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Features

DURING my years working with astronauts, it was routine to hear about returning crew being carried from their re-entry capsules on stretchers. Even last year, we saw this when NASA astronauts Suni Williams and Butch Wilmore finally came home after their unexpectedly long nine-month stint on the International Space Station.

Despite the top-notch health and fitness required to become an astronaut and the hours spent exercising while on missions, after several months in space, some astronauts can be more frail, less able to walk and more prone to injury than many older people back on Earth.

In fact, what an astronaut's body goes through in orbit is, in some ways, like an accelerated preview of human ageing. The way that a space mission affects the spine,

weakens muscles and detunes the balance system is a fast-forward version of what many of us experience when recovering from certain injuries, after a spell of hospital bed rest or simply due to years of sitting around.

This means that the way astronauts fight to maintain fitness during their missions, and then work to fully regain it when they return from space, holds crucial clues to healthier lives – and less back pain – for the rest of us. It also highlights the importance of the anti-gravity activities we should do each day if we want to stand up to the force that constantly tugs us down – and it's not all about conventional gym workouts.

Humans have been going to space since 1961 and started occupying the International Space Station (ISS) in 2000. Since then, we have learned much about how a lack of gravity harms the body, especially the

musculoskeletal system. Bones lose up to 2 per cent of their mass per month, with those that bear weight during walking losing the most, whereas arm bones are usually unaffected. Similarly, muscle strength can be reduced by up to 10 per cent in just a few weeks, rising to 20 per cent within three to six months.


To counteract these effects, astronauts on the ISS now spend around 2 hours a day on exercise regimes, using a special treadmill, cycling or using a resistance machine designed for workouts in low gravity. But, for many, this still isn't enough to compensate, and studies conducted on astronauts over the years have revealed more details about the impacts of microgravity.

One of the key lessons from space medicine is the importance of our “forgotten” core: the stabiliser muscles,

The astronaut workout

The same principles that help astronauts stay strong in microgravity can help us all resist the slow collapse of ageing, says **Simon Evetts**





situated deep behind our “six pack” abs, which keep the lumbar spine steady and braced within the abdomen. These include the multifidus, which lines each side of the spinal column and supports the movement of the vertebrae, and the transversus abdominis, a layer of muscle that wraps horizontally around our trunk like a corset.

In the low gravity of space, many of the body’s muscles get smaller and weaker, and this is particularly true for postural muscles that keep us upright such as the multifidus and transversus abdominis. For instance, a 2021 study led by Julie Hides at Griffith University in Brisbane, Australia, looking at five astronauts who spent six months on the ISS found that the cross-sectional area of the multifidus in their lower back shrank by around 10 per cent, while their transversus abdominis shrank by 34 per cent.

In microgravity, the brain signals that activate these core muscles also become poorly timed, which means groups of fibres within the muscle aren’t fired up when needed for certain movements.

Muscle atrophy contributes to the elongation of the spine seen in low gravity conditions. For instance, the torso of crew members can lengthen by over 6 centimetres – more than double the change typically experienced in our natural daily cycles on Earth.

The outcome of all this is that many astronauts experience back pain. A 2024 review found that more than half reported moderate to severe lower back pain during space flight, and some of those affected were still experiencing pain a year later.

So, keeping deep core muscles in good condition is now a key part not only of space

medicine, but also of the rehabilitation of people with chronic back pain. However, these postural muscles don’t respond well to conventional weightlifting regimes typically used to build bigger muscles in our arms and legs, says Kirsty Lindsay at the Aerospace Medicine and Rehabilitation Laboratory at Northumbria University in Newcastle upon Tyne, UK. This means that even some well-trained sportspeople can have poor multifidus strength.

Instead, these spinal support muscles require a specific pattern of training in which they are working at a low level, almost continuously, says Lindsay – something that doesn’t happen in space. And, unlike with our abs or biceps, it is often hard to know when these muscles are “switched on” and contracting. This is why post-mission astronaut reconditioning programmes, ➤

like the one I was involved with at the European Astronaut Centre in Cologne, Germany, emphasise purposeful, controlled movement – what physiotherapists call motor control. In this, subjects learn how to activate muscles such as the multifidus and transversus, often using ultrasound to provide real-time biofeedback to show when they are contracted.

Core strength

Once these activation skills have been mastered, the astronaut can then progress to other exercises, such as sitting to standing or stepping up and down, with gradually increasing loads and intensity and a focus on correct spinal posture. Such exercises are part of the post-flight reconditioning protocols of both NASA and the European Space Agency (ESA). Indeed, there are now devices like FRED (the Functional Re-adaptive Exercise Device, developed at Northumbria University) – a type of modified cross-training machine that provides little resistance – that have been designed to target the core stabiliser muscles and are suitable for people with frailty in physiotherapy clinics, as well as for deconditioned astronauts.

But new ways to exercise in space are also needed to maintain back health during missions. At Northumbria University, my colleagues are developing another method of training the deep core stabiliser muscles called low-intensity continuous activation (LICA) exercise. The idea is to enable these muscles to work in the correct way while in space and when astronauts return from their missions. When on the ground, the training involves making slow, controlled movements while the user's balance is challenged, such as standing up on a stationary cycle-ergometer and slowly cycling with no resistance against which to work (there is also a walking version of this that can be replicated with machines like FRED). For use in space, however, new exercise devices will be needed.

LICA movements automatically recruit the core muscles, causing a low-level contraction. However, rather than simply flicking the muscles on and off – as happens with walking or weightlifting – LICA exercise keeps them activated throughout the movement, so the user doesn't need to know where or how to contract the muscles.

Again, this development could benefit people on Earth, too, and tests show that LICA exercise can help with reconditioning following bed rest, as well as helping alleviate

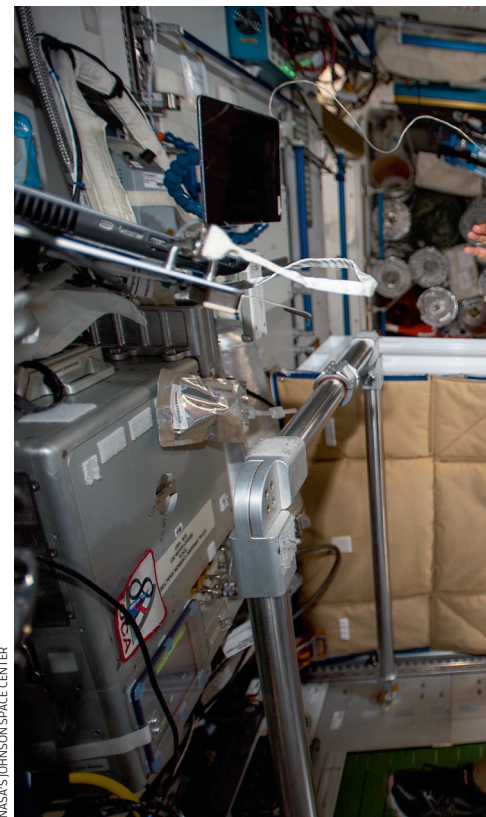
lower back pain and urinary stress incontinence following childbirth.

A number of “gravity-altering” systems can also help clinicians dial in appropriate levels of gravity for the people they are treating, to cue the core. After an injury, for instance, body-weight-support or anti-gravity treadmills can enable walking or running at 50 to 80 per cent of body weight, while trunk control is gradually re-established. These technologies were originally developed so that astronauts could practise walking on the moon and retrain for life under gravity after months in orbit.

The most well-known of these devices is the Alter-G treadmill developed at NASA, which uses a sealed chamber enclosing the lower body in which increased air pressure lifts the runner. Studies show that such devices can reduce pain in people recovering from spinal, hip or knee surgery and can improve walking confidence in older people and those with neurological conditions.

Wearable technology, too, can offer assistance. Take the Gravity-Loading Countermeasure Skinsuit, an elasticated skintight suit mimicking the head-to-toe pull of gravity, which I led the development of at ESA for five years. The suit, designed for use in space, has been shown to reduce spinal elongation and back pain, while helping to keep the posture properly aligned and the deep stabiliser muscles working. This concept is now being spun into garments for people who remain firmly grounded on Earth, in the shape of clothes that support posture and trunk endurance – how long your core muscles can keep working without getting tired – in those with weak

NASA'S JOHNSON SPACE CENTER

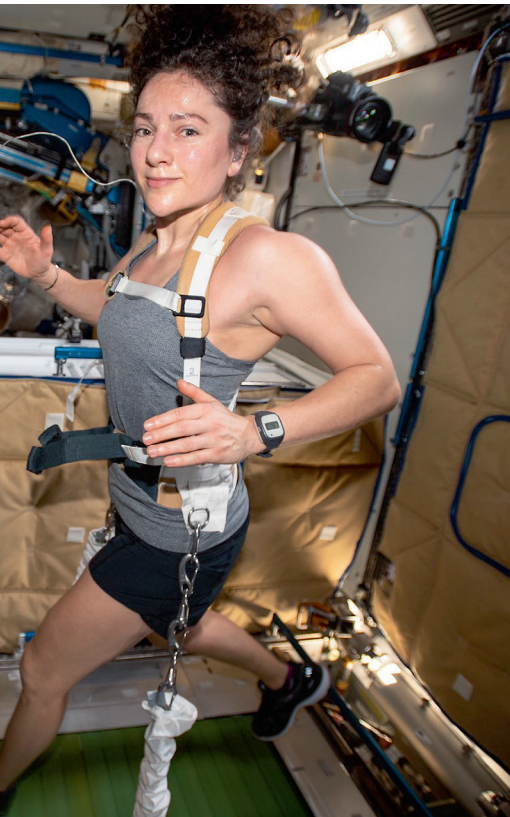


“What an astronaut’s body goes through is like an accelerated preview of ageing”



NASA/KEGAN BARBER

NASA astronaut Butch Wilmore was wheeled out of his return capsule after a nine-month stint on the ISS



Left: Astronauts like Jessica Meir have to spend 2 hours a day exercising on the ISS to counteract microgravity. Below: Keeping your balance on a train can help build hidden support muscles



backs, chronic pain or age-related stoop.

However, leaving aside these high-tech measures, there are many simple anti-gravity habits we can all adopt. These include sitting for 10 minutes without a backrest; standing instead of sitting when taking a phone call; choosing the stairs instead of the lift; and, one of my favourites, standing on a train while loosely holding a rail or strap, forcing your body to make many tiny balance corrections. I started to do these activities regularly when I began to feel lower back pain after long working days, and experienced significant improvements. There is also some evidence that exercise regimes with a strong focus on building the strength of the core, such as Pilates, can help.

Time in space doesn't just unmoor the body, it also confuses our balance system. In microgravity, the inner ear's balance structures no longer respond to head tilts or gravity's pull in the usual way. The sensory receptors in our muscles and joints that the brain relies on for proprioception – the sense of where our limbs are – are affected as well. Over time, the brain reduces its reliance on these cues and relies more on vision.

When astronauts come back to Earth, their time spent in low gravity leaves them unsteady and prone to overcorrecting or veering over when they walk, as their balance system recalibrates. NASA astronaut Tom Marshburn says that, 2 hours after returning from a space shuttle mission, he and his crewmate were

laughing at the exaggerated steps they took when trying to walk up a ramp, lifting their feet far too high. "Also, when turning a corner in a hallway, I tended to miscalculate and stumble into the far wall." One practical consequence is that astronauts aren't allowed to drive for a week or two on return.

Balance challenge

To restore coordination, space agencies prescribe what is known as sensorimotor reconditioning. I have watched astronauts working through eyes-closed balance tasks, some using wobble boards or carrying out exercises that combine the wearing of motion-tracking goggles with head-turn tasks to retrain the reflexes that link balance and vision.

What we see working for astronauts also benefits the rest of us. Indeed, honing and improving your balance is possible well into later life if you practise similar, progressively destabilising tasks, like standing on one leg while turning your head, walking heel to toe along a line or using balance boards or discs. For older adults, this kind of "neural tuning" can reduce the risk of falls and sharpen spatial awareness. In short: drills used for post-flight rehabilitation can help Earth-bound humans stay upright and independent.

Another bodily impact of time in space is the loss and weakening of bone. Healthy bones are the work of a dynamic process, a delicate dance

of bone being broken down and built back up, known as bone reabsorption and formation. Microgravity uncouples these processes, which can cause bones to become more fragile and so more prone to fracture. One possible remedy for this is vibration. This was originally researched as a possible way to protect the bones and muscles of people on Earth, and evolved into the technique of whole-body, low-intensity vibration (LIV), which has now been extensively investigated as a way to preserve the bone health of astronauts.

Here, the individual stands on a machine that looks like a set of bathroom scales, which sends tiny vibrations up through their feet and into their legs, hips and lower spine. In doing so, stem cells found in bone marrow can be stimulated to turn into the cells that build bone back up. Now, short bouts of LIV are being clinically tested for use in treating osteoporosis and frailty, as well as in post-operative spine or hip rehabilitation, though firm evidence to support its use is pending.

Perhaps none of this should be a surprise. Humans are bipedal creatures, highly adapted to spending much of our day upright in spite of gravity's pull. Without this hidden kind of daily workout, our body quickly becomes undone. This is highlighted in studies of the impact of prolonged bed rest. Although the body still experiences gravity when we are lying down, it is no longer acting along our head-to-toe axis, and many of the consequences are similar to those seen in astronauts. Studies show that, just like in space, postural muscles become disproportionately weaker after prolonged bed rest. This is also why bed-rest studies, where volunteers lie down for months at a time, are used to investigate how the body adapts to weightlessness.

In the end, my years working in the field of space medicine have caused me to view gravity not as a simple constant, but as a training partner. The same principles that help astronauts stand tall after months in microgravity can help us all resist the slow collapse brought on by time and inactivity. Gravity, it turns out, is both the challenge that wears us down and the medicine that holds us up. ■



Simon Evetts has worked in the field of human spaceflight for 35 years and led the European Astronaut Centre's Medical Projects & Technology Unit