Nutritional Requirements

for

Exploration Missions

up to 365 days

JSC-67378
Rev 1
April 20 2020

Introduction

Crew nutritional requirements described here are aimed at supporting optimal crew performance during extended-duration (<365 d) exploration missions, including planned Orion and Gateway missions. The requirements for specific nutrients (on a per-day basis) are included here, as are recommendations for foods and food types. Additionally, requirements are delineated for nutritional assessment, including monitor of dietary intake, and nutritional requirements for specific tasks (e.g., extravehicular activity).

Nutrient Requirements

The daily diet will supply the basic nutritional requirements as specified below. Mass size should be taken into account in individual calculations, since the following requirements are designed for a 70-kg person.

Energy Intake

Intake of energy shall be sufficient to maintain body weight, body composition, and the level of activity required for the exercise activities planned for Orion and Gateway mission crewmembers, that is, approximately 30 minutes/d of resistance type exercise. Energy requirements will be defined on an individual basis as calculated using the using the National Academy of Medicine's Dietary Reference Intake (DRI) equations:

EER for men 19 y and older

$$EER = 622 - 9.53 \times Age\ [y] + 1.11 \times (15.9 \times Mass\ [kg] + 539.6 \times Ht\ [m])$$

EER for women 19 y and older

$$EER = 354 - 6.91 \times Age\ [y] + 1.11 \times (9.36 \times Mass\ [kg] + 726 \times Ht\ [m])$$

- Note that these equations account for "low active" levels of activity, evidenced by the 1.11 activity factor. If additional exercise equipment and time become available, the energy requirements shall be adjusted accordingly. If, as projected, Gateway includes exercise equipment on par with ISS, then the activity factor would revert back to 1.25.
- These equations are for general population use, but have generally proven applicable for ISS crews. In the event resting metabolic rate (RMR) data are available, individual calculations should be made when evaluating intake for those crewmembers.
- Based on evidence from ISS and other programs, it is highly recommended that food provisions be supplied in greater amounts than exactly calculated from the defined requirements. That is, crew will naturally not consume exactly what is provided, and an overage allowing for choice would better support adequate consumption.
- Based on data from EVAs on previous space missions, it is recommended that an additional 200 kcal/h of EVA be supplied to crewmembers on days of extravehicular activity (EVA); the extra energy should be of similar nutrient composition as the rest of the diet.

Protein

Protein intake shall be 1.2-1.8 g protein per kg body mass. This should be provided from both animal and plant sources, in no higher than a 60:40 ratio. This ratio will facilitate meeting other nutrient requirements while ensuring an adequate intake of all essential amino acids. It is important to provide protein in the amounts specified, as higher or lower intakes may exacerbate space-induced musculoskeletal changes and renal stone risk.

Carbohydrate

Carbohydrates shall provide 45 to 65 percent of daily caloric intake. This should be provided primarily in the form of complex carbohydrates (i.e., starches) such as cereal products - flour, bread, rice, and corn, and should include whole grain products whenever possible. Less than 10 percent of calories should be from added sugars (e.g., sucrose and other sweeteners).

The dietary intake of fiber shall be 38 g/d for men, and 25 g/d for women, including both soluble and insoluble forms. This will help maintain gastrointestinal function and decrease the incidence of constipation.

Fat

Fat shall comprise 20-35% of the total daily energy intake. Dietary intake of n-6 fatty acids shall be at least 17 g/d for Men and 12 g/d for Women. Intake of n-3 fatty acids shall be at least 1.6 g/d for men and 1.1 g/d for women. Consumption of saturated fat, trans fatty acids, and cholesterol should be as low as possible, with saturated fat intake not to exceed 10% of kcals, trans fatty acids not to exceed 1% of kcals, and cholesterol not to exceed 300 mg/d. This is designed to increase the palatability and caloric density of the diet while simultaneously reducing the health risks associated with a high-fat intake.

Fluid

Intake of fluid shall be sufficient to reduce the incidence of kidney stones and prevent dehydration. The daily fluid requirement, met through food content and beverages, is 32 ml/kg body mass, and no less than 2500 ml/d for men, no less than 2100 ml/d for women. It is imperative for the health of the crew that fluid intake be maintained.

Fat-Soluble Vitamins

Vitamin A

Intake of vitamin A shall be 900 µg RE/d for men and 700 µg RE/d for women. (RE = retinol equivalents; 1 RE = 1µg retinol or 6 µg ß-carotene) Vitamin A intake of preformed vitamin A (i.e., not from ß-carotene) should not exceed 3000 µg /d which is based on hepatotoxicity. Vitamin A is important for maintaining immune function, vision, and gene expression.

Vitamin D

Intake of vitamin D shall be 25 µg/d (1000 IU/d) for men and women. This is designed to maintain vitamin D status in light of decreased exposure to ultraviolet light (and thus, decreased endogenous production). If not easily available in food sources, this shall be provided in supplement form. Vitamin D is required for maintaining serum calcium and phosphorus concentrations by influencing absorption of these nutrients in the small intestine. There is also evidence that vitamin D supports immune system function.

Vitamin E

Intake of vitamin E shall be 15 mg TE/d for men and women. (TE = α-tocopherol equivalents; 1 TE = 1 mg d-α-tocopherol, which is the naturally sourced formed of vitamin E; synthetic forms have lower biological activity). Vitamin E serves as an antioxidant that prevents propagation of lipid peroxidation. Supplements should not contain any more than 1000 mg/d of any form of vitamin E based on the adverse effect of increased tendency to hemorrhage.

Vitamin K

Intake of vitamin K shall be 120 µg/d for men and 90 µg/d for women. Meeting this requirement is important because of the role of vitamin K in calcium and bone metabolism. Vitamin K requirement shall be provided as vitamin K-1 (phylloquinone), which is obtained primarily from plant sources.

Water-Soluble Vitamins

Vitamin C

Intake of vitamin C intake shall be 125 mg/d for men, and 110 mg/d for women. Vitamin C provides antioxidant protection, and this level of intake should maintain near maximal neutrophil vitamin C concentration with little urinary excretion. This intake level is 35 mg/d more than the current Dietary Reference Intake and is in agreement with their recommended intake for individuals exposed to increased oxidative stress (e.g., smokers). Intake from supplements and diet should not exceed 2000 mg/d based on the potential for osmotic diarrhea and gastrointestinal disturbances.

Vitamin B_{12}

Intake of vitamin B_{12} shall be 2.4 µg/d for men and women. Vitamin B12 is a cofactor for two enzymes involved in methyl transfer reactions ultimately involved with DNA synthesis.

Vitamin B_6
Intake of vitamin B_6 shall be 1.3 mg/d for men and women. Vitamin B6 is a required coenzyme in the metabolism of amino acids and heme synthesis. Intake from supplements should not exceed 100 mg/d based on possible sensory neuropathy effects.

Thiamin
Intake of thiamin shall be 1.2 mg/d for men and 1.1 mg/d for women. Thiamin is a required coenzyme for carbohydrate and branched-chain amino acid metabolism.

Riboflavin
Intake of riboflavin shall be 1.3 mg/d for men and 1.1 mg/d for women. Riboflavin is a required coenzyme for numerous redox reactions.

Folate
Intake of folate shall be 400 µg/d DFE for men and women. (DFE = dietary folate equivalents; 1 µg DFE = 1 µg food folate = 0.6 µg folic acid from fortified food or supplement taken with meals = 0.5 µg folic acid from a supplement taken on an empty stomach) Folate is required for DNA synthesis and methylation.

Niacin
Intake of niacin shall be 16 mg NE/d for men and 14 mg NE/d women. (NE = niacin equivalents; 1 NE = 1 mg niacin = 60 mg dietary tryptophan). Niacin from supplements and food fortification should not exceed 35 mg/d based on flushing as a critical adverse effect. Niacin is required for energy utilization, redox reactions, biosynthetic reactions, and DNA replication and repair.

Biotin
Intake of biotin shall be 30 µg/d. Biotin is a required nutrient for bicarbonate-dependent carboxylation reactions.

Pantothenic Acid
Intake of pantothenic acid shall be 5 mg/d. Pantothenic acid is involved in fatty acid metabolism.

Choline
Intake of choline shall be 550 mg/d for men, and 425 mg/d for women. Choline is a dietary component required for the structural integrity of cell membranes, neurotransmission, cell signaling, and lipid and cholesterol metabolism. Choline intake should not exceed 3.5 g/d related to concerns of cholinergic side effects.

Minerals

Calcium and Phosphorus

Calcium intake shall be 1000-1200 mg/d for men and women to minimize bone and calcium imbalance during the mission. The phosphorus intake shall be 700 mg/d for men and women, and shall not exceed 1.5 times the calcium intake. Calcium intake shall not exceed 2500 mg/d.

Magnesium

Intake of magnesium shall be 420 mg/d for men and 320 mg/d women. The upper limit for both sexes is defined as 350 mg/d from supplements (i.e., not from dietary sources). Magnesium is a required cofactor for over 300 enzymes involved in energy production.

Sodium

Intake of sodium shall be 1500-2300 mg/d. Sodium plays an important role in maintaining physiological homeostasis. Excess sodium has detrimental effects, including on bone metabolism and renal stone risk.

Chloride

Intake of chloride shall be 2300 mg/d. Chloride intake shall not exceed 3500 mg/d.

Potassium

Intake of potassium shall be 3400 mg/d for men, and 2600 mg/d for women. Potassium also plays an important role in maintaining physiological homeostasis.

Iron

Iron intake shall not exceed 8 mg/d for men and women. This is based on space-induced changes in iron storage, and is designed to prevent iron overload, a situation that may lead to oxidative tissue damage. Note: for women under 50 years of age who do not pharmacologically suppress menstruation, iron intake shall be at least 18 mg/d.

Copper

Intake of copper shall be 900 μg/d for men and women. Copper serves an important catalytic role in many metalloenzyme reactions to reduce molecular oxygen. These enzymes are involved with blocking histamine release, reactions to degrade serotonin, metabolism of catecholamines, and collagen cross-linking reactions. Intake of copper should not exceed 10 mg/d based on protection from liver damage.

Manganese

Intake of manganese shall be 2.3 mg/d for men and 1.8 mg/d for women. Manganese is involved in the formation of bone and in lipid, carbohydrate, and amino acid metabolism. Intake should not exceed 11 mg/d.

Fluoride

Fluoride shall be provided in the diet in amounts of 4.0 mg/d for men and 3.0 mg/d for women. Fluoride is mainly associated with maintenance of calcified tissues.

Zinc

Intake of zinc shall be 11 mg/d for men and 8 mg/d for women. Zinc serves many roles, including regulatory, structural, and catalytic functions. Intake should not exceed 40 mg/d, based on reduced red blood cell copper-zinc superoxide dismutase activity.

Selenium

Intake of selenium shall be 55 µg/d for men and women. Selenium is required for its role in oxidant defense, and it functions as a dietary antioxidant. Intake should not exceed 400 µg/d which is based on selenosis as the adverse effect.

Iodine

Intake of iodine shall be 150 µg/d for men and women. Iodine is a required component of thyroid hormones. Intake should not exceed 1.1 mg/d, which is based on the effect on elevating serum thyroid stimulating hormone.

Chromium

Intake of chromium shall be 35 µg/d for men, and 25 µg/d for women. Chromium is involved with maintaining glucose homeostasis.

Molybdenum

Intake of molybdenum shall be 45 µg/d for men and women. Molybdenum is involved in the catabolism of sulfur amino acids and heterocyclic compounds including purines and pyridines.

While there is a dietary requirement for arsenic, review panels have opted not to set a requirement for space exploration. However, the recommendation was made to be sure to use low arsenic rice in space food products.

Table 1 – Nutritional Requirements for Exploration Missions

Nutrients	Daily Dietary Intake
Energy	Based on DRI equations
Protein	1.2-1.8 g/kg BW
	and the ratio of animal:vegetable protein no higher than 60:40
Carbohydrate	45-65% of the total daily energy intake <10% of energy from added sugars
Fat	20-35% of the total daily energy intake
omega-6 Fatty Acids	Women: 12 g Men: 17 g
omega-3 Fatty Acids	Women: 1.1 g Men: 1.6 g
Saturated fat	ALARA, <10% of total calories
Trans fatty acids	ALARA, <1% of total calories
Cholesterol	<300 mg
Fiber	Women: 25 g Men: 38 g
Fluid	32 mL/kg
	And Women: > 2100 mL Men: >2500 ml
Vitamin A	Women: 700 µg RE Men: 900 µg RE
Vitamin D	1000 IU (25 µg)
Vitamin K	Women: 90 µg Men: 120 µg
Vitamin E	15 mg TE
Vitamin C	Women: 110 mg Men: 125 mg
Vitamin B12	2.4 µg
Vitamin B6	1.3 mg
Thiamin	Women: 1.1 mg Men: 1.2 mg
Riboflavin	Women: 1.1 mg Men: 1.3 mg
Folate	400 µg
Niacin	Women: 14 mg NE Men: 16 mg NE
Biotin	30 µg
Pantothenic Acid	5 mg
Choline	Women: 425 mg Men: 550 mg
Calcium	1,000 – 1,200 mg

Phosphorus	700 mg
	And ≤ 1.5 x calcium intake
Magnesium	Women: 320 mg Men: 420 mg
	<350 mg from supplements per day
Sodium	1,500 – 2,300 mg
Potassium	Women: 2600 mg Men: 3400 mg
Iron	8 mg And: for 18 mg for women under 50 who do not pharmacologically suppress menstruation
Copper	900 µg
Manganese	Women: 1.8 mg Men: 2.3 mg
Fluoride	Women: 3 mg Men: 4 mg
Zinc	Women: 8 mg Men: 11 mg
Selenium	55 µg
Iodine	150 µg
Chromium	Women: 25 µg Men: 35 µg
Chloride	2300 mg
Molybdenum	45 µg

Provisions

The above-listed nutrients shall be provided in standard foods. This is critical for many reasons. Standard foods provide other non-nutritive substances such as fiber, carotenoids, and flavonoids, as well as a sense of palatability and psychological well-being that will be critical on missions outside low-Earth orbit.

Many nutrients when provided as supplements/pills are not metabolized by the body as when in foods, and thus can increase the risk of diseases and side effects. Vitamin or mineral supplements shall be used as a countermeasure only when the nutrient content of standard foods do not meet the requirements.

Standard foods also provide energy, macronutrients, and vitamins and minerals, also provide thousands of phytochemicals of which we don't fully understand their impact on health. This has been proven time and again in epidemiological studies on Earth, where consumption of healthy diets, fruits and vegetables, and sources of omega-3 fatty acids and other nutrients mitigate risks of cardiovascular disease, cancer, dementia, and other chronic degenerative diseases, while supplements do not.

Optimal Diet

While the provision of individual nutrients is critical, especially with regard to preventing deficiency, there are food elements that are required to help provide an optimized diet, especially with regard to mitigating disease. Fruit and vegetable intake is critical, and general recommendations are for more than 6 servings of fruits and vegetable per day. This helps ensure intake of the thousands of phytonutrients that do not have defined requirements, including lycopene, flavonoids, carotenoids, etc.

Monitoring Nutrient Intake During Flight

Provision of nutritious foods is critical for mission success, but this can only happen if the foods are consumed. Thus, adequate monitoring of food consumption by crewmembers is important from several perspectives. Real-time intake information aids in crew autonomy, which will be more critical on missions outside low-Earth orbit. Dietary intake information is important for the Flight Surgeon in crew health care. Furthermore, dietary intake data provide important supporting information regarding countermeasure effectiveness. As such, Dietary, and thus nutrient, intake data are required as a part of biomedical monitoring.

Summary

Food and nutrition are the one countermeasure guaranteed to be included on space exploration missions. Ensuring that the food system provides nutritional support of crew health is integral to mission success.