NUTRITION IN SPACE FLIGHT: SOME THOUGHTS

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We know that going into space will cause physiological changes related to microgravity and on which nutrition has a bearing. Some examples are: muscle atrophy-protein; bone atrophy-calcium, phosphorus, vitamin D; space sickness-fat; cardiovascular deconditioning-sodium, water, potassium. In the following discussion, I will touch on these and some others which relate to living in space.

Any trip into space, whether for two days or a week, will result in a 2% body weight loss even with an isocaloric diet and adequate water-salt intake. During longer missions, an increase in caloric intake greater than eaten on Earth can decrease this weight loss. The U.S.S.R. has increased the caloric intake of its crews during long-term flights. The U.S. did it in Skylab IV (84 days). What happens, however, is not very desirable for an athletic astronaut. He continues to lose muscle mass as is usual for space flight but replaces it with fat as a result of the extra calories. What is a surprise about living in the microgravity of space is the amount of calories required. NASA originally believed that a lower number of calories would suffice in space flight just as it had learned that bed rested subjects fed an isocaloric diet gain weight during the bed rest period. Experience in space flight operations proved that this was not the case and that to maintain a normal weight, it is necessary to feed the crewman about the same number of calories in orbit as he eats before the flight.

Skeletal atrophy is the biggest medical problem NASA will face in space station crews. Our knowledge about the skeletal changes of microgravity is based on Skylab data which is now over 10 years old. Since that era, the U.S.S.R. has had longer missions but no metabolic balance study has been performed, and therefore, the U.S.S.R. studies do not tell us whether or not their crewmembers are losing calcium at the same rate as found in Skylab crews.

You may recall in Skylab, there were three missions with three people each. The first mission lasted 28 days. The second mission lasted approximately two months, and the third, three months. The numbers represent only nine individuals at the beginning and only three at the end of three months. Thus, the entire world data on the subject are very scanty. If these data turn out to be representative of the general population, then Skylab will have been a great contributor to the knowledge base of what happens to the bones when you live in a microgravity environment. The Skylab results indicate that after the first week or so, each crewman lost about 0.5 of his skeletal calcium each month. In some areas, like the weight-bearing skeleton, the loss may have been as high as 5% per month. All crewmembers lost calcium and this loss continued through the mission.

NASA studies have shown that if a subject is placed at bed rest, some of the physiological responses simulate space flight because gravity effects on the length of the supporting skeleton are removed. Bed rest will produce bone atrophy similar to that found in Skylab crews. After returning to normal living conditions, the subject's calcium balance returns to near normal. But the subject's skeleton contains less calcium than it would have if the subject had not been placed at bed rest.

The calcium loss of space flights poses no problem if you are a gung-ho astronaut who goes up once, gets the Congressional Medal, meets the President, and then resigns to go into industry. It will be different in the space station era when a worker is trained to work in space, goes up for 90 days, comes back for 90 days, goes back, and so on for many trips. Would the worker retire at the end of his life's work in serious jeopardy as far as his skeleton goes? In a way, he is somewhat like the worker exposed to radiation. What is the allowable lifetime loss of calcium before NASA as an employer should call a halt?

There is not much known about calcium and the skeletal changes over a lifetime. There have been several studies, but they are flawed because the researchers have not followed a single individual over several decades. What they do is rely on measuring a group of 50-year olds, a group of 40-year olds, etc. When this is done, the average calcium of a person at 50 is less than in a 40-year old which in turn is less than in a 30-year old and it is less than in a 20-year old. Skeletal calcium is maximal around 20 to 25 years of age in a male and female, and from then on calcium decreases gradually at a rate of about 5%/decade. There is a certain skeletal density below which a person will become very prone to stress or traumatic fractures. A woman starts out at a maximum skeletal calcium at age 20, but this is somewhat less calcium than a male because her skeletal size is smaller. During the reproductive years, her calcium loss is at the same rate as a man, although losses might increase some during pregnancies and breast feeding. When she goes through menopause at age 50 to 55, the calcium loss is equivalent to about three decades of loss prior to that. Thus, by the time she goes through menopause, her calcium loss is equivalent to a man 30 years older. Thus, starting with less calcium and losing it faster, women have more trouble at ages 70, 80, and 90 with fractures than males of the same age. We can predict then, if a man spent a lifetime occupation in space flight losing calcium at 0.5% per year, he would probably have a problem with his skeleton at age 70 or 80 like some women, and a woman astronaut would have trouble earlier. The big unknown at this time is how to stop the crew's calcium loss.

Various ideas come to mind on how to stop the calcium loss: One, we could increase the calcium in diet. If we ingested more calcium, would it preserve calcium in the bone, would the calcium loss level off sooner? The answer tested in bed rest studies says yes it does, but the effect lasts only for about 12 weeks. Other things have been tried. High phosphorus in diet may help decrease urinary calcium. Certain nutrients have been tried as pharmaceuticals. Fluoride will probably be of some benefit. Phosphanates which are a detergent-like compounds will stop calcium loss. A high protein diet increases the rate of calcium loss. Should the diet be low in protein?

The bones in a human are trabecular or cortical. Trabecular areas are constantly being remade and torn down and remade--constantly remodeled. Bones trabeculae are changed in thickness and number depending on physiological need. In space flight, we believe but have not yet proven, that the remodeling, even if it proceeds under the influence of a therapy, would probably be in the wrong spots. For example, as I stand here, I stress my femur which is a bone that responds to remodeling. As I move around, I am stressing it and it may take up more calcium. Jogging and hitting the heel on the pavement may induce stress fractures. When it does, the body may increase the calcium supplied to that area. In space there is no gravity, there is no pull; therefore, any calcium added to the skeleton might be distributed indiscriminately. For example, calcium might be added to the skull near openings where nerves come out. These openings could be made smaller resulting in pressure on the nerves. In space flight it is important not only to prevent the loss, but if bone remodeling is going to go on, to find a way to make the remodeling meet the body's requirements for living on Earth.

The urinary calcium increases immediately after exposure to weightlessness since the body starts to unload calcium in the first few days. This means the kidney has to increase calcium excretion up to a maximum of about 500 milligrams. With further loss of bone calcium, less food calcium is absorbed by the intestines. Increased urinary calcium could result in renal stones. Would dietary modification decrease this health hazard? Would increasing the dietary phosphorus decrease this? Would an acid-producing diet help?

There are many studies that have been done to try to determine what causes the calcium loss. Today we really do not have a good understanding of its cause. Hormones do not seem to change a lot, the level of phosphate and calcium in the blood goes up, and protein stays about the same. There is not much we can say about it other than that lack of stress and strain on the bone causes the bone to lose calcium. NASA hopes that by the time the space station is developed that it will have found a therapeutic measure. Perhaps it will be a food additive. There are some interesting sidelights in NASA data. For example, just because a person is a jogger during adult life does not necessarily mean that he or she has more calcium in the skeleton. Studies have shown that runners can have low calcium or high calcium skeletons depending on factors other than exercise stress.

When an astronaut is exposed to weightlessness, unpleasant symptoms develop. The most unpleasant is space sickness. Space sickness is somewhat similar to car sickness or air sickness. Nutritionists might help astronauts by finding foods which tend to decrease the symptoms of space sickness. Shortening gastric emptying might help. Fatty foods slow stomach emptying. Therefore, should NASA reduce fat in the diet during the first few mission days? Vomiting in space is not a retching type of vomiting often associated with food poisoning. It is more like, "Oh my golly, it happened," type of situation. One of the most useful drugs to combat space sickness is a combination of a centrally acting anticholinergic and a stimulant to overcome the soporific effects of the anticholinergic drug. Anticholinergic drugs dry the mouth and the stimulant decreases appetite; both undesirable effects for a crewmember. Even if they have had no problem in airplane spinning and on merry-go-rounds it does not mean that an individual will not be sick in space. Terrestrial motion sickness does not correlate with space sickness.

We know there is a fluid shift on entering space, and maybe the fluid shift is one of the causes of space sickness. If the individual's extracellular water is high, or if there is edema of the legs it might help to reduce it before launch by eating less salt and drinking less water. Some astronauts try to dehydrate themselves before they go up to decrease the rate of urine formation during launch and to postpone urination in early orbit. It is not much fun to have to urinate while waiting on the launch pad.

The astronauts sometimes do not want to drink the water offered while in orbit. The water often comes out of the spicket containing excess gas because it is a by-product of the fuel cells and can contain uncombined oxygen and hydrogen. The gas bothers them, and they prefer to avoid drinking gas-filled water. However, on reentry, if the body's fluid content is too small, there is a tendency to faint, to have a lower blood pressure, and to excrete more adrenalin. If the crewman increases his salt-water intake just before he comes back, he feels better. They do that by taking a liter of isotonic saline solution. This is made up in the stomach by eating 8 salt tablets and drinking 1 liter of water.

There is an old wives tale that the astronauts used to believe that Gatorade had significant amounts of salt in it. For a while they took Gatorade instead of the salt tablets because people remember getting sick after taking salt tablets on Earth. It took a while before the flight surgeons convinced crews that Gatorade is mostly sugar and almost no salt, and that they could drink it as a personal preference beverage but could not use it for the countermeasure.

Muscle mass in the calves, thighs, and back needs to be maintained during orbital living. Protein intake may have to be increased to do this during long missions, along with administration of anabolic steroids. Red cell loss of 10% occurs in space flight. We do not know how to prevent it. After return to Earth, the individual will need a little more iron and definitely need more folic acid to regenerate the lost red cells. It may also be desirable to decrease cholesterol and carbohydrates in the diet since on return, high density lipoproteins (HDL) are decreased for a period of time predisposing the individual to increased cholesterol deposition in the blood vessels.

The toilet facilities on the spacecraft are not a lot of fun. During long missions, we might want to increase the fiber content of the diet to aid evacuation. A higher fiber diet might help reduce intestinal gas pains which are unpleasant.

We will have to guard against vitamin deficiency. The processed food for a space diet may be five or more years old, and therefore, may lack some vitamins and nutrients. We should by all means plan to use fresh foods whenever possible. The caloric intake should be planned to be as on Earth and should not be decreased even though it appears that astronauts floating around in space would not be working so hard. During extravehicular activities (EVA) very high metabolic rates have been recorded. Most of this occurs because the astronaut does not have experience with this type of activity, so in a sense, he is clumsy. He does not know how to pull on a bolt without flying off in the opposite direction, and trying to hold on, he uses more energy than is needed. By the time the space station is built, astronauts will be trained to work effectively in space suits. Their caloric use or metabolic rate when they are working in EVA should not be any greater than it would be on Earth except that if the space suit is not functional and pleasant to wear, calories will be used to move around in the suit and to endure the discomfort. In present space suits, using the hands causes pain from the glove. With a better suit and especially better gloves, training, and experience, working in space should be like any other job.