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Weightlessness and Weight Loss: Malnutrition in Space

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**Author**

Senter, Carlin

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## Introduction

In the new millennium NASA hopes to explore beyond earth's orbit and orchestrate space missions that last up to five years; however, this goal is currently unrealizable in part due to problems with food and nutrition in space. In the last 30 years, approximately 370 people have traveled to space (1). Most of them have returned to earth with weight loss, muscle wasting, fluid loss, and decreased bone density, the degrees of which correlate with mission duration (2). Astronaut nutrition not only plays a crucial role in body physiology, it is also important psychosocially. The psychosocial role of food and meals may be enhanced in the stressful, exciting, remote, exhausting environment of a shuttle mission (3). Thus, for both physiological and psychosocial reasons it is important to ensure proper cosmonaut nutrition and this importance will increase as mission lengths increase. Studying the nutritional challenges in space could improve our understanding of many human health issues on Earth.

Why do astronauts become malnourished in space? First, human physiological responses to microgravity alter the body's nutritional requirements from those on Earth. Second, environmental and time constraints limit the variety and quality of food available to astronauts.

## PHYSIOLOGICAL EFFECTS OF MICROGRAVITY AND NUTRITIONAL CHALLENGES

### *Negative Energy Balance*

Almost every astronaut who has been monitored for energy balance in spaceflight has shown a deficit. Dietary intake is suppressed as much as 75% on the first day of orbit, due to motion sickness; later the body adjusts to a new energy intake point, far lower than energy expended (4). A negative energy balance continues for weeks into space flight---Stein et al. reported a calorie reduction of two-thirds from pre- to in-flight dietary intake (5). In space the body adapts to this lower energy intake by reducing lean body mass and subsequently reducing basal metabolic rate. This leads to reduction in total body protein and corresponding reduction in body fluid.

Energy required for work performed in spaceflight appears to be greater than those estimated from studies performed on the ground. Researchers are not sure if this increased need is due to stress, changes in metabolism, or less efficient metabolic processes in microgravity (6).

### *Muscle Atrophy*

Unloading of antigravity muscles results in muscle protein loss, while stress hormone circulation increases protein turnover rates. Both these effects result in muscle wasting which has been shown in astronauts, most notably when they return to Earth with appreciable decreases in strength of weight-bearing muscles (3, 6).

### *Fluid Balance*

In the past, researchers thought that astronauts' body fluid loss in space was the primary cause for their decreased body weight. Recent research has shown otherwise. Microgravity causes body fluid to shift from the lower extremities to the head and upper body, but unlike the effects of hypervolemia on Earth, in space this perceived increase in blood volume does not cause diuresis and natriuresis, nor does it result in negative water and sodium balances (7). In fact, astronauts retain sodium in space, which indicates that lower-sodium diets may be desirable (3). Astronauts'

fluid loss and corresponding loss of body weight is therefore not due directly to absolute fluid loss; the weight loss is due to gradually occurring fluid loss as a consequence of the loss of water binding capacity due to labile protein stores which may have been activated to counteract the malnutrition induced energy deficit (7, 8).

During space flight there is a shift of fluid from extracellular to intracellular compartments in the body. This decreases plasma volume increases serum electrolyte, osmolality, and urine osmolality. Increased osmolality activates antidiuretic hormone, as the body tries to retain water and normalize osmolality. Reduced fluid intake during spaceflight (probably due to the reduced food consumption) exacerbates the situation. Decreased body fluid causes production of concentrated urine, which increases the risk of kidney stones; decreased body fluid also might affect astronauts' orthostatic tolerance after landing (3).

### *Space Osteoporosis*

Microgravity causes loss of bone tissue due to decreased rates of bone formation and increased rates of bone resorption, most notably in weight-bearing bones (3). Moderate weight loss of 10% typically results in 1-2% loss of bone mineral density. Both microgravity and weight loss contribute to the phenomenon of space osteoporosis. After a 6-month mission, astronauts suffered from severe space osteoporosis resulting in a 12% loss of bone mineral density in the femur (8). If microgravity-induced changes in bone aren't taken into account, a deficient calcium and vitamin D intake leads to calcium resorption from bone to maintain a constant serum calcium level.

### *Space Adaptation Syndrome*

Space Adaptation Syndrome (SAS) affects about 70% of astronauts during spaceflight, and involves motion sickness, changes in olfactory and gustatory sensory function and, ultimately, decreased energy intake (6). Motion sickness results because an astronaut in orbit experiences a mismatch between what is perceived by the eye and what is sensed by the inner ear. This sensory-motor disconnect causes disorientation and affects astronauts for the first 2-3 days of orbit. Altered olfactory and gustatory senses in SAS might be a result of the fluid shift that occurs in microgravity (see FLUID above), as discomfort results from sinus and nasal congestion due to the cephalad shift of extracellular fluids (6). Many astronauts report a diminished or drastic change in their sense of taste during spaceflight that makes previously preferred foods unpalatable.

### *Radiation*

Another factor that leads to health consequences from spaceflight is exposure of astronauts to ionizing radiation. On NASA/MIR 1996-1998, depressed protein metabolism caused decreased anti-oxidant defense that led to more extensive free-radical propagation and irreversible DNA damage. The free radical damage persisted for over 2 weeks after these astronauts returned to Earth (probably due to the time necessary to regenerate lost proteins), and caused oxidative stress comparable to that induced by smoking a pack of cigarettes a day. It is hypothesized that dietary antioxidant supplements might improve outcomes, but this has yet to be tested in space (3, 4).

## *LOGISTICAL LIMITATIONS TO NUTRITION IN SPACE*

Preparing food for astronaut consumption during a long-duration space mission (greater than 2 weeks) is complex, and has been evaluated for missions lasting only up to 1 year (3). The menu in space includes foods that are fresh, dehydrated, intermediate-moisture, thermostabilized, irradiated, and natural. Every food item is analyzed for weight, volume, preparation time and technique, odors, and waste materials. Each food item is prepared as an individual portion, and packaged in such a way as to minimize mess (in a tube or bite-size pieces.) Astronauts' nutritional needs are generated from ground-based studies that have been adjusted according to current understanding of physiology in microgravity (for example, the iron requirement has been reduced because iron metabolism is decreased due to decreased red blood cell mass and increased tissue iron availability and storage in space flight (3). Before departure, astronauts select desired food items from those available and balanced meals are assembled by nutritionalists. The space program is constantly updating its food selection, and works to include international or ethnic foods and foods that are frozen, refrigerated, and of ambient temperature for variety (6).

Not only is food variety and quality limited by the environment of the space shuttle, it is limited by the time constraints put on astronauts who are at work in orbit. Often crewmembers are too busy carrying out their mission to spend time preparing and eating meals. Even though people on the ground provide well-balanced, nutritious meals, the astronauts may not eat the food while in space because nutrition is not a top priority.

## PREVENTION OF WEIGHT LOSS IN SPACE?

The key to improving nutrition in space is positive energy balance. A number of solutions have been tested so far. Crewmembers have been given exercise regimes, in hopes that this would prevent muscle atrophy. This did not work---the prescribed exercises led to severe energy deficits, while those astronauts who were allowed choice in when and how much to exercise had musculoskeletal systems better adapted to the space environment than those who were forced to do the pre-determined exercises (4). In an attempt to insure adequate energy intake, astronauts on the Skylab mission were prescribed diet regimens; however this was not well-received by the crew due to adverse gastrointestinal effects and feelings of being "overloaded" with food (4).

Future studies will further investigate nutritional supplements for their potential benefits in counteracting the problems described above. Research will be conducted to evaluate which specific amino acids are needed in microgravity, to analyze calcium and vitamin D supplementation and their effects on space osteoporosis (initial studies on increased calcium uptake, vitamin-D supplementation, and exposure to ultraviolet light have not proven effective in spaceflight however) (3, 8).

It is possible that structural modifications to the shuttle environment could improve energy balance among crewmembers. Stein hypothesizes that "the adverse effects of exercise on energy intake during space flight are due to problems in disposing of the metabolic by-products produced during exercise." According to Stein, thermo-regulation is less efficient in microgravity (less convective heat loss due to decreased air flow across the skin surface, decreased blood flow

to the extremities, and decreased sweat losses); energy balance could be improved by improving the efficiency of heat and/or CO<sub>2</sub> removal for astronauts (4). Other researchers suggest development of a "salad machine" system that will grow fresh vegetables on space stations (6). Finally, scheduling should be devised that allows ample time for astronauts to prepare and eat healthful well-balanced meals while in orbit.

## CONCLUSION

Providing astronauts with adequate nutrient intake during space missions is imperative for the success of lengthy space missions. Vodovotz et al write, "without an adequate food system, the success of long-duration space missions will be compromised and could lead to incapacitation, delayed ability to return to active status after reaching an outpost such as Mars, and the inability to rehabilitate after returning to Earth. Furthermore, as on Earth, foods provide both social and psychologic well-being, which is even more important on such dangerous missions" (3). As scientists investigate various nutritional means to solve the physiological challenges faced by astronauts in microgravity, we will learn more about nutritional countermeasures for similar physiological problems on Earth.

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