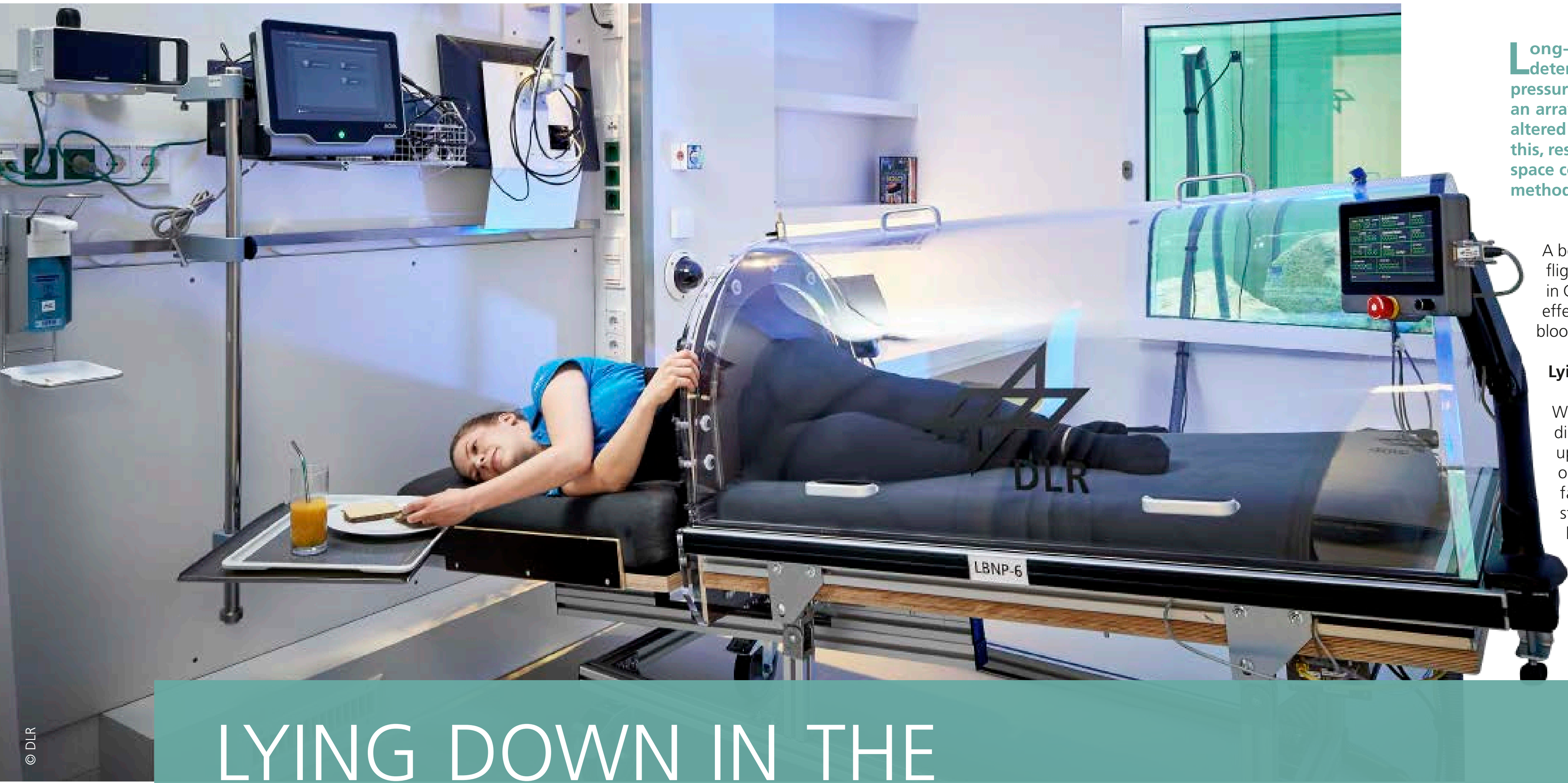

LYING DOWN IN THE NAME OF SCIENCE

Bedrest studies explore spaceflight-related diseases

by Philipp Burtscheidt

In the current NASA bed rest study, the test persons lie in special negative pressure chambers. These are used to test whether negative pressure can help against the undesirable effects of microgravity.

Long-term stays in space put an immense strain on the human body: muscles and bones deteriorate, and body fluids shift from the legs to the head due to the lack of gravity. The altered pressure conditions do not just result in cold feet and a puffy face; this shift in fluids can give rise to an array of medical issues. Among other things, it affects the eyes. Astronauts increasingly report altered vision, with around 70 percent experiencing this when they return from space. To counter this, researchers seek a better understanding of the complex physiological changes that occur under space conditions. For decades, examining the effects of lying in bed head-down has been a proven method to investigate this phenomenon.

A bedrest campaign commissioned by the US space agency NASA to evaluate countermeasures to Spaceflight Associated Neuro-ocular Syndrome (SANS-CM) began at the DLR Institute of Aerospace Medicine in Cologne in autumn 2021. CM stands for the countermeasures to delay or even prevent the undesirable effects of microgravity on the human body. Low-pressure chambers are used in the study. These 'draw' blood and other body fluids back into the lower half of the body.

Lying with your head tilted six degrees down – space conditions on Earth

When people lie in bed with their head tilted six degrees below the horizontal, their body fluids are distributed in the same way as they would be in microgravity – over half a litre of fluids shift to their upper body. Being subjected to these conditions, the participants become 'terrestrial astronauts'. Here on Earth, under the controlled conditions of the study, the researchers can examine more people with far less effort and cost than would be possible in space. Bedrest studies are considered the gold standard of aerospace medical research into the degenerative processes that occur within the human body in microgravity conditions. Nevertheless, they are complex and costly undertakings that depend not only on international collaboration, but also on the commitment of stakeholders from a wide variety of disciplines.

HISTORY

Bedrest studies go back a long way at DLR. The first bedrest study was conducted in 1988 in preparation for the D2 mission. At that time, the Columbia space shuttle took German astronauts Ulrich Walter and Hans Schlegel into orbit for 10 days with the Spacelab space laboratory. Three decades later, the research is focusing on potential long-term missions, such as to the Moon or Mars.

Summer 1988

HDT88
Head-down-tilt bedrest study

- **10 days** bedrest in a head-down position, tilted **6° below** the horizontal
- **6** male participants

- Cardiovascular regulation and fluid/electrolyte metabolism
- Preparation and methodology for the German D-2 mission in 1993

2001 to 2002

STBR
Short-term bedrest study

- **14 days** bedrest in a head-down position, tilted **6° below** the horizontal
- **8** male participants

- Impact of a low-calorie diet (-25% fat) on different physiological systems in the body
- ESA study

2005

VBR
Vibration bedrest study

- **14 days** bedrest in a head-down position, tilted **6° below** the horizontal
- **8** male participants

- Influence of vibration training on muscle and bone metabolism

2006 to 2007

Salty life7

- **14 days** bedrest in a head-down position, tilted **6° below** the horizontal
- **8** male participants

- Impact of a high/low salt intake on sodium and water balance and bone metabolism

March to October 2010

NUC
Nutritional countermeasures

- **21 days** bedrest in a head-down position, tilted **6° below** the horizontal
- **8** male participants

- Using bicarbonate in diet as a countermeasure
- ESA study

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Pneumatonometrical measurement of intraocular pressure is carried out in the lying position and in the sitting posture, which is intended as a control.

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The change in the length of the eye axis is measured to rule out the contraction of the eyeball

WORKING TOWARDS EYE HEALTH IN SPACE AND ON EARTH

In space, people experience eye problems and increased intraocular pressure due to the lack of gravity. On Earth, the same can happen when lying down for a long time. As eye damage can go unnoticed by those affected and can lead to irreversible blindness, it is vital to gain a better understanding of the origin and progression of the disease and develop appropriate countermeasures for people in space and on Earth.

One of the focuses of research is the eye. Why does the optic nerve swell? Why does raised intracranial pressure cause the eyeball to contract, leading to longsightedness? The precise causes and correlations of spaceflight-related eye conditions are unclear. Those affected do not realise that their blind spot – the optic nerve – swells up, and this can be dangerous. The retina, choroid and optic nerve also change. Why such conditions only affect some astronauts is still a mystery; theories abound, but there is no conclusive proof.

What is certain is that eye problems can occur, so taking preventive action and countermeasures is a must. During the bedrest studies, the optic disc of the participants swells. However, the eye recovers a while after the study comes to an end. When staying in space, however, it is a different story. Some astronauts' eyes never fully recover, needing to wear glasses on a daily basis upon their return to Earth. With the goal of sending humans to the Moon and Mars, stays in microgravity are set to last longer and longer in the future, and ensuring the health and safety of such astronauts is of vital importance.

From former bedrest studies to SANS-CM

The VaPER study in 2017 was the first to detect the swelling of the optic nerve head. The test participants – which included women for the first time in the history of bedrest studies at DLR – lay in bed with their head tilted six degrees below the horizontal for 30 days. They did not use pillows – another first. Not using a pillow might sound like a trivial detail, but it marked significant progress, as it

THREE QUESTIONS FOR DLR PROJECT LEAD EDWIN MULDER

Private

Edwin Mulder
studied sports science in Amsterdam, the Netherlands, and has always been interested in astronaut training. He has been involved in bedrest studies at the DLR Institute of Aerospace Medicine since 2010. He is the Project Lead for the SANS-CM bedrest study and works as a Business Developer at the institute. In this capacity, he also devises programmes for other areas of research that focus on space psychology issues, organising isolation studies and the like.

Why are bedrest studies being carried out?
: We can think of the human body as a machine that is geared towards efficiency. Whatever it doesn't need, it dispenses with. That leads to problems when people spend long periods in space. As such, scientists have been conducting research into countermeasures since the very advent of human spaceflight. We can use bedrest studies to simulate the degenerative processes that take place in the body in microgravity by creating standardised conditions on Earth. The changes experienced by the participants in the study are similar to those experienced by astronauts in space.

In terms of quality, the results are practically on a par, so we can determine the effects that occur in weightlessness in the lying phases of our bedrest studies. Our measurements on Earth provide us with knowledge that we can apply to human spaceflight. Quantitatively speaking, the results derived from studies on Earth are usually somewhat lower than in space, so they appear weaker. However, qualitative comparability is key to the significance of bedrest studies as analogue to the experience in space.

What is the reason for the head-down position, with the body tilted six degrees?
: Lying horizontally is sufficient for examining changes to muscles, tendons and bones. The lack of mechanical stress can be simulated by lying down and keeping the body at rest. However, if you want to replicate the fluid distribution in a body in weightlessness to investigate its negative effects and devise the necessary countermeasures, participants must be positioned at an angle, with their head slightly downwards. Lying in a head-down position, with the body at a six-degree angle and without a pillow has become the standard setup for bedrest studies that examine the eye.

This angle is not absolutely optimal, but it is sufficient to observe physiological changes similar to those that occur under microgravity conditions. In the past, we have also conducted studies in which participants lay in bed, tilted head down at a 12-degree angle. The results were slightly better, but the inclined position is so extreme that the lying phase would become too uncomfortable for the participants over time. Expecting them to lie like that for weeks would not be reasonable. Six degrees is the ideal compromise: you get meaningful results and are also able to see the study through. This set-up is also very good for testing countermeasures with simulations.

What impact will DLR's bedrest studies have on international aerospace medicine?
About two thirds of all studies of this type are carried out at DLR. The agencies invariably focus on possible countermeasures. We can make a lot of things possible here with our :envihab facility. NASA has now closed its own facility for conducting bedrest studies and entrusts our team in Cologne with this work. ESA also carries out its studies with us. This demonstrates their trust and satisfaction with what we do and makes us feel very proud. At the beginning of the year, NASA signed a new contract with us for the coming years. We are very much looking forward to continuing our long-term cooperation.

As far as we're concerned, it is a win-win situation. Bedrest studies are very expensive and require intensive preparation. Conducting such studies would not be feasible for DLR alone, so cooperation with the international scientific community and financial support are fundamental. Over the years, a global network of specialists has formed, from a wide variety of disciplines in the field of space medicine. We play a key role in that network.

November 2010 to April 2011

SAG
Simulated artificial gravity

- **5 days** bedrest in a head-down position, tilted **6° below** the horizontal
- **10** male participants

▶ 30 minutes of movement replacement training versus standing as a countermeasure
▶ ESA study

September 2011 to May 2012

MEP
Medium-term bedrest whey protein study

- **21** days bedrest in a head-down position, tilted **6° below** the horizontal
- **10** male participants

▶ Using whey protein in diet as a countermeasure
▶ ESA study

June to July 2015

SpaceCOT
Studying the physiological and anatomical cerebral effects of CO_2 during head-down tilt

- 28 hours bedrest in a head-down position, tilted **12° below** the horizontal
- **6** male participants

▶ Some of the participants exposed to carbon dioxide-enriched ambient air in a double-blind test
▶ Effects of shifting body fluids to the upper half of the body and increased carbon dioxide levels on the brain and eyes

March to July 2016

IPCog
Intracranial pressure and brain function: effects of HDT upon brain perfusion and cognitive performance

- **3 days** bedrest in a head-down position, tilted **12° below** the horizontal, and horizontal lying for **3 days**
- **13** male participants

▶ Comparison of cognitive performance at -12° head-down and horizontal position

September 2015 to April 2016

RSL
Reactive jumps in a sledge jump system as a countermeasure during long-term bedrest

- **60 days** bedrest in a head-down position, tilted **6° below** the horizontal with pillow
- **23** male participants

▶ Horizontal sledge jumps as a countermeasure to bedrest-induced muscle and bone loss during long-term bedrest
▶ ESA study

2017

VaPER
VIIP and psychological :envihab research study

- **30 days** bedrest in a head-down position, tilted **6° below** the horizontal without pillow
- **12** male and female participants, i.e. first time women participated

▶ Impact of increased CO_2 in the air (+0.5%) on the development of eye diseases
▶ First long-term bedrest study in conjunction with NASA

was necessary for the researchers to be able to detect the changes to the eye by performing special tests. Previously, the eyes of the test participants had not changed in the same way they would in space.

The results of the follow-up study AGBRESA (Artificial gravity bedrest study) in 2019 confirmed the change to the optic nerve papilla. Rides on DLR's short-arm human centrifuge were investigated as a possible countermeasure, with the centrifugal force artificially replicating the effects of gravity. During these 30-minute sessions, the participants' body fluids shifted back towards the feet and their intracranial pressure decreased. However, AGBRESA showed that 30 minutes is not enough to counteract the adverse effects of microgravity on the body. What is more, longer 'rides' or several spread out throughout the day would not be possible on a space station or a long-duration spaceflight mission. The researchers realised that they needed to come up with a countermeasure that astronauts would be able to incorporate into their daily routine – for hours, if necessary.

If the current SANS-SM study proves lower body negative pressure to be a suitable countermeasure, the next step would be to develop negative pressure trousers that could be worn over long periods without astronauts having to interrupt their work routine. The DLR institutes of Aerospace Medicine and Materials Physics in Space have worked with the Systemhaus Technik at DLR and together with NASA to develop a lower body negative pressure device (LBNP), with the aim of testing the suitability of such a measure in everyday life. Such devices enclose the body from the waist down. With a reduced pressure of 25 mmHg, they draw blood and other fluids into the lower half of the body. 25 mmHg equates to about three percent of the atmospheric air pressure on Earth.

During the lying phase, six participants spend three hours twice a day in the vacuum chambers, in which the pressure is about three percent lower than in the environment.

Many tests and experiments were carried out during the lying phase to determine the effectiveness of the device. Under the leadership of the ophthalmologist and Head of the Department of Clinical Aerospace Medicine, experts from DLR regularly checked intraocular pressure, examined the retina and optic nerve, and used magnetic resonance imaging (MRI) to scan the brain. They also constantly monitored the cardiovascular system. Coherence tomography recorded changes to the retina and optic nerve. NASA uses this method on the International Space Station (ISS), and the DLR device is also being employed in the studies. It can be used to pinpoint changes to the retina with micrometre precision.

Eating while lying down and in a head-down position makes for a strange experience, at first.

2019

AGBRESA
Artificial gravity bedrest study

- **60 days** bedrest in a head-down position, tilted **6° below** the horizontal without pillow
- **24** male and female participants

- Investigation of altered gravity as a countermeasure: first use of the DLR short-arm human centrifuge in a bedrest study
- First joint bedrest study carried out by DLR, ESA and NASA

2021 onwards

SANS-CM
Spaceflight associated neuro-ocular syndrome-countermeasures

- **30 day**s bedrest in a head-down position, tilted **6° below** the horizontal without pillow
- **48** male and female participants

- Test of using a negative pressure device as a countermeasure against the development of eye conditions compared to sitting upright for 6 hours daily
- DLR/NASA study

In the first two SANS-CM study campaigns, 12 participants spent almost 60 days in :envihab, DLR's medical research facility. These included two weeks of preparation and initial examinations, 30 days of lying in bed and two weeks of follow-up examinations and advanced training. During the bedrest phase, six people spent three hours in a low-pressure chamber twice a day. The control group of six people sat upright in a nursing chair, also twice a day for three hours at a time. In the third and fourth campaigns, thigh cuffs will be used in conjunction with special cycling training. Who knows? Perhaps future astronauts will travel through space using negative pressure trousers thanks to the data obtained at DLR.

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These pumps provide the negative pressure in the LBNP chambers, in which the participants lie with their lower bodies for a total of six hours a day. So that the operating noises are not disturbing, they are placed outside the rooms.

What is :envihab?

:envihab is DLR's unique aerospace medical research facility in Cologne, Germany. Among other things, bedrest studies are carried out here. Covering 3500 square metres, it houses eight modules designed according to a house-within-a-house principle. Research activities focus on space and flight physiology, radiation biology, aerospace psychology, operational medicine, biomedicine and analogous terrestrial scenarios such as bedrest studies. The facility has a short-arm human centrifuge, laboratories in which the effects of oxygen reduction and pressure are studied, a whole-body MRI/PET facility, zones for simulating psychological stress and recovery situations, and microbiological and molecular biological research instruments. The name :envihab combines the words 'environment' and 'habitat'.

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