Dietary Protein Changes Human Bone Turnover: A Nutritional Countermeasure for Spaceflight

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Bone loss is a significant concern for long-duration spaceflight. Exercise and pharmacology are often the first things that come to mind regarding countermeasures to protect bone, and nutrition is often overlooked as a source of countermeasures for bone loss associated with spaceflight. Nutritional countermeasures have the benefits of a low risk of side effects and minimal (or no) requirements for additional crew time during flight. Several nutrients are important for bone health and it is, therefore, necessary to look beyond individual nutrient effects and examine the complete diet closely. Diet can also have an effect on acid-base homeostasis, which, in turn, can have an impact on bone health.

Because bone contains a substantial reservoir of ions that can buffer excess acid, chronic small perturbations of acid-base balance in the body can induce metabolic changes in bone. Dietary intake can influence acid production in the body because acid and base precursors (compounds that yield acid, or base, after they are absorbed and metabolized) exist in foods. If the diet contains more acid precursors than base precursors, chronic low-grade metabolic acidosis can result. One example of an endogenous acid is sulfuric acid, which may be produced from the breakdown of sulfur-containing amino acids. Diets high in protein (and/or sulfur-containing amino acids) are commonly associated with increased urinary calcium excretion and lower urinary pH.

Bed rest, an analog of spaceflight, induces a state of negative calcium balance and bone loss. Thus, it provides an experimental model in which healthy subjects are studied and dietary intake is both adequate and well controlled. We hypothesized that the effect of bed rest on bone in subjects lying with their head tilted down would parallel the effect of low calcium intake on bone in ambulatory (i.e., not bed-rested) subjects.

We found that in healthy subjects consuming adequate amounts of all nutrients, a higher ratio of acid precursors to base precursors (estimated as the ratio of dietary animal protein to dietary potassium) in the diet has a more substantial effect on bone metabolism during bed rest than during ambulatory conditions. During the latter part of a 4-week bed rest, the ratio of acid-to-base precursors in the diet was positively correlated with the rate of excretion of calcium and chemical compounds (markers) associated with bone resorption (loss). An increase of 30% in the ratio of animal protein to potassium intake was associated with an approximately fourfold increase in urinary n-telopeptide excretion, marker of bone loss. The slopes of the regression lines between the ratio of animal protein to potassium and the markers of bone resorption increased with time, suggesting that changes in diet may have a greater impact on bone when bone health is already compromised (as it is during bed rest).

We also examined whether the combination of an amino acid supplement, which included sulfur-containing amino acids, and a carbohydrate supplement modified bone metabolism during bed rest. Although the amino acid supplement protected against loss of lean body mass, the supplemented group tended to have more bone resorption than the control group. The rate of urinary calcium excretion was greater and urinary pH was lower in the amino-acid-supplemented group than in the control group during bed rest, suggesting that the amino acid supplement may have altered acid/base balance.

It is important to note that these studies do not necessarily support the use of low-protein diets for bone health. Rather, they support the idea that a balanced diet with base precursors (vegetables and fruits), acid precursors (protein sources), and adequate calcium and phosphorus intake is optimal for bone health. These findings also provide an example of space research that could have an impact on the health of the general public. Use of a spaceflight analog system has led to a better understanding of the role of diet in bone health, which has helped to clarify some of the discrepancies in the general scientific literature.