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Ruptured Disks in Space

Amber Blake

For astronauts, being in outer space means adapting everyday tasks to a weightless environment. Once they return to earth, astronauts may find that they not only struggle to perform these same tasks, but they also face an increased risk of back pain and injury.

"Astronauts have a significant problem with disabling low back pain in space, and a high risk of disk herniation when they return to Earth," explained Britta Berg-Johansen, a PhD candidate at the University of California (UC) Berkeley-UC San Francisco (SF) graduate program in bioengineering, at the annual meeting of the Orthopaedic Research Society (ORS). "This is not only a dilemma for crew safety, but also for NASA's plans for future long-duration space travel," she said.

Ms. Berg-Johansen and her team of researchers have been exploring mechanisms of the increased rates of disk herniation that astronauts experience. "Without gravity loading, spinal disks swell, trunk muscles atrophy, and vertebrae become osteoporotic. This creates a triple jeopardy for astronauts and a major hurdle for future long-duration space travel, such as planned missions to Mars."

Mice in space

Researchers from the UCSF Orthopaedic Bioengineering Laboratory have been working with mice obtained through a NASA tissue-sharing program. Six mice were sent on a 30-day microgravity Bion M1 mission and acclimated to normal gravity for 12 hours before they were sacrificed, while eight mice remained on the ground for the 30 days in standard vivarium cages.

The C3-C4 motion segment was isolated from each mouse tail. The ventral side of each motion segment was marked with tissue dye to track orientation. Surrounding ligaments and soft tissues were removed to isolate the disks and vertebrae, and each specimen was radiographed to estimate disk height and cross-sectional area.

Differences found

Researchers found that the mice who had been in space exhibited reduced spine bending strength and flexibility as well as significant bone loss compared to mice in the control group.

Spaceflight reduced bending strength by 17 percent ($P < 0.05$) and reduced toe region by 32 percent ($P < 0.05$) with no significant effect on bending stiffness ($P > 0.25$). Disk height was reduced by 16 percent in flight mice ($P = 0.054$).

Histology identified two modes of failure—separation within the growth plate and annulus avulsion at the disk-vertebra junction. Spinal segments tended to fail within the growth plate in mice that had been in space, while spinal segments of earth-bound mice tended to fail at the disk-vertebra junction. Polarized light microscopy showed annulus collagen fibers inserting into the cartilage endplate but not continuing through the endplate to the subchondral bone.

How does this relate to men and women in space? "Our research indicates that bone loss and spinal stiffening during spaceflight may contribute to the increased herniation risk in astronauts. This motivates the development of countermeasures related to maintaining spine posture and flexibility as well as monitoring and preventing bone loss during spaceflight and limiting heavy lifting activities upon returning to Earth," said Ms. Berg-Johansen.

According to the researchers, the increased likelihood of failure at the growth plate before the disk-vertebra junction in the space mice suggests a decrease in growth plate integrity and may explain the reduction in bending strength without a corresponding reduction in stiffness. The reduction in toe region is consistent with reports of decreased range of motion in astronauts, and the shortened disk height is consistent with prior studies investigating post-flight mice.

The fact that failure occurred at soft–hard-tissue interfaces between cartilage and bone in all specimens is presumably due to stress concentrations caused by abrupt changes in material properties at these junctions, they wrote.

Limitations

A limitation of animal models used in shuttle missions is the lack of clarity on whether post-flight changes in mice are caused by the same mechanisms as in human astronauts.

"Microgravity likely has different effects on murine spines due to anatomic and physiologic differences," wrote the researchers. "The growth plate separations observed in this study are not relevant to adult humans, but may provide insight for mechanisms of vertebral growth plate fractures observed in children before growth plate closure. Interestingly, mice have been observed using their tails to move about inflight enclosures, which may be a confounding variable in accelerating disk degeneration. It should also be noted that the flight mice in this study acclimated to normal gravity for 12 hours before they were sacrificed, and the effects on tissue properties during this period are unknown.

"Despite these limitations, this study provides the first analysis of bending properties of intervertebral disks following spaceflight and provides insight into possible mechanisms for increased herniation risk following spaceflight.

Next mission?

The next step for the team is to further investigate the contributions of bone loss, disk stiffening, and other tissue differences such as muscle atrophy toward disk herniation risk in human spines. “Our hope,” said Ms. Berg-Johansen, “is that our data will have importance for improving rehabilitation protocols such as avoiding heavy lifting activities and excessive spinal movements as astronauts acclimate to gravity after returning to Earth.”

Ms. Berg-Johansen’s coauthors for “Spaceflight Decreases Bending Strength and Alters Failure Mode in Murine Spinal Segments” include Ellen C. Liebenberg, Brandon R. Macias, PhD; Alan R. Hargens, and ***Jeffrey C. Lotz, PhD.*** *The authors report no conflicts of interest.*

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