Space travel: Bone aging in fast forward

Long periods in space damage bone structure irreparably in some cases and can make parts of the human skeleton age prematurely by up to 10 years. This is what a sport scientist at Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) has now discovered in conjunction with other researchers from Germany, Canada and the USA. Adapted training programs in conjunction with medication could provide better protection for astronauts on future space missions. The researchers have published their findings, which will now be also be used for treating rheumatic conditions in clinical practice, in the scientific journal Nature Scientific Reports.

Will humans one day fly to Mars? Such a mission has been the subject of debate for several decades and does not depend simply on technical requirements. “If human beings are in space for three years at a time, we need to keep an eye on the health risks involved as well,” says Dr. Anna-Maria Liphardt. “This already applies today for missions where astronauts are subject to zero-gravity conditions for usually no longer than six months.”

After space travel: Bones age by up to ten years

Liphardt is a sports scientist and gained her doctoral degree at the German Aerospace Center (DLR) and the German Sport University Cologne and now researches the effects of rheumatic-inflammatory diseases on the human skeleton at Universitätsklinikum Erlangen. In conjunction with fellow researchers from Germany, Canada and the USA, she investigated how bone structure changes in space and recovers back on Earth in a long-term study. 14 men and three women were checked before their flights into space as well as six and twelve months after their return. The bone density and strength of the tibia and radius (shin bone and lower arm bone) were measured as well as the trabecular microstructure inside the bones. The bone turnover was also measured using biomarkers in their blood and urine.

The results are worrying: Even twelve months after the end of their missions in space, nine out of the 17 astronauts had not completely recovered and had a reduction in bone strength and bone mineral density of up to 2 percent. “This may not sound like much, but it corresponds to age-related bone loss of at least a decade,” explains Anna-Maria Liphardt. “For those affected, this means they will have to expect a much earlier onset of osteoporosis and susceptibility for fractures.” In contrast to aging on Earth, the inner structure of astronauts’ bones are affected more than the periosteous on the exterior surface. Some of the astronauts examined even have irreparable damage to the rod-shaped units or trabeculae. “We were able to demonstrate that regeneration is more difficult the longer the astronauts were in space,” says Liphardt.

Training and medication must be adapted

Astronauts with higher bone turnover before spaceflight also had more significant problems with bone regeneration. “Bone turnover is the process by which cells are broken down and new ones form,” explains Liphardt. “People with higher activity levels have a higher bone turnover and the challenge is to keep up these activity levels during missions in space.” Even though the ISS has various types of equipment such as a running machine, exercise bike and a weight
A training program for the astronauts to maintain their levels of activity, adapting the training programs during spaceflight to better meet the individual needs of the astronauts is crucial. Liphardt: “Developing new sports equipment that works in zero-gravity conditions and that does not take up much space is particularly challenging.”

Astronauts could also benefit from medication if it is taken during spaceflight in addition to exercise programs. This medication includes, for example, bisphosphonates, which are already successfully used for treating and preventing osteoporosis because they prevent bone degradation. “Bisphosphonates are already used by NASA, but we do not yet know enough about exactly how they work in microgravity,” explains Liphardt. “We recommend conducting further systematic research into the combination of medical therapy and physical exercise.”

Findings for clinical practice

The researchers’ study not only supplied findings for future missions to space. Muscle and bone loss due to a lack of activity are also key problems in chronic diseases here on Earth. “In the field of rheumatology, it is not always clear which damage is caused by the inflammation and which by inactivity,” says Liphardt. “Our study could thus also lay the foundations for new or adapted therapies.”

A new generation of high-resolution peripheral quantitative computer tomography (HR-pQCT) machines used during the study with the astronauts could be beneficial for these therapies. These machines are capable of producing high resolution images of the interior structure of bones. “An algorithm was used in older machines in order to generate the individual parameters of the microstructure from the images it produced,” explains Liphardt. “This led to imprecise results, especially in trabecular changes to the bone.” The Department of Medicine 3 at Universitätsklinikum Erlangen now has a latest generation HR-pQCT machine – which is set to benefit not astronauts but patients suffering from diseases of the muscular and skeletal systems.

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