Space Life Sciences Research Highlights

Space Research Is Enhancing Our Understanding of the Control of Muscle and Movement and Aiding Patients with Spinal Cord Injuries

Space research is producing down-to-Earth benefits for people with spinal cord injuries. Some spinal cord-injured individuals may learn to walk again using technologies developed for the space program by V. Reggie Edgerton and his colleagues. This research is also advancing scientific understanding of how gravity influences muscle function and movement in humans and other mammals.

Astronauts and people with spinal cord injury have something in common—both suffer from deterioration in their muscles. V. Reggie Edgerton wants to understand how the nervous system controls muscle wasting and how muscles act to maintain posture and produce movement. What changes occur in the muscular and central nervous systems of humans and other mammals as they adapt to a different pattern of muscle use or a different level of gravity? What role does gravity play in locomotion? Can these findings be used to aid individuals paralyzed with spinal cord injuries?

Answers to questions such as these may point the way to measures to prevent the muscle wasting experienced by astronauts who spend even a short time in space, says Edgerton, Professor of Physiological Science at the University of California, Los Angeles. Insights gained through this research also have considerable potential to help people with spinal cord injuries regain at least some use of their legs.

Muscle growth and function depend on the mechanical forces generated as humans and animals move about Earth's gravitational environment. In the absence of gravity, muscles rapidly weaken. On Earth, normal movement occurs as a result of the central nervous system's interpretation of signals from specialized nerve receptors in the muscles that carry information about muscle use and gravitational load. Experiments both in space and on the ground have shown that a chronic lack of resistance to movement due to the absence of gravity can modify the neural mechanisms that regulate the use of specific muscles and muscle-nerve combinations.

Space Flight Experiment on Bion 11

In one recent experiment, Edgerton and his colleagues monitored the effect of space flight on the control of locomotion in Rhesus monkeys that spent two weeks aboard the Russian Bion 11 spacecraft.

Aboard the spacecraft, the monkeys' muscles were relatively inactive because the animals stayed seated in chairs. And of course their muscles were free of the effects of gravity during the flight. The monkeys had been fitted with electrodes that enabled their muscle activity to be precisely measured. Before and after the flight, the researchers measured the monkeys' ability to move around and perform a fine motor task (pressing a foot pedal). They also took the same measurements before and after a ground simulation using the same experimental conditions.

After the flight, animals that flew in space showed less activation of their postural muscles—muscles that work against gravity—compared to "fast" muscles which are used mostly for movement. Comparing the different adaptations observed in muscles following the space flight experiment to those of the simulation, the researchers concluded that changes in the nervous system controlling locomotion could not be attributed to restriction of movement alone; rather, the changes appeared to result from changes in the nervous system's interpretation of load-bearing signals from specialized sensory receptors in the postural muscles. They con-

V. Reggie Edgerton and co-workers from his laboratory at UCLA.

cluded from these and other results that some aspects of the control of muscle-nerve combinations during locomotion are dependent on the presence of Earth's gravity.

"We see this as evidence that exposure to microgravity induces adaptations in the nervous system," says Edgerton. "What we think is happening is that the human or animal is learning how to perform motor tasks in a microgravity environment. If they stayed in space, they would eventually adapt to that environment—but when they return to Earth, they are maladapted to movement on Earth."

Research Benefits Patients with Spinal Cord Injuries

Both the basic scientific insights and the technologies originally developed for the space program and through various NASA collaborations have found further application in Edgerton's NIH-sponsored research into spinal cord injury rehabilitation. The implantable sensors, other electronic devices, and computer software developed to monitor and analyze muscle activity in animals flown in space are now turning out to be extremely useful in studies aimed at finding ways to recover locomotion after spinal cord injury.

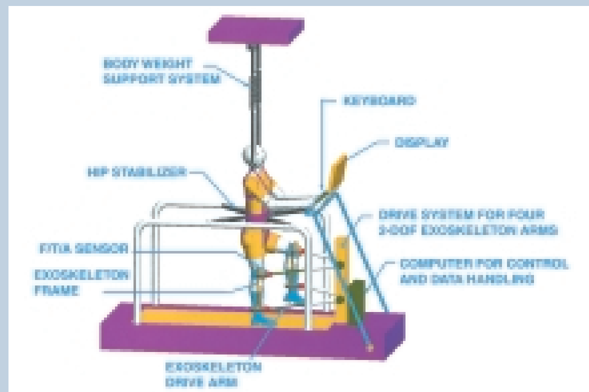
From a scientific perspective, the modifications in motor control that occur in space flight have much in common with those that occur in spinal cord injury, says Edgerton. "When the spinal cord is injured, the person loses—either wholly or partially—the function of weight support in stepping. In space flight, the weight-supporting function of the lower legs is eliminated for a different reason—the person is in a microgravity environment."

The work of Edgerton and his colleagues offers intriguing evidence that, contrary to conventional scientific wisdom, the spinal cord—even when completely severed from the brain, as occurs in complete spinal cord injury—can relearn to step and to stand.

The conventional view, says Edgerton, is that learning a motor skill requires the involvement of the cerebellum—the lower rear region of the brain. However, his team conducted a series of experiments in which they showed that with weeks of daily practice, cats whose spinal cords had been completely severed could be trained to walk on a treadmill. Without practice, the ability to stand and step declined. These data suggest that some motor learning occurs outside the cerebellum.

A clinical trial in which people with spinal cord injuries will be trained to walk on a treadmill is now getting under way at five centers in the United States. Participants in the trial use a weight-supporting apparatus that was developed in several spinal cord injury laboratories like the one at UCLA. The person is suspended above the treadmill in a harness that provides varying levels of weight support during stepping over a range of speeds.

In Germany, where this device has been used experimentally for more than five years, patients who underwent several months of daily treadmill training have regained more mobility than patients who received conventional therapy for spinal cord injury.



Treadmill with weight-supporting harness used to treat spinal cord-injury patients.

This technology is a direct result of improved scientific understanding of the role of weight-bearing in Earth's gravitational environment in maintaining healthy muscle and accurate motor function. Ultimately, Edgerton says, this and other such technologies could benefit more than 10,000 patients with spinal cord injuries and more than 500,000 stroke patients who are admitted to hospitals in the United States each year.

References

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