Program: Nutritional Aspects of Human Space Flight
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Historically, nutrition has driven the success – and often the failure – of terrestrial exploration missions. For space explorers, nutrition provides indispensable sustenance, provides potential countermeasures to some of the negative effects of space travel on human physiology and also presents a multifaceted risk to the health and safety of astronauts.

At a minimum, the need to prevent nutrient deficiencies is absolute. This was proven on voyages during the Age of Sail, where scurvy – caused by vitamin C deficiency – killed more sailors than all other causes of death. On a closed (or even semi-closed) food system, the risk of nutrient deficiency is increased. On International Space Station (ISS) missions, arriving vehicles typically bring some fresh fruits and/or vegetables to the crew. While limited in volume and shelf-life, these likely provide a valuable source of nutrients and phytochemicals every month or two. One underlying concern is that availability of these foods may be mitigating nutrition issues of the nominal food system, and without this external source of nutrients on exploration-class missions, those issues will be more likely to surface.

As a cross-cutting science, nutrition interfaces with many, if not all, physiological systems, along with many of the elements associated with space exploration including the spacecraft environment. Thus, beyond the basics of preventing deficiency of specific nutrients, at best, nutrition can serve as a countermeasure to mitigate risks to other systems. Conversely, at worst, diet and nutrition can exacerbate risks to other physiological systems and crew health. For example, many of the diseases we worry about as related to space exploration are nutritionally modifiable on Earth, including cancer, cardiovascular disease, osteoporosis, sarcopenia, and cataracts.

The NASA Nutritional Biochemistry Laboratory approaches astronaut health using both operational and research efforts. These efforts aim to keep current crews healthy while working to understand and define optimal nutrition for future crews, to maximize performance and overall health while minimizing damaging effects of spaceflight exposure.

A Clinical Nutrition Assessment is conducted for ISS astronauts dating back to ISS Expedition 1, which includes pre- and post-flight biochemical analyses conducted on blood and urine samples, along with inflight monitoring of dietary intake and body mass. These data are reported to the Flight Surgeon soon after collection for use in the clinical care of the astronaut.

In addition to inflight dietary intake monitoring, research to understand the impact and involvement of nutrition with other spaceflight risks, such as bone loss, visual impairments, and interaction with exercise and spacecraft environment, are performed by the Nutrition Team using both flight and ground analog research efforts. Tracking body mass is a very basic, but nonetheless indispensable element of crew health. Loss of body mass during spaceflight and in ground-analogs of spaceflight is associated with exacerbated bone and muscle loss, cardiovascular degradation, increased oxidative stress, and more.

From a pure nutrition perspective, ISS and associated ground-analog research has identified several specific dietary effects on bone health. Fish intake, likely secondary to omega-3 fatty acid intake, is beneficial for bone health. Conversely, high intakes of dietary protein, iron and sodium are detrimental to bone. The data from terrestrial research, along with the more limited spaceflight research, clearly identifies nutrition as important in maintenance of bone health, and in the mitigation of bone loss. While initial evaluations of dietary quality and health are underway at NASA, much work remains to document the full potential of nutrition to mitigate bone loss and other disease processes in space travelers.

Another health risk with nutrition underpinnings is Spaceflight-Associated Neuro-Ocular Syndrome. When this issue first arose, an examination of data from the aforementioned ISS Nutrition project was conducted. This analysis revealed that affected crewmembers had significantly higher circulating concentrations of homocysteine and other one-carbon pathway metabolites when compared to non-cases, and that these differences existed *before* flight. After identifying differences in one-carbon biochemistry, the next logical step was to examine the genetics involved in this pathway as possible causes of the biochemical differences, but perhaps also their association with the astronaut ocular pathologies. An initial study found that B-vitamin status and genetics were significant predictors of many of the observed ophthalmic outcomes in astronauts. Interestingly, the same genetics identified in astronauts to be associated with ophthalmic changes after flight were associated with greater ocular changes in a strict head-down tilt with 0.5% CO_2 bed rest study.

A hypothesis was developed to plausibly link these genetics and biochemical differences with these ophthalmic outcomes, as there is no existing literature regarding such a relationship. This multi-hit hypothesis posits that genetics combined with one or more other factors (e.g., fluid shifts, carbon dioxide, radiation, endocrine effects) lead to these pathologies.

To summarize, nutrition is a cross-cutting field that has influence on virtually every system in the body. While we need to understand nutrition to avoid frank deficiencies, we need to understand how optimizing nutrition might also help mitigate other spaceflight-induced human health risks. Examples of this are myriad, ranging from effects of dietary intake on cognition, performance, and morale, inadequate intake on cardiovascular performance, excess nutrient intakes leading to excess storage and increased oxidative stress, nutrient insufficiencies leading to bone loss, insufficient fruit and vegetable intake on bone health, radiation protection, and cardiovascular health, to name a just few. Throughout history, nutrition has served, or failed, many a journey to explore.

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(Photo courtesy of NASA)