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# SOME BIOPHYSICAL PROBLEMS ASSOCIATED WITH FITNESS MAINTENANCE IN PROLONGED SPACE FLIGHT

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## INTRODUCTION

With the advent of controlled space travel, the biodynamic potential of man is being put to the supreme test. Never before has it been so necessary to teach men how to do a given job in an alien environment with a minimum expenditure of energy and with a maximum efficiency. A successful astronaut must combine the qualities of a pilot, engineer, athlete, mathematician, astronomer, and have knowledge of many allied sciences in order to maintain his orientation in space as well as return valuable information for future space exploration.

One must approach the study of space travel from a somewhat different viewpoint than terrestrial adventures in a view of our limited knowledge of the long-term effects of such travel on the individual physiologically and psychologically. At best, we can only hope to mimic or imitate a few of the physical environmental situations the space flyer will encounter. Our inability to imitate low gravity conditions for long periods of time may lead to a great deal of misunderstanding as to what the effects of prolonged low gravity residency may have on the human organism.

## Nature of the Problem

On the assumption that space travel of long duration will be possible in the not-too-distant future, several problems or questions stand out above all others.

What effect will prolonged space flight have on the hemodynamic responses of a well-conditioned healthy man who will be physically incapable of gross muscular movements during the period of his flight confinement?

On the assumption that our astronaut may ultimately land on an alien satellite station or planet, and thereafter be dependent upon his own physical strength for survival, how much physical strength deterioration will take place during flight and how can this deterioration be delayed or prevented?

## What We Know

Graybiel (1), Graveline (2), and Beckman (3), have many studies of pseudo-hypogravic conditions by water immersion techniques over varying periods of time. Keys' (4) studies of enforced bed rest and immobilization are of great interest in this same general area of investigation. Several specific effects were noted in these studies which may have direct implications for prolonged flight as expected with orbital flights of Gemini and Apollo and future interplanetary flights. The more obvious effects are: loss of cardio-vascular and neuromascular tone; formation of kidney stones and deterioration of the structural integrity of the bones (osteoporosis). All of these hazards of space flight may be prevented by physical ex ercise. Studies to elucidate training programs for pre-flight conditioning in flight maintenance of fitness and post-flight rehabilitation are urgently required. The present schedule of planned, prolonged manned orbital flights for 1965 emphasize the urgency of this program.

## Evaluation of the Problem in Light of Present Knowledge

### A. Changing Concepts of Training

In the past, studies of training effects have been concentrated on the cumulative effects of the training rather than the persistency of these effects. In this type of program we are concerned with the deterioration of the individual after training and techniques, other than the conventional training technique, which may be useful in delaying the fitness deterioration. It will be necessary to study the time-rate of fitness deterioration with different training procedures to evaluate the "fitness persistence factor" -- to coin a phrase.

Our space pilots have not as yet remained aloft long enough to require this type of fitness reappraisal; this is a problem of future space flight of prolonged duration, which must be anticipated.

### B. Pre-flight Conditioning

In orbital and other space flights of less than one week duration, the physical stresses of take-off and entry and the movements necessary to accomplish the many objectives of these brief missions may be adequate to preserve physiological integrity. As space missions increase in duration beyond a week the astronaut becomes increasingly likely to suffer the debilitating effects of hypogravity unless preventive measures are taken.

Hypogravity may be less debilitating if the astronaut has developed a reserve of neuromuscular strength and cardio-vascular endurance in preparation for the flight. Useful residues of hard physical training may persist for weeks after training has stopped. Physical condition persists after training roughly proportionate to the length of the training program. Once a high level of condition is established, only brief and infrequent exertions serve to maintain it -- that is, if these exertions are fairly intense--DeLorme (5). Isotonic strength exercise is superior to isometric--Darcus (6) and Muller's (7) findings that one daily isometric contraction of 30% of maximal value or greater will maintain and even increase muscle tonus is subject to question--Peterson (8). Streimer (9) has discussed the problem of strength performance in relation to prolonged space flight. The pre-flight conditioning program must be vigorous--Hellebrandt (10) to have lasting effects.

The problem of pre-flight conditioning, therefore, is to raise the levels of neuromuscular and cardio-vascular condition to near capacity limits with the least expenditure of the astronaut's time and energy, and without risk of injury or overfatigue.

### C. In-flight Maintenance of Condition

Orbital experiences to-date seems to indicate early swimming pool studies -- showing that hypogravity is not an acute problem in human performance. Tasks are accomplished with less effort, adaptation to lessened kinesthetic cues comes readily and motions soon become precise. There is little or no disorientation and the sensation of weightlessness is a pleasant one. Indeed, the antigravity mechanisms of man are so inadequate that they undoubtedly shorten his life span and contribute to many of his ills and discomforts. In a sense, hypogravity environments such as water and space, may be man's most "normal" environment. While in water or space he is comfortable and functions well. It is when he resumes the upright position on earth, after prolonged hypogravic states, that he senses his loss of adaption to the dragging force of gravity. Thus, it is not so much his condition in space that needs concern, it is his return to earth for which he must become prepared.

However, there is one exception in prolonged hypogravity, bones and cartilage soften and thin--Inglemark (11). The mechanism is not completely understood, but evidently the pressure of gravity against bones facilitates their metabolic processes. Whether or not exercise in space can be an effective substitute for gravity in the maintenance of integrity of bone is an urgent subject for study.

Physiologically, in space it is as if the man was freely suspended in water, like the Cartesian diver. Or, it is as if he had executed the orbital portion of his mission in a hospital bed with physical therapists helping him to make every motion a passive one. We know what effect this would have. Without preparatory physical training and physical maintenance procedures, man in space will - in about the same time as the bedridden victim - find bones disintegrating, his muscles atrophying, and his vasomotor adjustments to changes in posture depressed.

As long as he remains inactive in space, these debilitations will not be felt unless he attempts a maximum effort as in pushing, pulling, or bracing. Then he will discover his weakness. If the position of the effort is mechanically unfavorable, he may seriously injure himself.

The problems of in-flight maintenance of condition, therefore, are (1) to prevent demineralization of bones, and (2) to devise a regimen of exercises making use of the operator's environment in space craft which will maintain sufficient strength, endurance and vasomotor tone to meet the stresses of gravity when he returns to earth, and to meet emergencies requiring muscular effort and cardiovascular endurance in space.

Electrical stimulation of muscles of the galvanic type to maintain muscular and circulatory tone is potentially dangerous if the "program" of electrical stimulation comes on when the spaceman is in the middle of the performance of a task. Besides that, the effectiveness of this method of conditioning is doubtful. Lacking automatic exercise procedures, then, we may be forced to rely upon the man's conditioning regimens, it is quite likely that there will always be a few men in space crews who have not keptfit for gravity.

D. <u>Post-flight Rehabilitation</u>

It is when he returns to earth or lands upon planet with similar or greater gravity after a long journey in space that the deconditioned voyager will discover his physical deterioration. Accelerative forces of entry and landing will crush him and he will lack the strength and cardio-vascular tone to resist it--Beckman (3). Like the hospital patient after a month lying quietly on his back, on return to earth the mere postural effort to sit or stand may cause him to faint.

Ground support procedures must be ready to care for space crewmen who have not taken adequate exercise in space. Motivation to exercise is low when man is at ease and confined to small space. Forcing a space crew to exercise by linking mechanical resistance to food-getting, elimination, or other life support functions is dangerous.

The problem of post-flight rehabilitation, or it might be called "terrestrial rehabilitation," therefore, is to study the applicability of existing hydrotherapy--Lowman (12) and other procedures which could be applied immediately after return to earth and continued until the spaceman's fitness to resume life on earth has recovered.

## Can Machines Maintain Fitness?

### A. Development of a Bio-ergometer

A basic instrument for the research studies is now being considered. It is a bio-ergometer -- a man-machine system designed to elucidate phenomena of human adaptation to work. Work input is to be controlled automatically by physiological outputs. For example, a myoelectric output could determine work force; cardio-electric output could determine work rate; and theromo-electrical output could determine work duration. From standards obtained in this earth laboratory, comparisons could be made of work situations in space and on the moon and other planets. The immediate practical application of this instrument is its use as a physiological training device for space crew preparation and terrestrial rehabilitation. Orbital space flights have demonstrated that slight variations in function of environment control systems severely tax man's performance and limit his tolerance to the point of jeopardizing the success of the flight. Astronauts realizing that neurmuscular, cardio-respiratory and temperature-regulating mechanisms may be limiting factors in their survival in space, are now giving some attention to training. Running is seen as one effective means of physiological preparation for space. The bio-ergometer instrument herein described could tell the space candidate how fast to run, what grade to run up, and how long to run to best achieve the physiological objectives of his training. This program could be established in a space-training laboratory and then used outdoors by employing telemetry or a hard wire instrument which yields "faster," "higher," "farther" signals to the performer to regulate his training.

A training regiment which employs a workload of a certain intensity appears to result in chronic physiological responses which are specific to that load. For example, all-out runs to early exhaustion imporve anaerobic mechanisms. If the running load is reduced slightly below maximum level so that exhaustion is delayed some minutes, the oxidative mechanisms are benefited. Running load reduced even lower, prolonging exhaustion, benefits the body's temperature-regulating mechanisms. Results of this type of work are improved resistance to hyperthermia and improved salt retention in sweating. Thus, the three parameters' load, rate and duration can conceivably be combined in program to induce specific physiological training results.

Individual differences in response to exercise, and different states of training affect the physiological response to a fixed workload. Thus, regimens of training require progressive gradations of work of all types to prevent premature exhaustion of injury, and to insure adequate stimulus for further training as physiological mechanisms improve.

Planning of training schedules consists ideally of matching workload to physiological response. This task might be better accomplished by automation than by human judgment, since the individual or his instructor must rely upon sensations and outward signs to detect if the workload is too heavy or too light to accomplish the physiological or performance objectives of the training program. Living under hypogravic conditions may make these senses unreliable.

The bio-ergometer, as conceived, is designed to do this. Human physiological outputs are fed into a computer where appropriate calculations are made. The computer outputs are signals that adjust treadmill grade and speed to achieve preset "anaerobic," "aerobic," or "temperature regulation" objectives. The candidate can terminate the work voluntarily by hitting a STOP button.

## CONCLUSION

All of our thinking to-date has been geared to training men to run or swim faster and farther or making man jump higher. Training regimens are patterened to prepare a man to do a relatively specific job within a given time interval; little thought has been devoted to appraising the "persistency" of the training effects.

Very little thought has been given to training a person for prolonged periods of physical immobility which we must anticipate in connection with space flight. Some studies in the area of physical therapy have concerned themselves with the maintenance of specific kinds of fitness, such as muscle strength, with little consideration for the other multi-faced facets of fitness which are of concern to the whole man.

Despite the limited scope of hypogravic and bed-rest experiments to-date, certain physiological variables have been assessed and are suggested areas for further inquiry. The pre-flight and in-flight maintenance of normality of function of the respiratory, circulatory, digestive and excretory system may hinge entirely upon persistent physical activity--activity which will, of necessity, be carried on in a most limited space.

The problem of post-flight fitness conditioning under lunar gravity conditions has been discussed in detail by Gaume and Kuehneggar (12).

In some of the earlier investigations of men confined for long periods at simulated altitudes (10,000 feet) and elevated oxygen partial pressures (418 mmHg), some oxygen toxicity in 1/3 of the subjects was observed by Gell (13). The question arises as to whether or not oxygen toxicity can be deferred or prevented by vigorous physical activity.

The recent summarized reports of the blood pressure and heart rate responses of the Mercury Astronauts are of great interest, but apparently not of immediate concern. The high pulse rates, in excess of 160 just prior to launch, is of the order of pulse rate response one finds in the laboratory in a man working at his maximal aerobic working capacity on a treadmill walk, but perhaps, only reflects extreme emotional tension! The persistent elevation of the systolic blood pressure of the subjects in flight, subject to future re-appraisal, is perhaps of more significance. (14)

The psychological implications of prolonged physical inactivity, which have a tendency to lead to emotional depression and inanition, must be given every consideration. Experience with the long underwater nuclear submarine voyages has shown, that reading, per se, is a very inadequate substitute for physical inactivity. Some nuclear sub commanders have recommended less automation and more physical effort for the crew. The automated responses of the vehicle and the man in a free-flight space vehicle may be the astronauts' greatest psychological handicap, especially in the face of neglibible physical activity.

Those areas in which biological deterioration can be expected have been summarized by many authors and can be generally categorized by: declines in strength and neuro-muscular coordination, circulatory asthenia and allied hemodynamic responses, perceptual and orientation difficulties, distrubed hormonal secretions, bone and cartilage distrubances and possibly, blood dyscrasies.

What we are asking, therefore, are these broad questions: CAN SOME FORM OF PRE-FLIGHT TRAINING DEFER OR PREVENT THESE ANTICIPATED BIOPHYSICAL DETERIORATIONS? CAN AN IN-FLIGHT TRAINING PROGRAM BE DEVELOPED WHICH CAN ADEQUATELY SUBSTITUTE FOR NORMAL PHYSICAL ACTIVITY IN THE MAINTENANCE OF FITNESS GENERALLY? HOW CAN THIS PROGRAM BE SUPERIMPOSED ON THE NORMAL EVERYDAY ACTIVITY OF THE ASTRONAUT?

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