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HOW DOES SPACE EXPLORATION AFFECT THE HEART AND BLOOD VESSELS?

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YOUNG REVIEWERS:


EDOARDO
AGE: 8


ILYAN
AGE: 8


LORYAN
AGE: 12


MATTIA
AGE: 9


REAGAN
AGE: 10


VITTORIA
AGE: 10

During missions in space, men and women are exposed to many factors that can alter the cardiovascular system, which consists of the heart and blood vessels. Both onboard the International Space Station and in space crafts in deeper space, people experience very little (micro) gravity. Because the human cardiovascular system is used to working against the gravity we have on Earth, living in microgravity can lead to unwanted changes. Moreover, exposure to space radiation, the diet onboard space missions, and the mental stress of long-term missions can all influence cardiovascular health. This article reviews the current knowledge of how the environment in space can alter the heart and blood vessels of space explorers, and it discusses some things that we still do not fully understand. The research in this area is ongoing and is very important to make future human missions into deep space possible.

FROM THE INTERNATIONAL SPACE STATION TO MISSIONS IN DEEP SPACE

The International Space Station (ISS), the largest object in space ever built by people, is a collaboration between the space agencies of many countries. The area within the ISS where people live is about 390 cubic meters in size—about the same size as a family home in the United States or Canada, or 1.5–2 homes in Europe. More than 200 men and women have lived aboard the ISS for various lengths of time, mostly between 3 months and a year per mission. Exciting plans have been made for manned missions that go much further than the ISS, deeper into our solar system. In the near future we may see multi-year missions to the Moon, other near-Earth objects such as asteroids, and even the planet Mars. During those deep-space missions, explorers will be exposed to an environment that is very different from that on Earth.

INTERNATIONAL SPACE STATION (ISS)

A station built by several space agencies that circles about 400 km above Earth. It is a laboratory for space research and can hold space explorers for weeks to months.

THE HEART AND BLOOD VESSELS OF SPACE EXPLORERS

The human **cardiovascular system** is made up of the heart and all the blood vessels, including the tiny ones that reach into all the organs and tissues. It is important to have a healthy cardiovascular system, and we know that there are things people can choose to do on Earth that can reduce cardiovascular health, such as smoking or eating an unhealthy diet. The environment that deep-space explorers will be in also has several factors that could influence the health of the heart and blood vessels. This article focuses on four of the main factors: **microgravity**, psychological stress, space radiation, and diet (Figure 1). We will describe what we know and what we do not know about these factors of space, and we will tell you about some of the research that

CARDIOVASCULAR SYSTEM

The body system made up of the heart and blood vessels, which bring oxygen and other nutrients to all organs and tissues and remove carbon dioxide and other waste products.

MICROGRAVITY

The experience of very little gravity, so that people and objects appear to be weightless.

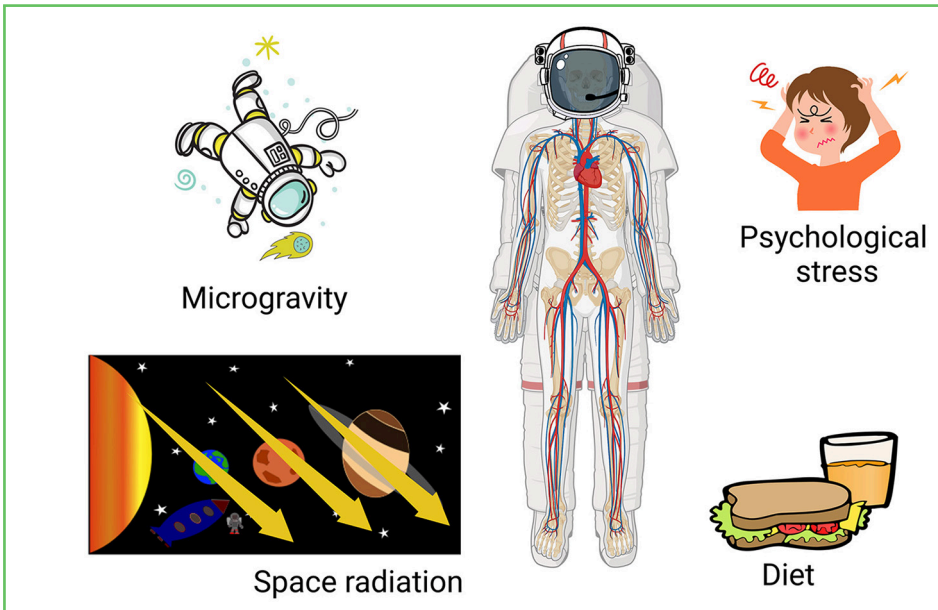

Figure 1

During missions in deep space, factors such as microgravity, psychological stress, space radiation, and diet may all effect the hearts and blood vessels of space explorers (Figure created with BioRender).

is being done to increase our understanding and find ways to make space travel safer for crew members.

MICROGRAVITY AND THE CARDIOVASCULAR SYSTEM

Because humans have evolved on Earth, the cardiovascular system is built to function in Earth's gravity. However, far from Earth, deep-space explorers will be living in a state of very little gravity, called microgravity. Even missions to other space objects will involve altered gravity, as gravity on the surface of the Moon is only about one sixth of that on Earth, and gravity on Mars is about one third. The ISS is close enough to the Earth that gravity still exists, keeping the station circling around our planet. However, people inside the ISS experience no forces on their bodies, so to them it feels the same as being in microgravity.

When people live in microgravity, more blood and fluids will be in the tissues of the chest and head compared to the lower parts of the body, because the pull from Earth's gravity is not there to draw those fluids downwards. That is why the faces of people traveling in space can look slightly puffy compared to when they are on Earth (Figure 2). When space travelers return to Earth, their appearances go back to normal.

Figure 2

Faces of people in space often look a little puffy because microgravity inhibits body fluids from moving to the lower parts of the body. **(A)** NASA astronaut and Expedition 68 Flight Engineer Nicole Mann on Earth, and **(B)** working on a physics experiment aboard the ISS. **(C)** NASA astronaut and Expedition 68 flight engineer Woody Hoburg in training on Earth, and **(D)** while preparing a spacesuit inside the ISS for an upcoming spacewalk (Photo source: NASA Image and Video Library).

In addition to the appearance of the face, several studies on people aboard the ISS have shown changes in the shape and rhythm of the heart. However, we do not yet understand the consequences of living in these conditions for many years.

RADIATION IN DEEP SPACE

GALACTIC COSMIC RAYS (GCR)

High-energy, positively charged particles that move through space at almost the speed of light. They originate outside the Solar System in our own galaxy and from distant galaxies.

Several types of radiation travel through our solar system at almost the speed of light. The types of radiation that are particularly harmful to the human body are composed of very small particles that have a positive charge and very high energy. These particles come from elements of the periodic table, from helium all the way up to iron, which is the largest charged particle in space. When these particles, also called **galactic cosmic rays (GCR)**, pass through the human body, they damage the body's cells. This could negatively affect many organ systems, including the heart and blood vessels. Earth's magnetic fields reflect a large portion of GCR, which is why Earth dwellers are protected from this type of radiation. The levels of GCR are also not very high aboard the ISS, because the ISS is close enough to the Earth that it has some protection from Earth's magnetic fields. However, exposures to GCR will be higher on deep-space missions, where there is no protection.

For many years, we have known that radiation exposure on Earth, such as from nuclear accidents or from certain types of work, increase cardiovascular diseases. Therefore, there is concern that the cardiovascular system may be impacted by radiation in deep space—although we must keep in mind that GCR is different from the types of radiation on Earth.

DIET OF EXPLORERS ON SPACE MISSIONS

Deep-space explorers will likely have to bring most of their food with them on the mission. So, their diets will be limited by the weight and volume that can be carried onboard. We know how important a healthy diet is for the cardiovascular system. Therefore, we must make sure that the most optimal food products will be brought aboard, and/or that space explorers will have the technology to grow their own crops during long missions.

PSYCHOLOGICAL STRESS OF DEEP-SPACE TRAVEL

Another concern of deep-space missions is the psychological stress that explorers will have to face, for instance from being far from family and friends, being confined in a small space, and the absence of days and nights as we have on Earth. Stress can become worse if crew members do not get enough sleep. Research on Earth is showing a connection between psychological stress and reduced cardiovascular

health. Therefore, on deep-space missions, psychological stress may be one more risk factor that we should try to manage as much as we can.

WHAT RESEARCH CAN TEACH US

While we know all these factors can have negative effects on the cardiovascular system, we do not know the *exact* risks for cardiovascular disease in deep-space explorers. We do not always know exactly how each of these factors alters the heart and blood vessels. And we must still do more research to find ways to reduce the risks and make deep-space missions safer, such as through dietary changes or medications. To answer some of the questions we have described, research is being done on people aboard the ISS. Some scientists can also send living cells or small animals to the ISS for research purposes.

Since only a few people have traveled to the moon, we must rely on research performed here on Earth to determine the health risks of space travel. For instance, to simulate the effects of microgravity, research volunteers are asked to remain in bed for several days to weeks, with their heads slightly tilted down. These studies are safe and respectful of human rights and allow us to examine what happens when fluids shift to the head and chest, similar to microgravity.

Because the doses of GCR aboard the ISS are lower than what deep-space explorers will encounter, we must simulate GCR-like radiation on Earth to test its effects. Luckily, the technologies for such research are now available [1], and studies are being done in which small animals are exposed to simulated GCR while under the constant care of scientists and veterinary doctors. These studies have shown only small changes in the structure and function of the heart and the main arteries [2, 3]. However, we must keep in mind that the human body functions differently from the body of a small animal. Therefore, we must be careful when we make predictions about human health based on the results of animal studies.

Lastly, there is an exciting new development called human **organs-on-chip**, which uses human cells to grow mini-organs that are kept alive in the laboratory for research. The use of human organs-on-chip allows researchers to study the effects of the ISS environment as well the effects of simulated GCR on human organs on Earth—without using humans *or* research animals.

ORGAN-ON-CHIP

Various cell types grown on a device with simulated blood flow, so that tiny organs develop and can be tested in the lab.

METHODS FOR INTERVENTION

Research is being done to find ways that we might reduce the negative effects of space travel on the human body. For instance, crew members of the ISS are asked to exercise every day, because exercise

is known to increase the health of the cardiovascular system, the muscles, and the bones [4]. Exercise reduces stress, too. In addition, researchers are testing dietary supplements and medications to protect the heart and other organs from the effects of space radiation. One strategy proposed to reduce psychological stress involves inviting artists to put their artwork on the ISS. Viewing or making art is thought to make people feel better and reduce stress.

In conclusion, we have exciting times ahead for deep-space travel. There is a lot of exciting research happening to make space travel safe for humans, but there are still many questions to be answered and discoveries to be made.

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REFERENCES

1. Simonsen, L. C., Slaba, T. C., Guida, P., and Rusek, A. 2020. NASA's first ground-based Galactic Cosmic Ray Simulator: enabling a new era in space radiobiology research. *PLoS Biol*. 18:e3000669. doi: 10.1371/journal.pbio.3000669
2. Bishawi, M., Lee, F. H., Abraham, D. M., Glass, C., Blocker, S. J., Cox, D. J., et al. 2022. Late onset cardiovascular dysfunction in adult mice resulting from galactic cosmic ray exposure. *iScience* 25:104086. doi: 10.1016/j.isci.2022.104086
3. Soucy, K. G., Lim, H. K., Kim, J. H., Oh, Y., Attarzadeh, D. O., Sevinc, B., et al. 2011. HZE ^{56}Fe-ion irradiation induced endothelial dysfunction in rat aorta: role of xanthine oxidase. *Rad. Res*. 176:474–85. doi: 10.1667/rr2598.1
4. Peterson, N., Jaekel, P., Rosenberger, A., Weber, T., Scott, J., Castrucci, F., et al. 2016. Exercise in space: the European Space Agency approach to in-flight exercise countermeasures for long-duration missions on ISS. *Extreme Physiol. Med*. 5:9. doi: 10.1186/s13728-016-0050-4

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

EDOARDO, AGE: 8

Hi, my name is Edoardo and I really like Pokémon. I am 8 years old, I live in Monte Porzio Catone in the neighborhood of Rome and I have a very pretty little sister. I am interested in constellations, especially Sagittarius because it is my zodiac sign. I really like jumping, climbing, and running so I practice parkour.

ILYAN, AGE: 8

Hi, my name is Ilyan, I am 8 years old and I come from Borghesiana, a town close to Roma. My school is GermogliAmo. I like to play soccer, tap dance, piano, and love singing. I like gifts and surprises. My favorite animal is the gorilla. My best friends are Edoardo, Yuri, Leonardo, and Flavio.

LORYAN, AGE: 12

My name is Loryan and I am 12 years old. I live in Roma, I love football and music. I am very interested in all what concerns climate, pollution and planet Earth, and space environment.

MATTIA, AGE: 9

Hi! I am Mattia, I like skateboard, basketball, and draw comic strips. I think that scientific articles could be more interesting if they were written in cartoon bubbles. Maybe one day I will be a scientific cartoonist!

REAGAN, AGE: 10

Reagan is a ambitious 10 year old. She loves learning about space and is fascinated with NASA. She hopes to one day work at NASA. She loves to learn anything about science but also has a black belt in karate and is very disciplined and focus on achieving her goals. She lives with her mom, who is a retired Navy officer, and her chihuahua, Dax.

VITTORIA, AGE: 10

My name is Vittoria, I am 10 years old and I am in fifth grade at the GermogliAmo school. My favorite subjects are: history, geography, and science. I like to read and my favorite sagas are Fairy Oak and Harry Potter. My family is composed by me, my mom and dad, my little sister, and my dog Celeste. I like pop corn, drawing, playing chess, and attending school. I have been Young Reviewer for already 1 year and I enjoy doing it so much, reading articles is more and more interesting!

AUTHORS

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Ashley Nemec-Bakk received her PhD at Lakehead University in Thunder Bay, Ontario where she studied the effects of low dose radiation in the heart. In 2021 she became a postdoctoral fellow at the University of Arkansas for Medical Sciences in the United States. She has received a postdoctoral fellowship from the NASA Translational Research Institute for Space Health to test two new models of the space environment here on Earth. This research will help determine the effects of the space environment on the cardiovascular system and test a new dietary medicine to protect astronauts from the space environment.

MARJAN BOERMA

Marjan Boerma received her PhD in radiation biology from the University of Leiden, the Netherlands. In her thesis work, she used animal and cell culture models to investigate biological mechanisms of radiation-induced heart disease. Then, she moved to the United States for her postdoctoral training. She is now a professor in the department of Pharmaceutical Sciences at the University of Arkansas for Medical Sciences in the United States. Her research uses research models to understand cardiovascular effects from radiation such as in radiation therapy, radiation accidents, and space radiation. *mboerma@uams.edu