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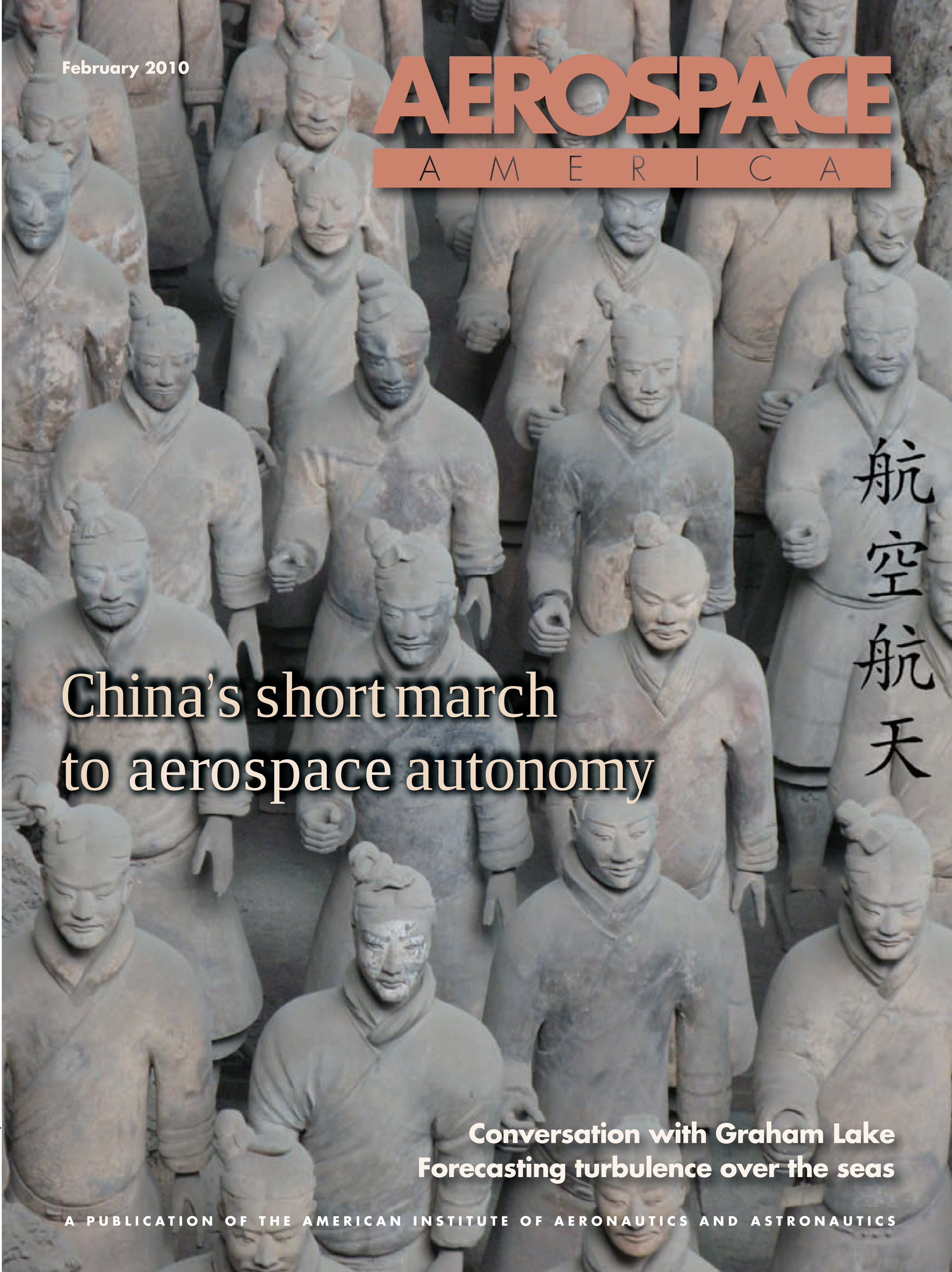

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Hearts in free fall

WE HAVE ALL SEEN VIDEO OF ASTRONAUTS drifting and gliding gracefully around inside the ISS like fish in an aquarium. It looks so relaxing. Enjoyable as it appears, however, there is a down side to all that freefalling.

"When astronauts land back on Earth after a long time in space, not only is their vestibular system mixed up and their kinesthetic sense thrown off," says Benjamin Levine of the University of Texas Southwestern Medical Center, "but also their bones and muscles have deteriorated."

Critical mass?

In space, even more than on Earth, the phrase "use it or lose it" applies. The human body and all its parts need to work to remain vital. Bones must bear weight to keep their density and strength. Muscles need to push or pull against resistance to stay in shape; without work they waste away.

Is this also true of our most critical muscle, the human heart? To find out, NASA is launching a new study known as Integrated Cardiovascular.

Astronaut Clay Anderson floats through the Unity node of the ISS.

We know that astronauts lose heart mass and exercise capacity when they are in microgravity for a long time," says NASA Johnson's Julie Robinson, ISS program scientist. "We suspect that this could lead to impaired heart function, which could cause low blood pressure and even fainting when astronauts get back to gravity. But we need detailed information. In the future, astronauts will spend longer and longer [times] in space, and even live and work on the Moon and Mars. We want to know exactly how space living will affect their hearts and heart function."

Levine is a principal investigator for the experiment, along with Michael Bungo of the University of Texas Health Science Center at Houston. The two have enlisted the support of several other cardiovascular experts to conduct this research—the most comprehensive and advanced study of its kind to date.

"We are investigating how, how much, and how fast deterioration occurs in the heart during long-duration space travel," says Levine.

The space station crew, which has recently increased to six, will help Levine and his team find answers by serving as subjects for Integrated Cardiovascular. The experiment will last for over two years—long enough to gather plenty of data on 12 different astronauts before, during, and after their stints in space.

"We are incorporating the most sophisticated tools ever used in such an experiment to look at the heart and its chambers and valves," Levine notes. "This is the first investigation ever to use advanced echo-Doppler techniques to follow the structure and function of the heart during long periods in space and confirm findings by using advanced magnetic resonance imaging tools on the ground. For example, we are using an echocardiogram to determine how heart muscle atrophy influences the way the heart relaxes and fills, and an MRI to quantify this atrophy precisely and determine whether [the heart] scars or gets infiltrated by fat."

Echocardiograms use high-pitched sound waves that are picked up as they reflect off different parts of the heart. These echoes are turned into a moving picture, allowing researchers to watch a movie of the heart in action as blood flows through it. By looking at such movies before, during and after spaceflight, the team can discern mechanical changes that happen in a person's heart after he or she is away from Earth's gravity for a long time. With the MRI, they can look at detailed computer images of the heart tissues to pinpoint exactly what kind of atrophy occurs.

The researchers will also try to determine whether the heart's deterioration is simply a matter of size—as with weightlifters who lose muscle mass if they stop lifting weights—or if the heart scars and cells die.

In addition, the team is studying the effects of heart atrophy on crewmembers' ability to exercise and on the likelihood of their developing unusual heart rhythms, both on the station and after they return to Earth. The researchers will also look closely at other cardiovascular issues, such as how blood pressure responds to the reintroduction of gravity at the levels experienced on Earth, the Moon and Mars.

"All of the results will help us fine-tune exercise protocols for the space station crew," Robinson says. "We will also learn what to look at in astronauts' hearts before we send them to, say, Mars. We will identify a set of risk factors that can help flight surgeons determine the best candidates for long missions."

Levine adds, "We may, however, show that the heart does just fine in space, and that the strategies now used to keep astronauts in shape are adequate to keep the heart functioning normally and in good health. If so, flight surgeons can turn their attention instead to other potentially critical problems, such as bone loss or radiation exposure."

Atrophy and arrhythmia

The study's results will also have the important benefit of helping researchers develop preventive and rehabilitative regimens for people on Earth.

"The information we get from these experiments will be relevant for patients after long-term bed rest or other physical activity restrictions, as well as for patients with congestive heart failure, heart disease and even normal aging."

Cardiac atrophy, a decrease in the size of the heart muscle, appears to develop during spaceflight or its ground-based analog (bed rest), leading to diastolic dysfunction (abnormal left ventricular function in the heart) and orthostatic hypotension (a drop in blood pressure upon standing). Such atrophy also may be a potential mechanism for the cardiac arrhythmias (irregular heart rhythms) identified in some crewmembers after long-duration exposure to microgravity aboard the Mir space station.

Recent investigations have suggested that cardiac atrophy may be progressive, without a clear plateau over at least 12 weeks of bed rest, and thus may be a significant limiting factor for extended-duration space exploration missions. This study will quantify the extent, time course and clinical significance of cardiac atrophy and identify its mechanisms. The functional consequences of this atrophy also will be determined for cardiac filling dynamics, orthostatic tolerance under both normal (Earth) gravity and fractional gravity (Mars and the Moon) conditions, exercise tolerance and arrhythmia susceptibility, both on the station and following return to Earth.

Using MRI, the Integrated Cardiovascular study will determine the magnitude of left and right ventricular atrophy associated with long-duration spaceflight and will then relate this atrophy to measures of physical activity and cardiac work in flight. In addition, it will use ultrasound to determine the time course and pattern of the progression of cardiac atrophy in flight. The study will also determine the functional importance of cardiac atrophy for cardiac diastolic function and the regulation of stroke volume (the volume of blood pumped by the heart in one contraction) during gravitational transitions and will identify changes in ventricular conduction, depolarization and repolarization during and after long-duration spaceflight. It will then relate these to changes in heart mass and morphology (shape and form).

Astronaut Cady Coleman performs a remotely guided echocardiogram on a test subject using Integrated Cardiovascular protocols, while Betty Chen, a training coordinator, observes.

NASA connection

This experiment is supported entirely through NASA funding mechanisms using grants to the University of Texas Southwestern Medical Center and the University of Texas Health Science Center at Houston, with on-site civil service and contractor support at NASA Johnson. The study's full name is Cardiac Atrophy and Diastolic Dysfunction During and After Long Duration Spaceflight: Functional Consequences for Orthostatic Intolerance, Exercise Capability and Risk for Cardiac Arrhythmias (Integrated Cardiovascular). The payload developer is the NASA Johnson Human Research Program.

Taking measurements

The researchers will use echocardiography before, during and after spaceflight, and MRI before and after. In addition, they will use a special imaging technique called magnetic resonance spectroscopy to quantify the amount of fat in the subjects' hearts.

Before and after flight, they will tilt the subjects on a table at angles to approximate various levels of gravity—from lunar levels to those experienced on Earth. During the tests, they will monitor each subject's heart rate and blood pressure and measure blood flow from the heart with an echocardiogram. All these functions will be monitored and measured during exercise as well, both before and after flight, to determine the subjects' reaction to the stress.

Electrocardiograms will be taken on several occasions during the study and will last up to 48 hr at a time. These recordings will be concurrent with continuous measurements of blood pressure and activity (using Actiwatches worn at the waist and ankle) to estimate the amount of work the heart is doing daily on Earth and in space.

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Astronauts as a group are perhaps as healthy and fit as is humanly possible. But to the risks of bone loss and muscle weakness from prolonged spaceflight are now added concerns about potential risks to the heart.

Astronauts take medication and perform exercises to counter the effects of weightlessness. This study will try to determine the extent of the effects of weightlessness on their hearts and discover what steps are needed to prevent damage. And studies like this may also result one day in better cardiac health for those of us here on Earth as well.

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