Effect of Weightlessness on Mineral Metabolism; Metabolic Studies on Skylab Orbital Space Flights

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After eight years of preparation, which took place before and during the Apollo-Moon space-flight series, the National Aeronautics and Space Administration in May 1973 launched into orbit a cylinder 22 feet in diameter and 48 feet in length called the Skylab Orbital Workshop. The living quarters and storage area of this cylinder contained nearly all of the life support and scientific experimentation equipment and supplies for three separately launched three-man astronaut crews. The first crew remained in orbit for 28 days, the second for 60 days, and the last crew for 84 days.

Of the more than 100 scientific experiments or observations in the Skylab Program, 16 were devoted to the medical or physiological performance of man in the weightless state in space. This report provides the principal results of one of these studies, that on mineral and nitrogen balance. This “experiment” required of the cooperating astronauts fairly constant dietary intake, continuous 24-h urine collections and total fecal collections for 21–31 days before each flight, throughout each flight and for 17–18 days post-flight for a total of 909 man days of metabolic study.

Prediction that the various stresses of space flight, particularly weightlessness, would bring about significant derangements in the metabolism of the musculoskeletal system has been based on various mineral and nitrogen balance study observations of long immobilized or inactive bedrest. The earliest was that of Deitrick, Whedon and Shorr (1) in 1948.

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Immobilization of four healthy young men in body casts for 6 to 7 weeks led to marked increases in urinary calcium and significantly negative calcium balances, and there were related losses of nitrogen and phosphorus. Several subsequent bedrest studies of normal subjects confirmed these substantial metabolic derangements (2). The longest observation (3) showed that although the elevated urinary calcium subsided partially during the third and fourth months of bedrest, it nevertheless remained significantly higher than control levels for as long as bedrest was continued (for 7 months) and did not fall to normal until the subjects were put back on their feet.

The only attempt — not fully successful — at controlled metabolic observations in space flight prior to Skylab was performed by us (4) in conjunction with the 14-day Gemini-VII flight in 1965. That relatively short study revealed quite modest losses of calcium and phosphorus and varied changes in the metabolism of other elements.

**PROCEDURE**

A cardinal principle of metabolic study is that changes in the excretion of key nutrient elements, such as calcium or nitrogen, can only be interpreted as due to the influence or agent under test if environmental factors are kept as constant as possible from phase-to-phase and from day-to-day. One of the most important of these factors in metabolic study is the dietary intake. We had relatively little control over the selection by NASA, for various reasons of stability and acceptability, of the 70-odd space food items, the main types of which were solid foods in plastic packages, sticky semi-liquid foods in metallic tins, magnetically held in flight to a warming tray, and drinks in closed plastic cylinders. Selection was constrained for most items by the requirement of stability at room temperature in space for more than a year; only seven frozen food items could be used. In addition, in an effort at best acceptability, many items were mixtures of foods and thus not conducive to exactness of composition in their production. Although these foods were far from ideal for balance studies, nevertheless by skillful, lengthy consultations with the astronaut crew members, our dietitians developed for each crewman, sequences of six menus of similar elemental composition which were rotated steadily throughout the pre-flight, in-flight and post-flight study phases. Whenever a particular food could not be consumed, a system of rapid calculation and provision of supplement tablets for pertinent elements helped to maintain dietary element constancy. During the flight phase, the crew’s evening report to Ground Control included the relatively