plays a critical role in calcium absorption and metabolism. Sunlight, specifically ultraviolet radiation, is essential for synthesis of vitamin D. Spacecraft are heavily shielded to reduce crewmembers' exposure to the harmful types of radiation. Thus, the lack of ultraviolet light during space flight may decrease vitamin D pools in the body, which poses a concern over lengthy missions.

The absorption of calcium is decreased during space flight, further compounding the problem; thus bone loss in space is increased, while bone building is decreased. The recommended daily amount of calcium is 1,000 mg. Typically, the body absorbs 40 to 50 percent of the daily dosage on the ground but only 20 to 25 percent in space.

"We need to be able to identify the mechanisms responsible for bone loss and determine a means to counteract them for future extended exploration missions to become a reality," said Dr. Helen Lane, NASA chief nutritionist. "We can't go to Mars without first developing a countermeasure for bone loss."

Understanding the regulation of bone and calcium metabolism during space flight will be critical for identifying and developing methods for counteracting flight-induced bone loss. The ability to monitor calcium movement in and out of various storage pools throughout the body (blood, bone, etc.) would allow much more detailed and dynamic studies of how the regulatory systems are functioning over time.

During experiments to be conducted during shuttle mission STS-107 and aboard the ISS, researchers will use state-of-the-art tracer techniques to measure calcium kinetic changes before, during and after flight. This method involves the use of two stable isotopes of calcium, one of which is administered orally and the other intravenously. The appearance and disappearance of these isotopes in biological samples (e.g., blood, urine, and saliva) will be documented over the days and weeks following the doses. Mathematical modeling techniques will be used to monitor the movement of calcium through the body compartments using software developed at the National Institutes of Health. Information gained from these experiments will be critical for monitoring and counteracting the loss of bone mineral during flight, and for understanding Earth-based bone diseases, such as osteoporosis.

In-flight determinations of calcium kinetics have been collected thus far from six people, three from Mir 18 in 1995 and three from the Phase 1C Mir missions in 1997-98. For the Mir 18 crewmembers, calcium absorption during the last week of the 115-day flight was substantially lower than measurements noted pre-flight. Furthermore, absorption did not return to pre-flight levels until three months after return to Earth. Results also show that bone calcium is lost at rates of approximately 250 mg per day during space flight. This loss is due to lower calcium intake, reduced fractional absorption, increased calcium excretion, and increased bone resorption. Recovery continued for many months after flight at a rate slower than the in-flight loss. If it is assumed that the rate of bone mineral loss observed in flight is constant throughout the flight and that the rate of recovery is also constant, it will take about 2.5 times the mission length to recover the lost bone.

Potential countermeasures for in-flight bone loss include vitamin K, vitamin D, pharmaceutical agents, ultraviolet light treatment and resistive exercise. In a European Space Agency-sponsored study, vitamin K supplementation reduced urinary calcium loss for one Mir crewmember. This may have an impact on bone health during weightlessness, but more data are clearly needed.

Further study is also required to define the efficacy of vitamin D-fortified diets, supplemental vitamin D and the use of in-flight ultraviolet light treatment. Resistive exercise helps build bone mass and a resistive exercise device is planned for use aboard the ISS.

Iron Absorption

"The problem with iron that we see during space flight is the opposite of what we see on the ground," said Smith. "For people on the ground, iron deficiency is a concern. In flight, from the data that we have, it appears that there is abundant iron available for crewmembers. That's a concern because there are negative consequences of getting too much iron."

Upon examining astronauts who have returned from space, researchers have noted high amounts of iron stored in the body. Despite this noted increase, the amount of red blood cells is low. Thus the iron is not serving to build red blood cells during flight; it is just stored.

"We are concerned about iron storage because it can lead to peroxidation, which could damage the body's DNA," said Lane.

Due to this concern, the amount of iron included in the astronauts' diets has been lowered, but this may prove to be unnecessary. An experiment to be conducted aboard the space station will help determine whether or not iron storage is a problem for space travelers if it is not absorbed into the bloodstream.

Antioxidants (e.g., vitamins A, C, and E) may provide a feasible countermeasure for crewmembers during long-duration space flight. This may help reduce risks associated with high iron, as well as with radiation exposure. Further studies to determine the efficacy of antioxidants will be conducted aboard the ISS.

Conclusion

Researchers have only just begun to scratch the surface of understanding the impact of weightlessness on the human body. A more complete understanding will not only enable the exploration of our universe, but will provide the information needed for the maintenance of human health and treatment of diseases on Earth. ■

For more information:

JSC is publishing a book that contains the significant accomplishments of nutrition in space flight. This book, Nutrition in Spaceflight and Weightlessness Models, edited by Helen W. Lane and Dale A. Schoeller (University of Wisconsin), distributed by CRC Press, Boca Raton, Florida, will be an international distribution.

JSC Photo S99-05484 by Robert Markowitz

The JSC Nutritional Biochemistry Laboratory, from left, Diane DeKerlegand, Molly Whitley, Jeannie L. Nillen, Patti Gillman, Barbara L. Rice, Myra D. Smith, Scott M. Smith, Vernell Fesperman and Janis E. Davis-Street.