Biomechanics and
Sports Science Case Study

Preparing for Mars, starting with the spine

Researchers at Northumbria University are studying spinal conditions in low gravity to create exercises for astronauts that will take extended space flights.

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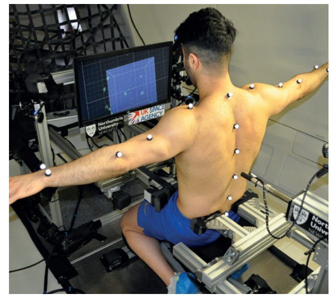
Preparing for Mars



If current predictions hold, at some point in the next 20 years humans will walk on Mars. It will be a defining moment for the human race, but before we can explore our nearest neighboring planet there are several problems we have yet to solve – including how to stay healthy during extended periods away from Earth's gravity.

While joints and muscles can all be affected by the absence of gravity, a major concern for astronauts who spend time in space is the spine. When you factor in the possibility of humans spending months in low gravity -- followed by heavy exertion under the gravity of Mars and then another lengthy period of time spent on low gravity on the lengthy return trip -- those spinal issues go from worrying to mission critical. To help prepare future astronauts, Northumbria University's Aerospace Medicine and Rehabilitation Laboratory, in association with the European Space Agency (ESA), is working on creating a new set of exercises for astronauts to engage with under zero-G.

The current record holder for the longest consecutive time spent in space is Russian cosmonaut Valeri Polyakov, who spent 438 days on Russia's Mir Space Station in 1994-95. Although he eventually made a full recovery after returning to Earth, his time in space showed that without gravity the body begins to experience the same effects found in the elderly, including both bone density loss and muscular deterioration. This is especially pronounced in the spine, and many astronauts have reported severe lower back pains following their time in space.

Astronauts on the International Space Station currently spend 2.5 hours per day following a strict workout schedule, but most still need to undergo rigorous physical therapy when they return to Earth. Fortunately for the astronauts, following their return to Earth's 1G environment, astronauts are not expected to engage in strenuous activity. A trip to Mars could take months, and when they arrive, the first humans on Mars will need to land and work under its 0.38 gravity. That's obviously significantly less taxing than the gravity on Earth, but the shift from zero-G to any gravity could provoke serious issues.

Space agencies around the world are also preparing for a return to the moon, which may eventually lead to a semi-permanent presence on the lunar surface, or at least frequent trips between the moon and an orbital station. Even though the lunar gravity is just 0.16G, the change between gravity conditions could also cause physical issues if not addressed.

With the moon and Mars both targeted for human visitation, ESA began accepting bids for research projects to study the effects of reduced gravity on the body. Northumbria's proposal to look at how reduced gravity affects spinal postural control was selected over several others, and in June 2018 it began tests.

In order to design exercises for a low-gravity or gravity-free environment, those conditions must be sim ulated and data must be recorded from multiple angles. It also requires working on a unique type of plane that is affectionately known as the "vomit comet."

To begin, the research team from Northumbria, led by Professor Nick Caplan, secured the services of a plane capable of parabolic flight. The exact model has changed over the years, but the concept remains the same – a plane large enough to house multiple people climbs rapidly, and when it reaches a nose up angle of about 45 degrees, the engines are cut and the plane enters a freefall state as it flies over the top of a parabolic curve. When the plane reaches a nose down angle of about 45 degrees, the engines switch back on and the pilots pull the plane out of its dive. While the plane completes the parabolic arc, the passengers are essentially in freefall, which in a contained environment can be used to simulate zero-G. Each weightless period lasts no more than 25 seconds, so a typical parabolic flight repeats the maneuver between 40-60 times, with 65 seconds spent climbing followed by under 30 seconds falling.

With the conditions established, Northumbria still needed to create a practical means to record participants under zero-G which meant using specialized equipment, including 14 Vicon Vertex optical motion capture cameras. The high-speed equipment was capable of withstanding the violent shifts in the parabolic flight while capturing precise -- and often unpredictable -- movements of its subjects. The team also created a bespoke rig to hold everything in place.

Northumbria used a Delsys Trigno system for the assessment of spinal muscle activity using fine-wire electrodes, with the data streaming live into Vicon's Nexus software. The tests were so demanding and thorough, not to mention unique, that Northumbria's feedback actually helped Vicon create future updates for the software.

To measure the gravity levels during each parabolic maneuver, Northumbria also used three IMeasureU inertial sensors attached to the custom rack in order to monitor and detect the target levels of gravity.

While the goal of this particular test was to help astronauts while in space, it is also a part of a bigger research program focused on maintaining the health of the spinal muscles that contribute to posture control. Lower back problems are becoming an increasingly common complaint, and spinal muscular deterioration is caused by a host of factors beyond aging, including a sedentary lifestyle. This form of research is meant to help that group as well.

During its time on the vomit comet, Northumbria collected a huge amount of data that the team -- now firmly back on the ground -- is currently analyzing. The researchers will use the data to create a series of exercises specifically designed to help strengthen and maintain spinal muscles in partial gravity, although the results may have a larger impact on spinal conditioning for those of us trapped under Earth's 1G.