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Nutritional Requirements for Space Station *Freedom* Crews

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Table of Contents

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at the Lunar and Planetary Institute
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Introduction

Current evidence strongly supports the role of nutrition in maintaining the health and optimal performance of astronauts during space flight and return to Earth. Significant research, with provision of valid data, is essential to improve understanding of how space flight affects human nutritional requirements. This workshop was convened to review the present state of knowledge of space nutrition, and to solicit recommendations from experts in the field of nutritional science. The panel was presented with an overview of physiological issues associated with space flight, and reviewed the food systems for the Space Shuttle and Space Station *Freedom* (see appended agenda). The panel then offered recommendations to the nutritional support plan for 90- to 180-day *Freedom* missions. These recommendations are presented here in four parts: nutritional recommendations; assessment of nutritional status (crewmembers) and nutrient content (diet); suggestions for future research; and summary.

Nutritional Recommendations

Dietary composition is important for the Astronaut Corps both with respect to their performance during space flight and after landing. The dietary guidelines reviewed by the Surgeon General [1] and the National Research Council [2] should be used as the starting point; these guidelines can be modified on the basis of data from previous space flights and from bed rest studies. The chosen menus for each 14-day cycle should reflect these nutritional requirements. Means of monitoring diet and gustatory changes should be included in the space station hardware. Specific requirements are as follows:

Fluid. Water intake should be adequate to reduce the incidence of kidney stones; a tentative guideline could be 1 mL per kcal of consumed energy.

Calories. Calorie consumption should be sufficient to maintain weight and body composition, with continuous monitoring during space flight. A 70 kg man exercising 1 to 2 hours per day is expected to require about 3,000 kcal/day.

Protein. It is difficult to recommend a protein-intake level because of the calcium and muscle loss observed during space flight. A high protein intake may slow muscle loss, but increases calcium loss. The panel therefore recommended adherence to the RDA of 12 to 15% protein, with further study of this nutrient. The type of protein should be balanced between animal and plant sources in a ratio of approximately 60:40 to facilitate meeting the requirements for other nutrients.

Fat. This nutrient should constitute between 30 and 35% of total calories, with a distribution among polyunsaturated/monounsaturated/saturated fats of 1:1.5-2:1. This relatively high percentage is recommended based on consideration of (1) the usual dietary pattern of astronauts, (2) palatability and satiety, (3) caloric density, and (4) concern that higher carbohydrate and protein levels could influence calcium loss.

Carbohydrate. By difference, the carbohydrates should provide approximately 50% of the total calories, and should be derived from foods that emphasize complex carbohydrates. Simple sugars should constitute no more than 10% of the total carbohydrate intake. The current consumption of 10 to 15 g of dietary fiber/day may be adequate; because of practical considerations, however, this point warrants further study.

Calcium. Bone and calcium losses are problematic, but it is not clear that calcium consumption of >800 to 1,000 mg/day will be beneficial. The source of calcium can be natural foods or calcium citrate. Those individuals who do not voluntarily consume >800 mg/d should take supplements. To augment bone retention, food supplies should be fortified to provide RDA levels of vitamin D and fluoride.

Vitamins. Crewmembers who will fly missions of 90 to 180 days should be provided with RDA levels of vitamins. Because stress levels are expected to be high before and during flight, and vitamin C turnover correspondingly high, the higher of the two RDA levels for vitamin C (100 mg/day) should be used. Vitamins A and B12, in contrast, are stored by the liver in sufficient quantities to maintain necessary levels, although B12 levels should be monitored in vegetarian astronauts. Consumption and maintenance of adequate levels of thiamine and vitamin K are important because of thiamine's role in high calorie intake and increased exercise levels, and vitamin K's association with calcium and bone metabolism.

Trace elements. As to mineral content, food supplied should also provide the RDA levels of zinc, selenium, and iodine, as well as safe and adequate levels of copper, manganese, fluoride, and iron. Because space flight has been associated with decreased erythropoiesis and increased serum ferritin concentrations, the use of iron supplements should be prohibited, and maximum intake held at the male RDA (10 mg of Fe per day).

Although many micronutrients can be provided by vitamin-mineral supplements, the panel recommended that food be the primary source of nutrients, with supplements to be used only when absolutely necessary. Natural foods contain other essential nonnutritive substances such as fiber and carotenoids. Consumption of natural foods also provides a sense of psychological well-being that will be important during long space missions. In light of potential skeletal changes during long missions, the intake of low-fat dairy products is to be encouraged whenever possible. Dairy products include multiple micronutrients such as vitamins A and D, riboflavin, zinc, and calcium. Because body vitamin D stores will become depleted in the absence of sunlight, dietary vitamin D levels may require an increase, or perhaps a means of ultraviolet irradiation of crewmembers should be considered. Provision and consumption of fresh fruits and vegetables should also be encouraged.

Assessment of Nutritional Status: Crewmembers

Establishing a baseline nutritional status before long-term space flights will be necessary in order to quantify the effects of microgravity, particularly in light of limited opportunities for in-flight assessment. Preflight dietary habits may well affect both adaptation to space flight and recovery upon return. The panel suggested offering nutritional consultations to astronauts in an effort to encourage compliance through education. Such interviews might include discussion of operational health issues, such as nutrition's role in in-flight stresses such as bone loss and exposure to radiation.

Nutritional status should absolutely be assessed before and after flight, and if at all possible during flight. A means of measuring body mass in flight must be available. In addition to interviews and other educational opportunities, tests can be performed on blood, urine, and fecal samples, perhaps in conjunction with Medical Operations collections. Such tests would include:

From blood samples:

- RBC and plasma folate concentrations
- ascorbate concentration
- Vit E, retinoids and carotenoids (performed together on HPLC)
- whole blood superoxide dismutase
- thrombotic potential (for Vit K)*
- erythrocyte glutathione reductase activity (for riboflavin)
- erythrocyte transketolase activity (for thiamine)
- plasma pyridoxal phosphate concentration (for Vit B6)
- 25-hydroxyvitamin D (Calcifediol)
- osteocalcin*
- iron status assays

From urine samples:

- iodine
- gamma-carboxyglutamate (GLA)*
- ascorbate
- flavins
- 4-pyridoxic acid (B6)

From fecal samples:

- occult blood

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*Given the possible influence of vitamin K status on calcium metabolism and/or osteoporosis, osteocalcin (B6P) and urinary GLA should be monitored before (during if possible) and after flight.

It is especially important to exercise better control in recording food intake in order to ensure adequate consumption of micronutrients. Methods of monitoring actual intake easily and unobtrusively need to be developed.

Assessment of Nutritional Status: Food Analysis

The amount and type of some vitamins in foods can be estimated from existing food composition tables; however, direct analysis of Space Station *Freedom* diets should be performed for levels of folate, ascorbic acid (vitamin C), thiamine (B1), pyridoxine (B6), riboflavin (B2), and vitamins E and K. In general, compositional table data for these compounds is incomplete; furthermore, levels of these vitamins will vary with food-processing techniques and storage conditions. Some compounds (folate, pyridoxine, and riboflavin) are light sensitive; ascorbate and vitamin E are susceptible to oxidation. Direct analyses should also include the concentrations of thiamine and vitamin K in foods, and their stability under the proposed storage conditions.

Direct analysis of zinc, copper, iodine, and selenium may also be required, as the food-composition table data for these minerals are inadequate for the foods to be provided in space.

In view of observations that serum ferritin levels increase with age, the use of iron supplements should be discouraged, and iron intake should be monitored carefully.

The planned use of iodine as an antimicrobial agent in the water supply mandates consideration of iodine intake from water as well as food, with the concern that increased iodine levels may affect thyroid function. The use of recycled water for consumption should be considered from a nutritional standpoint as well, because of the probable presence of calcium and other trace elements in the potable water supply.

Suggestions for Future Research

Maintaining lean body mass in space. Quantifying lean body mass in space, and understanding its role in maintaining strength, endurance, and optimal performance, is complicated by the lack of "hard" data on protein intake and exercise. As a first step, protein intake should be quantified, and then these values associated with total food intake, type and duration of exercise, net protein synthesis, and urinary calcium excretion. Accurate recording of exercise regimens (resistance vs. aerobic exercise, physical workloads, and length and frequency of exercise periods) must be instituted, as well as recording when meals are consumed relative to the exercise period. Other useful information can be provided by measuring mediators of protein catabolic response. Although this study will require data from human subjects, these data could be supplemented by studying rats that consume varying levels of protein before and after space flight. In addition, a more precise measure is needed to determine the number of calories required to maintain lean body mass and avoid deposition of fat.

Maintaining the skeleton in space. In order to achieve a better understanding of the mechanisms of skeletal loss in space, ideal intake (and form) of calcium, phosphorus, vitamin D, fluoride and zinc should be determined, as well as the ideal type and duration of exercise in terms of its effects on total body calcium, bone density, calcium kinetics, and hormonal response.

Preflight nutritional status. The role of preflight nutrition, including fluid intake, high protein intake, and glycogen loading, should be evaluated, in particular in relation to the amelioration of motion sickness symptoms.

Intake during flight. Food and fluid intake, and duration and intensity of exercise, must be quantified in flight. The described shift in food preferences in space should be explored.

Postflight recovery. This period should be extended to 3 to 6 months after landing, and more detail collected on recovery of skeletal mass in relation to all possible mediating factors, and recovery of muscle mass and function.

Micronutrients. The effect of microgravity on micronutrient utilization and turnover must be determined. In particular, micronutrients known to be involved in erythropoiesis (folate, iron, vitamin B12, and copper), and those known or presumed to be involved in bone stability (vitamins D, K, and A, zinc, fluoride, and manganese) should be assessed.

Although the panel recognized that some of these important nutritional issues can be addressed only by a mission specifically devoted to nutritional research, they emphasized that some baseline information can and should be collected during Space Shuttle flights in order to better define nutritional requirements for longer space missions.

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13. ABSTRACT *(Maximum 200 words)*
This CP reports the results of a meeting convened in Houston, Texas on February 4-5, 1991. The purpose of this panel, sponsored by the Biomedical Operations and Research Branch, was to set preliminary nutritional requirements for crewmembers flying 90- to 180-day missions on Space Station *Freedom*. NASA was strongly encouraged to provide nutritional education to the Astronaut Corps, with emphasis on how nutritional status affects performance during and after space flight. Specific recommendations included providing crewmembers with in-flight feedback on nutritional intake, weight, and strength, and incorporating issues of energy intake, body weight, body composition, strength, and protein intake in the flight medicine program. Exercise must be considered an integral part of any plan to maintain nutritional status, especially those modes that stress the skeleton and maintain body weight. Nutrient intake, amount of exercise, and drugs ingested must be recorded daily; high priority should be given to development of fully automated record systems that minimize astronauts' effort. A system of nutritional supplements should be developed to provide a method of reducing intake deficits that become apparent. Finally, postflight monitoring should include bone density, muscle mass and function, and iron status at 3 and 6 months after landing.

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