Medical Xpress

Pioneering muscle monitoring in space to help astronauts stay strong in low gravity

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NASA astronaut using the Advanced Resistive Exercise Device (ARED) onboard the ISS. Credit: NASA

Astronauts have been able to track their muscle health in spaceflight for the first time using a handheld device, revealing which muscles are most at risk of weakening in low gravity conditions.

An international research team, including the University of Southampton and led by Charité University in Berlin, monitored the muscle health of twelve astronauts before, during and after a stay on the International Space Station (ISS).

Findings published in *Scientific Reports* indicate that the astronauts' daily exercise regime was effective in preserving most muscle groups, but crucial lower leg muscles showed signs of deterioration.

The technology and assessment protocol used in space could also bring about a step-change in health care back on Earth, allowing health care professionals to better monitor muscle health in neuro-musculoskeletal conditions, such as Parkinson's Disease and stroke, and in patients in critical care.

"Being able to perform inflight muscle health checks will allow the astronauts to see which muscles are losing strength and adjust their exercise program accordingly," says Professor Maria Stokes OBE, U.K. lead of the project, from the School of Health Sciences at the University of Southampton. "Being able to personalize exercises like this will be crucial on future long-duration missions to the moon and Mars."

Muscle loss in space

Microgravity conditions during spaceflight mean astronauts' bodies aren't subjected to the workload they are used to on Earth, meaning muscles don't have to work very hard to perform functional tasks onboard the spacecraft. This puts astronauts at risk of muscle weakness and bone loss, with up to a 20% decrease in skeletal muscle mass over a month.

To counteract this, astronauts onboard the ISS perform an exercise program for around two hours a day, six or seven days a week. Until now, monitoring the effectiveness of this program has only been possible with pre- and post-flight checks due to a lack of appropriate equipment.

Handheld device

The MyotonPRO is a smartphone-sized device which measures the properties of superficial skeletal muscles, tendons, ligaments, adipose tissue (fat), and skin. It's non-invasive and uses a "tap and listen" method, sending a precision impulse causing the tissues to oscillate and recording the way the tissue responds to compute various characteristics, such as stiffness, tone and elasticity.

The device was used to measure specific points on the astronauts' bodies throughout their mission, before the flight, during a 4- to 11-month stay onboard the ISS, and up to three months post-flight. Researchers were particularly interested in measuring passive muscle stiffness, as it reflects muscle strength, which is not possible to measure in multiple muscles in space.

"People tend to associate stiffness with poor flexibility and mobility, but an adequate degree of passive stiffness is needed to maintain joint stability and posture," says co-lead author Paul Muckelt, a research fellow at the University of Southampton.

"Stiffness provides support during movement, preventing excessive stretching of muscles and reducing the risk of injury. It also contributes to the efficiency of movement by storing and releasing elastic energy during activities, such as walking or running."

Passive muscle stiffness can shift throughout the day, so recording conditions needed to be standardized to ensure accuracy.

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Weakening of crucial leg muscles

The team found that the astronauts' exercise program was effective in preserving muscle stiffness in most sites measured, including the shoulders, neck, back and thigh. But crucially, the tibialis anterior showed signs of waning in all 12 astronauts. The tibialis anterior, located in the front of the lower leg, lifts the foot upwards towards the shin. This movement is essential for walking and running.

The soleus and gastrocnemius muscles in the calf act in opposition to the tibialis anterior, pointing the foot downward. The soleus also showed a decrease in stiffness compared to preflight, but it did increase gradually over time on the ISS. The gastrocnemius increased in stiffness, indicating it might take over most of the function of the calf.

The Achilles tendon (attached to both muscles) also decreased in stiffness compared to preflight measurements. Monitoring the Achilles is important as sudden reloading, such as that induced by a change in gravitation force, could result in injury or even rupture.

Professor Dieter Blottner at the Charité -Universitätsmedizin Berlin, Germany, who led the Myotones Project said, "These lower leg muscles have a vital role in gait and ankle joint stabilization. Impaired function could hinder performance on missions during planetary excursions and risk injury on return to Earth's gravity, so exercises which target these muscles should be included in the astronauts' exercise regimes going forward."

Use on Earth

Measuring muscle health in this relatively simple way in space could translate to everyday life back on Earth—in health care settings, sports, remote communities and even people's homes.

Assessing stiffness and other muscle characteristics helps in managing neurological disorders, like Parkinson's disease and stroke. Currently, clinical assessments involve subjective methods, rating stiffness as mild, moderate or severe.

MyotonPRO offers objective measurements for a more accurate and sensitive assessment of the effects of different treatments. In the future, devices like this could be used by patients to monitor drug effects at home, akin to self-testing blood in diabetes.

Dr. Martin Warner, co-senior author of the research paper from the University of Southampton said, "This technology and the use of passive muscle stiffness as a muscle health indicator could be used by many health professionals during clinical assessments. Widespread uptake could revolutionize health care in neuro-musculoskeletal, critical care and geriatric medicine, rehabilitation and precision medicine."

Libby Moxon, Exploration Science Officer for Lunar and Microgravity at the UK Space Agency (UKSA), said, "As we approach increasingly ambitious missions that will see us travel deeper into space for longer, it's imperative we fully understand how space travel impacts human muscle properties, so we can protect astronauts' muscle health on long-duration missions.

"The University of Southampton's fascinating research, supported by the UK Space Agency, demonstrates how innovative technology can support this goal, taking advantage of the microgravity environment to provide insights that will also help improve health care in space and back on Earth."

More information: Britt Schoenrock et al, Muscle stiffness indicating mission crew health in space, *Scientific Reports* (2024). DOI: 10.1038/s41598-024-54759-6

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