CALCIUM KINETICS DURING LONG-DURATION SPACE FLIGHT

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INTRODUCTION

Bone loss represents one of the most significant effects of space flight on the human body. Understanding the mechanisms underlying this loss is critical for maintaining crew health and safety during and after flight. This investigation documents the changes in bone metabolism and calcium kinetics during and after space flight. We previously reported calcium studies on three subjects during and after a 115-d stay on the Russian space station Mir (*Am J Physiol*, 277:R1-R10, 1999). We report here data on an additional three subjects, whose stays on Mir were approximately 4 (n=1) and 6 (n=2) mos. Previously published data are included for comparison.

CURRENT STATUS OF RESEARCH

Methods

Subjects were three men, aged 44±3 years and weighing 82.7±5.4 kg. Calcium kinetic studies were performed before, during (at 2-3 months of flight), and after space flight. Stable isotope tracer kinetic studies were performed before, during, and after flight. Following administration of isotopes (^{44}Ca orally, ^{42}Ca intravenously), blood, urine, saliva, and fecal (pre- and post-flight only) samples were collected for 21 days. Isotope enrichments were determined using Thermal Ionization Mass Spectrometry, and the data analyzed using the SAAM (Simulation, Analysis and Modeling) software program and multi-compartmental mathematical modeling techniques. In addition to the kinetic studies, endocrine and biochemical markers of bone and calcium homeostasis were determined using standard analytical techniques.

Results

Biochemical and endocrine data are reported as percent differences from individual preflight data. Similar to previous reports, ionized calcium was unchanged (2.8±2.1%) during flight, calcium absorption was variable inflight, but was decreased after landing, and vitamin D stores were decreased inflight by 36±25%. By contrast, serum PTH was decreased more (59±9%) during flight than previously reported, while 1,25(OH)$_2$-vitamin D was decreased during flight in only 2 of the 3 subjects. Markers of bone resorption (e.g., collagen crosslinks) were increased in all subjects during flight. Bone-specific alkaline phosphatase, a bone formation marker, was decreased (n=1) or unchanged (n=2), while osteocalcin was decreased 34±23%.

Results from the recent Mir calcium kinetic studies confirm previous observations (**Fig. 1**) of increased bone resorption during space flight. These data demonstrate that the loss of bone during space flight is associated with increased resorption and either unchanged/decreased formation. Bone balance was negative during space flight (-232 ± 150 mg/d) in the recent crewmembers studied, very similar to previously published results (**Fig. 1**).

Figure 1. Bone resorption (left panel) and bone calcium balance (right panel) from early Mir studies (adapted

from Smith et al., *Am J Physiol*, 277:R1-R10, 1999).

Preliminary Conclusions

The data reported here support earlier reports, and demonstrate that the bone loss of space flight is clearly related to increased bone resorption, while the role of bone formation in this process is less clear. The calcium kinetic studies conducted to date (with one exception) have only been performed once per subject during flight - at approximately the same time (i.e., in the flight day 90-110 range). Further investigation is warranted in order to understand the time-course of bone-related changes during space flight, including both the immediate changes during the first days-weeks of flight, as well as the long-term adaptation.

FUTURE PLANS

In addition to the Mir flight data shown here, this research was also selected for International Space Station and Shuttle flights. Currently, this study is manifested on a 2001 Space Shuttle flight (STS-107) and potentially will fly on an additional Shuttle flight the following year. These short-term data, in addition to the long duration Mir and ISS studies will provide a better understanding of the time-course and nature of changes in bone and calcium metabolism during space flight. This research will aid in the understanding and treatment of both space-induced bone loss and Earth-based bone diseases (e.g. osteoporosis, paralysis).

INDEX TERMS

Bone, calcium, calcium kinetics, osteoporosis, bone loss, calcium metabolism