Femoral Head Bone Loss following short and long-duration spaceflight

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Exposure to mechanical unloading during spaceflight is known to have significant effects on the musculoskeletal system. Our ongoing studies with the mouse bone model have identified the failure of normal stem cell-based tissue regeneration, in addition to tissue degeneration, as a significant concern for long-duration spaceflight, especially in the mesenchymal and hematopoietic tissue lineages. The 30-day BionM1 and the 37-day Rodent Research 1 (RR1) missions enabled the possibility of studying these effects in long-duration microgravity experiments. We hypothesized that the inhibition of stem cell-based tissue regeneration in short-duration spaceflight would continue during long-duration spaceflight and furthermore would result in significant tissue alterations.

MicroCT analysis of BionM1 femurs revealed 31% decrease in bone volume ratio, a 14% decrease in trabecular thickness, and a 20% decrease in trabecular number in the femoral head of space-flown mice. Furthermore, high-resolution MicroCT and immunohistochemical analysis of spaceflight tissues revealed a severe disruption of the epiphyseal boundary, resulting in endochondral ossification of the femoral head and perforation of articular cartilage by bone. This suggests that spaceflight in microgravity may cause rapid induction of an aging-like phenotype with signs of osteoarthritic disease in the hip joint.

However, mice from RR1 exhibited significant bone loss in the femoral head but did not exhibit the severe aging and disease-like phenotype observed during BionM1.This may be due to increased physical activity in the RH hardware. Immunohistochemical analysis of the epiphyseal plate and investigation of cellular proliferation and differentiation pathways within the marrow compartment and whole bone tissue is currently being conducted to determine alterations in stem cell-based tissue regeneration between these experiments.

Our results show that the observed inhibition of stem cell-based tissue regeneration persists during long-duration spaceflight. Furthermore, spaceflight femurs from BionM1 indicate onset of an accelerated aging-like phenotype with signs of osteoarthritic disease shown by disruption of the epiphyseal boundary and endochondral ossification. These effects are likely caused by a failure of stem cells to regenerate degraded tissues and may have significant implications for bone and cartilage health following extensive periods of mechanical unloading during long-duration spaceflight.

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