How can we predict bone loss in astronauts?

Abstract

Have you ever dreamed of being an astronaut? Exploring outer space sounds exciting, and astronauts get to do that. However, going into space can lead to health problems. The lack of gravity has a negative impact on bones, called bone loss.

Astronauts try to compensate for bone loss with a lot of exercise – both in space and on Earth. But even exercising doesn't prevent bone loss in some cases. We wanted to find out what factors affect bone loss. We also wanted to find a way to predict bone loss in astronauts before spaceflight.

We analyzed the leg and arm bones of 17 astronauts before and after a space mission. We also looked for markers of bone change in their blood and urine.

We found out that bone loss happens quickly in space. The longer the space mission, the bigger the problem. More exercise before spaceflight predicted greater bone loss! Elevated markers of bone metabolism before flight also predicted greater bone loss.

Introduction

Every year astronauts go to the International Space Station to conduct scientific experiments. They have to live and work in microgravity for months. A big problem with this environment is bone loss.

Bones are alive. They grow and change all the time to adapt to your body's needs. One type of bone cells breaks down older bone tissue. Other cells build new bone tissue. Usually, there is a balance in this process (until a certain age). But in microgravity, the breaking down of bones happens faster than the rebuilding. This is because bones adapt to this new environment where they don't have to carry the body's weight. Much like muscles, if you don't load your bones, they weaken. The problem is that we don't know if astronauts' bones will recover when they come back to Earth (where there is gravity). They may be more likely to fracture their bones later in life.
HOW CAN WE PREDICT BONE LOSS IN ASTRONAUTS?

Results

The astronauts’ bone loss was rapid. Six months in space resulted in bone loss equal to 10–20 years on Earth! Longer missions led to even more bone loss (Fig. 2). This is especially true for leg bones.

We found out that exercising more before spaceflight caused greater bone loss, but exercising more during spaceflight protected the astronauts’ bones.

We analyzed the blood and urine for biomarkers of bone metabolism. The astronauts who had higher levels of these biomarkers before spaceflight lost the most bone strength and density.

But even with its help astronauts still suffer from bone loss. How much? How does the length of a mission impact bones? Does more exercise help? How can we predict the degree of bone loss? This is what we wanted to find out.

Methods

We examined the leg and arm bones of 17 astronauts before and after spaceflight. We used a high-resolution quantitative computed tomography scanner (Fig. 1). This allowed us to look at the bones in 3D at a high resolution. We examined the bones’ thickness, their strength, the density of their minerals, etc.

We also wanted to understand the role of exercising before and during spaceflight. So we asked the astronauts for their exercise habits.

To assess bone metabolism, we collected blood and urine samples before, during, and after spaceflight. We looked for biomarkers of bone growth and bone breakdown (also called resorption). Biomarkers allow us to see changes in bone metabolism before we can see changes in bone density and strength.

Because of this issue, astronauts spend a lot of their time in space doing exercises. They try to make up for the bone and muscle loss. But how do you exercise without any gravity? There is a special machine onboard the International Space Station. It simulates the use of weights, making many exercises possible.

How does mission duration affect astronauts’ bones?
Discussion

Our results show that we can predict bone loss before spaceflight. Astronauts who exercise more before a flight are more likely to lose bone strength. This is perhaps because they can't keep up the same amount of exercise in space (astronauts have very busy days!). Of course, it doesn't mean astronauts shouldn't exercise at all before going to space – exercise is vital for their health. But reducing their training in space (along with living in microgravity) is not good for their bones, so every astronaut should have a balanced training plan (Fig. 3).

The biomarkers of bone metabolism are also a good predictor of bone loss. We don't know why some of the astronauts had higher biomarker levels – it could be because of age, nutrition, medication, or other factors. Yet higher levels of these biomarkers predicted greater bone loss during flight. These astronauts need customized measures to reduce bone loss, such as different exercises, food, or medication.

The longer astronauts stay in space, the more bone they lose. This is very important to consider for future longer missions. Astronauts spend six months on the ISS, but longer missions could be more than double this. Imagine what this prolonged time could do to the astronauts’ bones! We are also not sure what happens to the bones years after spaceflight. Will bones slowly recover? Or is bone loss permanent? These are the questions for our next study.

Conclusion

Exploring space is exciting! But it’s not only for astronauts. You can explore space right here on Earth. Visit an astronomical observatory to watch the night sky through enormous telescopes.

You can also watch pictures and videos online from the Hubble and James Webb Space Telescopes, which float in space!

And even if you never go into space, you can look after your health – including your bone health – here on Earth. If you eat a varied diet with plenty of vegetables, calcium, and vitamin D, and make sure you stay active, you are more likely to have good bone health.

Acknowledgment: This article's adaptation was supported by the US Embassy in Bulgaria.
Glossary of Key Terms

Astronaut – people who are trained to travel to space. The word comes from Greek and means "star sailor".

Biomarker – a biological marker. This is a molecule (or sometimes a gene) that indicates the presence of a process in the body (i.e. a disease or increased bone breakdown).

Bone loss – bones constantly break down and reform again (bone metabolism). When bones break down faster than they rebuild, they become weaker and lose density. This happens in microgravity and when a person has a disease called osteoporosis.

High-resolution quantitative computed tomography – a medical technique that measures bone mineral density and structure in 3D. It uses small doses of X-rays from different angles. This way we can see three dimensional images of the bones at really high resolution.

International Space Station – a modular space station that orbits the Earth. Its main purpose is scientific research, but it also carries out exploration, observation, and education.

Metabolism – bone metabolism is the constant cycle of bone breakdown and regrowth.

Microgravity – an environment where people and objects are weightless. In low Earth orbit, the gravity is close to zero.

Minerals – the main minerals found in bones are calcium and phosphorus. They give the bone its strength. When bone loss happens, the mineral density is usually reduced and the bone becomes weaker.

Check your understanding

1. Why does bone loss occur in microgravity?
2. Why are leg bones more affected in microgravity than arm bones?
3. If you were an astronaut, what would you do to prevent bone loss?
4. Research some other health problems that spaceflight can cause.

REFERENCES


https://bjsm.bmj.com/content/56/4/196

James Webb Space Telescope
https://jwst.nasa.gov/

NASA: Preventing bone loss in space

The Hubble Space Telescope
https://hubblesite.org/