[Release 2020.2.2]

A Contest of the National Space Society (NSS) Space Health and Medicine Committee in Cooperation with Mars Academy USA (MAU) to

Plan a Diet for Long Duration Spaceflight

Open to Students and Citizen-Scientists age 18 and over

Introduction:

The ketogenic diet is an example of a diet that has caught the imagination of many people in recent years as a safe and effective means of losing unwanted body fat. In a therapeutic mode under the guidance of medical doctors, the ketogenic diet has provided recovery from diet-related maladies including diabetes, metabolic syndrome, and even cancer. Disorders that may occur as a result of the long duration exposures in space flight may be exacerbated by the diets currently used aboard the International Space Station (ISS). These diets resemble the Standard American Diet (SAD). Certain diets, such as some forms of the ketogenic diet, may alleviate these disorders. Beyond earth's immediate environment, these new, researched diets may improve the crew's physiological response to the radiation hazards of spaceflight.

The ketogenic diet emphasizes healthy fats (such as cold expeller-pressed olive and avocado oils) from natural sources with lesser amounts of protein derived from natural animal and/or vegetable-based sources. Various additions to this basic plan have been made, such as alkalinization, intermittent fasting, supplementation, thermal stimulation (cold and hot), sleep management, and various forms of environment control.

Major cited research has identified that the damage to nuclear DNA is a consequence of primary disruption to the mitochondria. Much of the work that supports the therapeutic use of the ketogenic diet originated in the cancer research community. All forms of cancer tumors grow as *a result of a major modification in the structure and function of otherwise healthy mitochondria.* This insight supports the notion that prolonged exposure to ionizing radiation in space may exacerbate pre-existing metabolic disease that may often lead to cancer. Ionizing radiation is not a primary or exclusive cause of cancer. Cancer is a "metabolic disease with metabolic solutions". [book] [YouTube video]

Successful application of the winning diet in normal earth environments will hopefully greatly reduce or eliminate the risk of cancer and other immune system related diseases. The core insight provided by the research studies is that toxins and/or ionizing radiation are not the primary cause of autoimmune diseases, rather they are contributory because they interfere with

or degrade cellular function. These toxins and radiation exposures need to be reduced. The primary cause for many cancers, especially those forming tumors, is dietary because the tumors can only grow on simple carbohydrates and/or a short list of amino acids (including glutamic acid).

The challenge of the student contest is to find *a diet* that serves the purpose of eliminating the primary cause of the aforementioned disorders. The proper diet should restore the natural capacity to resist or counteract the effects of ionizing radiation.

If this restoration/removal effect can be accomplished, the health of the human crew and biota will be restored prior to flight and maintained during flight, despite inflight ionizing radiation of some intensity. This health improvement will reduce the heavy shielding otherwise required and increase payload capacity for other vital mission components. It is not expected that the need for shielding will be completely eliminated in the event of high energy solar flares or coronal mass ejections (CMEs).

There are proponents of other improved diets whose macrobiotic content (protein, fats, carbohydrates) differ from the ketogenic diets. These diets may also be effective for long duration space flight. Dr. John McDougall, N.D. and Colin Campbell, M.D., PhD., make resistant starches and plant-based whole foods the major sources for protein and metabolic energy in their diets. This approach is in contrast to the high levels of carbohydrates in the SAD and to the high fat sources in the ketogenic diets. They advocate a low volume resistant starch and whole plant food diet as the main source of metabolic energy and adequate protein.

Challenge questions

- Can the pre-existing condition of metabolic disorder leading to autoimmune system related diseases and cancer be resolved or removed ***before*** space flight with a detoxifying diet?

- With pre-existing conditions removed or absent, would a healthy diet ***during*** space flight maximize the capacity of human crews and biota to prevent or counteract any genetic or tissue damage?

Contestants

Graduate students, undergraduate students, and citizen-scientists

Goal

Confirm some form of detox and healthy diet as a diet best suited to improve the health of the crew before, during, and after long duration spaceflight.

Task

Use the **Design and Development Guidelines** below for the paper and **Challenge Questions** above to develop the ketogenic/student-proposed alternative diet as the best available diet plan for long duration spaceflight. Consider your individual health or your team members' health including food intolerances and allergies. Doctors may give team members prescriptions or other medical advice that you will need to account for in your diet design and presentation. ***Submit a white paper with a seven-day diet plan to support an analog mission in the Los Angeles area***. Title your white paper **"Development of a Preflight and Inflight Diet for Long Duration Spaceflight."**

Design and Development Guidelines

- Address the dietary components listed below and how these components address the relevant metabolic processes. List each component both by percentage of total and caloric content (proteins, fats, carbohydrates). See the Table below.
- Specify the sources (processed and/or fresh, grown on-board) of the food.
- Specify types of fats and proteins such as insects and synthetic proteins as well as 3D printed foods (from stem cells), plant extracts, and perhaps 3D printed plant extracts.
- Be innovative about shelf life, packaging, sterilization, aesthetics: appearance, taste, smell, texture, etc.
- Provide exemplary seven-day diet plans for the pre-flight and in-flight phases (two .one-week diet plans).

Table 1. Nutrient description and ranges (low% -high%)

- Percentage of proteins (all kinds)
- Percentage of Fats (all kinds)
- Percentage of Carbohydrates (all kinds)
- Dietary Fiber (indigestible carbohydrates)
    - Soluble
    - Insoluble
- Carbohydrates classified by Glycemic Index (GI)
    - High GI: 70 and higher: sugars, starches
    - Medium GI: 56 to 69: potatoes, corn, white rice
    - Low GI (1 to 55): fruits, vegetables, nuts, beans, resistant starches
    - Glycemic load (GL)
- Micro nutrients and supplementation
    - Vitamins

    - Minerals
    - Probiotics and prebiotics
- Food intake intervals
    - Intermittent fasting
    - Alternate day fasting
    - Prolonged fasting

Possible Variations in Forms of Diets

For example, there are at least five variations in the major, or macrobiotic, components of ketogenic diets. Advocate one or more, if not all, of these variations as they may relate to individual crew member needs and profiles, e.g., focusing on weight loss, muscle or strength building, etc. See especially the following website that focuses on the use of the ketogenic diet for epilepsy and also gives useful information for all types of ketogenic diet: https://charliefoundation.org/diet-plans/.

Health Monitoring and Performance Evaluations

The winning Diets will be evaluated in a study designed by the Co-Principal Investigators within MAU and the NSS. While not a strictly controlled research study, the design of their study shall scientifically document the health of the crew before, during, and after the mission. A pre-mission evaluation of crew state of health shall provide a baseline. All analog crew members are subject to approval by the medical staff based on pre-flight physical and psychological tests. The Investigators will use performance tests and health monitoring measurements listed below to document the health progress of the crew. A spreadsheet of measurements will be provided to the mission participant(s). Measurements will be taken on-site by physicians and possibly by remote monitoring. Crews will be isolated in the analog “spacecraft” and in the immediate environment of the mission site. All crew members will be performing exercise routines and tests of their responses will also be made.

Table 2. Health Monitoring and Performance Evaluation tests

The following tests will be conducted by the MAU-NSS medical and health teams. Please consider these parameters as indicators of both the preflight benchmarks and in-fight mission results.

- Cognitive performance tests: number memory, reaction time, verbal memory and visual memory. See, for example, https://www.humanbenchmark.com/.

- Physical tests: psychomotor vigilance self-test, reaction self-test
- Blood tests: glucose, ketones, hemoglobin A1C, B-vitamins, vitamin D forms
- Live blood cell tests: microscopic examination for blood condition of red and white blood cells, contaminants and parasites including fungi, yeasts, bacteria, and their metabolites such as uric acid crystals, and plaques.
- Pre-mission evaluations for genetic markers of susceptibility to known conditions

White Paper Content

Use the following questions as guidelines for the Background section of your paper:

- How would you describe the basic benefits claimed for your diet and why?
- How do diets resulting from current research on the International Space Station differ from the standard American diet?
- How would you investigate the genetic damage from common exposures on earth (e.g., pesticides, dissolved metals, toxins in food)?
- Would you expect the genetic damage due to space ionizing radiation to add to these pre-existing genetic damages or would they differ?
- Would you expect the damage from space ionizing radiation to be reduced or eliminated by your diet?
- Would you use the pre-mission diet also for the mission and why? How long before flight should the pre-flight phase of the diet be started? How long do you expect the diet to help accomplish the preflight health benchmarks?
- What research during an analog training mission would you recommend to support this inference prior to an actual long duration spaceflight?
- Of the additions that have been proposed to the basic diet, such as fasting, would you support these additions to the basic design? Why?

White Paper Length, Formatting and Style Requirements

The white paper will be generated in Microsoft Word or equivalent and submitted electronically in pdf format, properly formatted as if it were a text document and following the guidelines below.

All papers must be typewritten, double-spaced on one side only of 8 ½" x 11" paper, with 1" margins on all sides. Use 12-point Times New Roman font.

1. Paper is limited to 15 pages. This does not include the title, table of contents, abstract, appendices or references pages. Appendices are limited to 5 pages maximum.

2. Do not place names of people involved in the creation of the paper or the school(s) involved in the paper.

3. The pages of the paper must be numbered consecutively beginning with the Introduction. Diagrams and tables may be included either within the paper or as part of the Appendices.

4. In general, the contents of the paper shall be organized as follows:

    a. Title page: Only include the title. The title should consist of the minimum number of keywords necessary to portray accurately the contents of the paper. Reader interest is stimulated by a well-chosen title. The author's name must **NOT** appear on the title page, nor should any other persons or schools.

    b. Table of Contents: The table of contents should consist of a list of the parts of the paper and the page numbers, in order in which they occur.

    c. Abstract: The abstract should not describe the paper, but should give, in brief, the essential facts of its contents; for example, a brief of the problem or objective and a concise summary of the results or conclusion, touching upon methods or other details only if they are unique or if they are of some particular significance. The abstract should be no longer than 100 words.

    d. Introduction: The introductions should lead to the development of the subject so that the reader may obtain a clear understanding of the significance of the content, data presented, and/or conclusion. This can often be done by briefly giving the state of the art as background and then by bringing out the added advantages of the method of approach and emphasizing the importance of the results or conclusions.

    e. Body: The main argument of the subject is carried out in the body or its subsections, complete with supporting data. The argument should proceed in a logical sequence according to a prepared outline. The writing should be in the third person. Support data and results can be presented most effectively as graphs, charts, or tables.

        i. Standard graphical symbols and abbreviations should be used on all drawings. Well- known abbreviations may be used in the text but should be defined where used the first time followed by the abbreviation in parentheses. Generally, the use of abbreviations should be confined to tables and illustrations.

ii. Illustrations and tables should supplement, not duplicate, text materials. Likewise, they should complement, not duplicate, each other.

f. Conclusion: The conclusions are often considered the most important part of a paper. They should be stated concisely in a separate section at the end of the paper. If there are three or more conclusions, better emphasis can be obtained by numbering or labeling each conclusion and setting it off in a separate paragraph.

g. Tables: Generally, each table should be typed on a separate sheet in an appendix and numbered consecutively using Roman numerals: Table I, Table II. However, they can be inserted as part of the 15 pages. Small tabulations or listings may be made in the text where necessary for continuity. Each table should be titled by giving the brief description as a heading following the table number at the top. Ditto marks should not be used in tabled data, but brackets may be used to group information on several lines.

h. Figures: Figures should be numbered consecutively using Arabic numerals: Figure 1; Figure 2, etc. Three types of figures may be used: photographs, biochemical pathways, and line drawings. The reading material on illustrations should be kept to a minimum. In short, the reading material should be included in the captions. Portions of the illustrations may be identified by letters and explained in the captions. Whenever feasible in graphs, several trend lines or regression curves should be combined on the same coordinates. Their identifying letters or numbers should be in clear spaces between cross section lines. Readers generally prefer having the figures distributed through the paper, although it is also permissible to bind them together at the end in an appendix.

i. Appendices: There may be no more than 5 pages of appendices. Detailed biochemical pathways, development of nutrition sub-components in tables and examples, which are subordinate to the main argument in the body of the paper, and not essential to following the argument, should be treated in the appendices. Main graphs as they are developed should be numbered consecutively. The graphs, figures, and tables in the Appendices should be numbered consecutively, following the numbers used for the graphs, figures, and tables in the text (such as, if table IV were last in the text, table V would be first in the Appendices.)

j. References: To enable the reader to consult important works used by the author incidental to the preparation of the paper and other related literature that might be helpful, a suitable reference list should be appended. References should be numbered consecutively and should follow MLA formats. Examples are shown below:

For a periodical: R.N. Hall, "Power Rectifiers and transformers," Proc. IRE, Vol.

40, pp. 1515-1518, November 1952.

For a book: W.A. Edison, "Vacuum Tube Oscillators," John Wiley and Sons,

Inc., New York, New York, pp. 170-171, 1948.

For an article: B. Lawrence, B.H. Weil, and M.H. Graham, "Making online search available in a industrial research environment," Journal of the American Society for Information Science, pp. 364-369, Nov- Dec. 1974.

For an online reference:

Jason Fung, Published on 3/5/17, YouTube Video “Jason Fung: “The Complete Guide to Fasting (& how to burn fat)”. https://youtu.be/n3dwizlGaRI.