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Author: Ms. Laura Rose
University of Alberta, Canada, lrose@ualberta.ca

Prof. Hasan Uludag
University of Alberta, Canada, hasan.uludag@ualberta.ca

MICROGRAVITY MODELS TO INVESTIGATE CELLULAR MECHANISMS IN MICROGRAVITY-INDUCED BONE LOSS

Abstract

Astronauts undergo a myriad of physiological changes during spaceflight. In particular, microgravity during spaceflight leads to skeletal unloading, resulting in bone density loss [1]. Approximately 1-2% bone loss is observed per month. Demineralization is especially seen at weight-bearing sites and may lead to increased fracture risk. Although bone density will return to pre-flight levels for most astronauts, it is a lengthy process and there is a possibility of irreversible bone loss. To impede bone loss in space, astronauts follow regimented resistance exercise programs and take nutritional supplements. Despite these preventative measures, bone loss is a major obstacle for future long-duration flight that would leave astronauts with osteoporotic bone. This level of demineralization would endanger the crew, and put the mission at risk. In order to develop effective counter-measures for future missions, the biology behind microgravity-induced bone loss must be better understood. The skeleton of normal healthy individuals undergoes constant remodelling where old bone is resorbed and new bone is formed. Bone metabolism is modulated by bone-forming osteoblasts and bone-resorbing osteoclasts. With unit gravity on earth, the skeleton is loaded and maintains equilibrium between bone formation and resorption, with no net change in bone density. Skeletal unloading during exposure to microgravity and the resulting altered cellular activity causes a shift toward bone resorption. Experiments have been performed both in simulated microgravity ground experiments and during space flight. Due to the limited spaceflight experiments, ground based models of microgravity have been developed. Microgravity experiments are generally performed in rotating cell culture systems or random positioning machines (vector averaging) to expose cells to microgravity. In ground-based experiments, osteoblast differentiation during exposure to osteogenic supplements has been found to decrease under simulated microgravity [2]. Similar reductions in activity have been observed in osteoblasts during spaceflight [3]. In contrast to the reduction observed in osteoblast differentiation, osteoblast activity is upregulated in simulated microgravity [2]. Osteoclast differentiation genes [4] and bone resorption activity [5] were found to increase during spaceflight, compared to unit gravity controls. This paper reviews the cellular mechanisms behind microgravity-induced bone loss, and compares experimental data from modelled microgravity in ground studies with microgravity in space flight.

References

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