rummel, Ph. D., E. L. Michel, M. S.
and C. A. Berry, M.D.

USA/USSR JOINT WORKING
GROUP ON BIOLOGY AND SPACE MEDICINE

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APOLLO SUMMARY REPORT

EXERCISE RESPONSE TESTS

ABSTRACT

During the Apollo Program, the physiological response to programmed work was measured pre- and postflight to evaluate the effects of weightlessness. Of immediate concern was the detection of any physiological differences which could have impacted the capability to complete lunar surface objectives. A longer range objective was to develop hypotheses concerning homeostatic adaptive mechanisms which could be evaluated on longer duration post Apollo flights.

Exercise response tests were conducted pre- and postflight on Apollo missions 7 through 11 and on Apollo 14 and 15. Operational constraints precluded obtaining work capacity data on Apollo missions 12 and 13.

A bicycle ergometer, having a heart rate control feedback loop, was utilized to produce an exercise load for the subject. This ergometer compares the actual heart rate to a pre-set heart rate and varies the work resistance accordingly. Thus, it was possible to produce the same relative heart rate stress pre- and postflight. The controlled ergometer was utilized to produce three stress levels: 120 heart rate for six minutes, 140 heart rate for three minutes, and 160 heart rate for three minutes. (One crew of three was taken to a level of 180 beats per minute).

Significant changes were observed immediately postflight for the Apollo 7 to 11 crews on the following dependent variables: workload, oxygen consumption, and systolic and diastolic blood pressure. There

were no changes in work efficiency at 100 watts or the oxygen utilization coefficient at 2.0 l/min V_{O_2}.

On the Apollo 14 mission, a significant reduction in work capacity was shown by the Command Module Pilot while there was minimal change noted in the two crewmen who participated in lunar surface exploration - 34 hours on the lunar surface and approximately nine hours each during extra-vehicular activity.

While the Apollo 15 data are still under evaluation, they appear to show a reversal of the Apollo 14 findings. The two Apollo 15 lunar surface explorers, with nearly 67 hours on the moon's surface and about 18½ hours each during extra-vehicular activity, showed a greater reduction in work capacity than did the crewman who remained in orbital flight.

What appeared to be a salutary effect of 1/6 g activity on Apollo 14 was not evidenced by the Apollo 15 crewmen who performed greatly increased work activities on the lunar surface.

During the remaining Apollo missions, attention will be directed to attempting to clarify these findings and to close evaluation of the effects of activity on the lunar surface in 1/6 g.

APOLLO SUMMARY REPORT

ABSTRACT

VESTIBULAR SYSTEM DISTURBANCES

J. L. Homick, Ph. D.

USA/USSR JOINT WORKING
GROUP ON BIOLOGY AND SPACE MEDICINE

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APOLLO SUMMARY REPORT

VESTIBULAR SYSTEM DISTURBANCES

ABSTRACT

It has long been recognized that the vestibular system plays a significant role in man's total response to the space flight environment. However, mission priorities have precluded a thorough inflight evaluation of this system to date. Although extensive ground-based research programs have been conducted which directly relate to the conditions encountered in space flight, the majority of our present knowledge of the actual effects of exposure to the space flight environment is qualitative in nature rather than quantitative. To date no vestibular experiments have been carried out in conjunction with Apollo missions.

Careful examination of available information on vestibular-related experiences of Apollo astronauts has revealed the following general findings:

1. Of the 27 individuals who have flown thus far, nine have experienced apparent vestibular difficulties. Of these nine, seven had some previous history of motion sickness, while two had negative histories. On the other hand 13 of 20 individuals with positive histories had no inflight symptomotology.

2. Of the nine individuals with inflight problems four experienced minor symptoms, two experienced moderate symptoms, and three had severe symptoms. It is questionable, however, whether the vomiting experienced by one of these latter individuals was vestibular in origin or due simply to gastro-intestinal virus.

3. Of the 11 astronauts making their first space flight, five or nearly 50 per cent, developed inflight symptoms. Of the 16 veteran pilots, only four or 25 per cent, experienced symptoms.

4. Finally, there is no clear relationship between previous aircraft flying hours and space flight motion sickness.

The lack of quantitative pre-, in-, and postflight vestibular data on individual crewmen renders a valid assessment of the Apollo findings and problems difficult. However, certain tentative conclusions can be made:

1. Increased intravehicular mobility and thus increased head movements as afforded by the larger volume of the Apollo CM/LM has resulted in a higher incidence of vestibular disturbances during Apollo flights than in previous programs.

2. In most cases where symptoms did occur they were mild to moderate and could be controlled by limiting head movements the first few days in flight.

3. Adaptation of the vestibular receptors to the weightless environment apparently does occur almost immediately or within a few days for most crewmen. Whether or not such adaptation is complete or partial, or will persist for very long duration missions remains questionable.

4. Extravehicular activity in 1/6 g on the lunar surface has resulted in no reported disorientation or vestibular disturbances during the missions conducted to date. Apparently the 1/6 g is an adequate stimulus for the otoliths in providing sensory information about gravitational upright and, hence, maintenance of posture.

5. With one very significant exception on Apollo 15 no crewmen have experienced vestibular disturbances after returning from space flight. This suggests that adaptation that occurs during weightless flight does not render the system hyposensitive or hypersensitive following sudden return to a 1 g environment. Whether or not this situation will be true following very long exposure to 0 g also remains uncertain.

6. It appears that individuals with a positive history of motion sickness have a slightly greater tendency to develop motion sickness symptoms during space flight than do individuals with negative histories. Also, rookie astronauts appear to have a greater likelihood of developing inflight symptoms than veteran astronauts.

A need is indicated for more inflight as well as pre- and postflight vestibular information on the astronaut population. Only by examining with quantitative methods the men who actually fly space flight missions can we achieve a complete understanding of the effects of weightless space flight on vestibular function.