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Assessment of nutritional intake during space flight and space flight analogs

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Abstract

Maintaining adequate nutrient intake during space flight is important not only to meet nutrient needs of astronauts but also to help counteract negative effects of space flight on the human body. Beyond these functions, food also provides psychosocial benefits throughout a mission. Dietary intake data from multiple space programs, including the Space Shuttle and the International Space Station, are discussed. These data arise from medical monitoring of dietary intake and crew health, as well as from research protocols designed to assess the role of diet in counteracting bone loss and other health concerns. Ground-based studies are conducted to better understand some of the negative issues related to space flight. Examples of ground-based studies are extended-duration bed rest studies, vitamin D supplementation studies in Antarctica during 6-month winterovers, and 10- to 14-day saturation diving missions on the floor of the ocean. The use of weighed food records, diet diaries, barcodes and food-frequency questionnaires to assess nutritional intake of space crewmembers is described. Provision of food and nutrients in space flight is important for many body systems including the cardiovascular, musculoskeletal, endocrine, and immune systems. Key areas of concern during long-duration space flight include loss of body mass, bone and muscle loss, radiation exposure and oxidative damage, nutrient intake during spacewalks (extravehicular activity), depletion of nutrient stores, and inadequate dietary intake. Initial experimental research studies using food and nutrition as a countermeasure to aid in mitigating these concerns are underway. Beyond their importance for the few individuals leaving the planet, these studies have significant implications for those remaining on Earth.

Keywords: space flight; microgravity; nutrient intake; International Space Station

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1. Introduction

Throughout history, exploration missions have often succeeded or failed according to the degree to which nutrition was considered and/or understood. The story of scurvy is a classic example of how a single nutrient deficiency led to more sailor deaths in the so-called age of sail than all other causes of death combined, including shipwreck [1]. The importance of nutrition on space exploration missions will be even more critical, given that no food will be found by travelers on these journeys. Food provision for the entire mission will need to be carefully planned to ensure that there will be enough food, and that the micro- and macronutrients will remain stable for the duration of the mission. A packaging failure and oxidation of macronutrients could mean the difference between a successful mission and an early end to a mission.

Space flight is associated with many physiological changes, as a result of the microgravity environment, including space motion sickness, fluid shifts, congestion and altered taste and smell. The environment of the spacecraft (including the spacecraft cabin, radiation, lack of ultraviolet light exposure, carbon dioxide exposure, and the spacesuit atmosphere) can affect nutrition and nutritional requirements for long-duration missions.

Because nutritional status is subject to so many influences, monitoring nutritional status on extended-duration (>30 d) space missions is important to ensure crew health and productivity, and ultimately mission success. We review herein findings from the first half-century of human space flight with regard to several key nutritional issues, and discuss some of the methods that have been used to assess dietary intake during space flight.

2. Space Food System

The International Space Station (ISS) food system provides a menu with a cycle of 8-16 days. Food items are supplied by all of the international partner space agencies (CSA - Canadian Space Agency; ESA - European Space Agency; JAXA - Japanese Aerospace Exploration Agency; Russian Space Agency; and NASA - US National Aeronautics and Space Administration), with the majority of items at this time coming from the latter two. Foods are packaged in single-serving containers and are intermediate-moisture foods, or are in natural form, thermostabilized, dehydrated, or irradiated [2, 3]. A "standard menu" has been developed for ISS missions, and is periodically re-assessed based on food item additions and deletions. Crewmembers are allotted "bonus containers" which contain either additional space foods, or commercially available products which meet space food constraints (e.g., shelf life). Thus, the food system is designed to fulfill defined nutritional requirements that have been derived from space flight research, extrapolated from speculation about the effects of space flight on nutrient needs, or applied directly from ground-based Dietary Reference Intakes for micronutrients and World Health Organization (WHO) recommendations [3-11]. A key concern for space flight, and a limitation of the food system, is providing adequate amounts of vitamin D (see details below).

3. Dietary Intake Assessment Techniques

3.1. Food Frequency Questionnaire

During flight, crewmembers are asked to record their dietary intake once per week using a Food Frequency Questionnaire (FFQ) designed for use with the space food system. The questionnaire asks how many servings of each food item were consumed in the past week. This FFQ has been validated in a ground-based model of long-duration space flight [12]. Given the closed food system (with repetitive menu cycle), known portion sizes, and precise nutrient content for each food item in the system, the FFQ designed for space flight is much more reliable than a standard food questionnaire.