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STEAM Project

Exploring Microgravity Induced Bone Loss in Astronauts

For my STEAM project, we are going to explore microgravity induced bone loss in astronauts. The objectives covered are to identify the 4 cells that comprise bone tissue, and know the stages of bone development and repair. It took me quite some time to decide what topic I wanted to choose for my STEAM project. Initially, I looked at osteoporosis, then expanded to other skeletal diseases such as Paget's, osteogenesis imperfecta, scoliosis, etc. Eventually, while thinking about osteoporosis causes and prevention, the idea to research the effects of microgravity environments on the bone health of astronauts piqued my interest.

The 4 cells that compromise bone tissue are osteogenic cells, osteoblasts, osteoclasts, and osteocytes. Osteogenic cells are undifferentiated cells with high mitotic activity that differentiate and develop into osteoblasts. Osteogenic cells are the only bone cell that can divide. Osteoblasts are the cell that is responsible for forming new bone tissue. Osteoclasts are the cell that is responsible for resorbing bone tissue. Osteocytes are the primary cell in mature bones that are responsible for maintaining the bone matrix.

The embryonic skeleton is made up of hyaline cartilage which eventually develops into bone. Around week 6-7, bone development begins of the embryo's skeleton through a process called ossification or osteogenesis. Ossification or osteogenesis is the process of bone formation. The mesenchymal cells in the embryonic skeleton begin to differentiate into specialized cells including osteogenic cells. The osteogenic cells differentiate and develop into osteoblasts. The osteoblasts secrete osteoid, unmineralized bone matrix, which will eventually calcify and entrap the osteoblast. Once the osteoblasts is entrapped, it becomes an osteocyte. The bones grow in both length and diameter. Osteoclasts break down and resorb old bone along the medullary cavity while osteoblasts produce new bone tissue beneath the periosteum. This bone modeling, the process where the matrix is resorbed from one surface by osteoclasts and deposited on another surface by osteoblasts, takes place during bone growth and stops in adulthood. A similar process called bone remodeling, where osteoclasts resorb old or damaged bone on the same surface where osteoblasts are forming new bone, takes place in adulthood due to injury, exercise, or other activity.

When astronauts embark on a space exploration mission, they inevitably put their body at risk for health complications that could have a life-long effects. One of those health complications is the effect that microgravity has on the skeletal system.

Studies has shown that bone mineral density decreases in microgravity states due to decreases in mechanical loading. The longer an astronaut is in space, the greater the impact on bone mineral density. The longer an astronaut is in space, the greater the osteoclast activity is, and the lower the osteoblast activity is. This results in a net bone loss with more breakdown of bone tissue than buildup of bone tissue.

Loss of bone mineral density in the upper extremities occurs at a lower rate than in the lower extremities. This could be due to the fact that the upper extremities are non-weightbearing on earth as well as in microgravity environments. Another hypothesis is that the upper extremities are utilized more in microgravity environments for movement, for example, pulling and pushing to get around the space station, which increases the exercise.

Although it is impossible to completely prevent bone loss in microgravity environments, there are tools to aide in slowing the process down. Astronauts can begin a workout routine prior to a mission in order to build up strength and bone density. Throughout the space mission, astronauts can exercise on specialty exercise equipment developed for use in microgravity environments. Resistance training is one type of exercise that can be adapted for microgravity environments and can help decrease the rate of loss of bone matrix density. Although tight quarters can limit the options for exercising at the space station, it is imperative that astronauts have the tools, equipment, and training to be able to exercise during their space missions.

Another prevention option is prescribing pharmaceuticals to aide in the prevention of bone loss during space missions. Anti-resorptive medications suppress bone resorption to help prevent bone loss. Two options of anti-resorptive medications are bisphosphonate (alendronate), and zoledronic acid.

In conclusion, microgravity induced bone loss in astronauts can be a devastating and long-term health complication experienced after space exploration and living in microgravity environments. Although these complications cannot be fully prevented at this time, there are options to help reduce the rate of bone loss experienced by astronauts.

Citations:

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