Chapter 10

Space Travel and the Musculoskeletal System

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ABSTRACT

Extended exposure to microgravity during space travel presents significant musculoskeletal risks for astronauts, primarily resulting in osteoporosis and muscle atrophy. Research indicates that astronauts experience a 1-2% decrease in bone mass per month due to reduced mechanical loading, which leads to increased bone resorption and decreased bone formation. Despite the implementation of exercise regimens aboard the International Space Station (ISS), such as the Advanced Resistive Exercise Device (ARED), bone loss remains a prevalent issue. This study reviews the physiological changes induced by microgravity, including cardiovascular weakening, immune system suppression, and cranial pressure increases that can

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lead to visual and neurological disturbances. The findings underscore the necessity for ongoing research into effective countermeasures to preserve astronaut health and performance during long-duration space missions, as well as the potential for integrating advanced technologies to enhance training and rehabilitation in microgravity environments.

2.1 EFFECT OF SPACE TRAVEL ON THE MUSCULOSKELETAL SYSTEM

2.1.1 Bone Density Loss in Microgravity

The first reports of μG-induced bone loss surfaced when Skylab astronauts experienced a bone mass decrease in the range of 1–2% per month compared to their pre-flight or ground-based control. However, bone loss has been identified as one of the primary risks experienced by astronauts, but it was determined that even with preventive exercises performed in space to counteract this deficit (exercises aimed at combating something entirely pathological), so not a new concept. In response to the decreased loading of weight-bearing bones in microgravity environment, adaptations include increased bone resorption and suppressed bone formation (Caillot-Augusseau et al., 2000) For example, bone mineral density (BMD) of the tibia in which is a weight bearing has been found to decrease substantially during spaceflight; whereas reports have reported loss at non-weight bearing sites similar as distal radius (Gabel et al., 2022). Several cross-sectional examinations of spaceflight have implicated bone resorption as an early response to unloading, with a peak after 2 weeks so that urinary C-telopeptide and pyridinium crosslinks become increased (S. M. Smith et al., 2005). In contrast, excretion of calcium in urine is increased revealing decreased absorption of calcium among astronauts. This leads to an overall negative balance of the element in question; calcium in this case, which adds up with bone formation reportedly not changing or decreasing due to immobility. However, circulating biomarkers of bone turnover preflight are suggested to predict in-flight bone loss with astronauts who demonstrate higher markers for bone resorption and formation before leaving Earth then exhibiting greater losses in BMD and strength at the distal tibia during spaceflight (Gabel et al., 2022).

Bone loss is also greater with increasing duration of spaceflight, and it may take up to 2 years post-flight for BMD measures to return baseline or pre-mission levels. In another subsequent study, 13 astronauts after missions of 4–6 months onboard ISS had their bone mass, microarchitecture and strength assessed. The subsequent bone recovery was assessed in each astronaut for up to 12 months post-landing. Cortical bone thickness and density in the weight-bearing distal tibia recover to

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