Saving Muscle In Space

Flying in space has some amazing benefits. You have the excitement of launch. You get to experience floating around in near-weightlessness. Don't forget a view that's unlike anything you've ever seen.

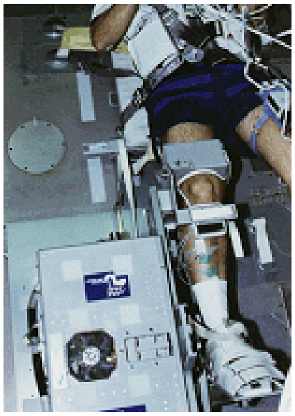
However, the experience is not without some challenges. If astronauts don't exercise to counteract the reduced pull of gravity, the body quickly begins to start shrinking away. There is a gradual weakening of your heart and other muscles since they are no longer challenged to resist the pull of gravity. After only 11 days in space, muscle fibers may **atrophy** as much as 30 percent. Soreness may occur as damaged muscles tear while readjusting to Earth's gravity. After astronauts return to Earth, their muscles can take 30 days to return to their earlier condition. Similarly, there is bone loss as your limbs no longer have to bear the skeletal weight they do every day on Earth.

Bone loss takes much longer to recover from than other physical symptoms of spaceflight. Instead of a couple weeks to get back your capabilities, bone can take up to 2 years to regenerate. The symptoms astronauts experience as a result of calcium loss in space are similar to **osteoporosis**. Dr. Scott M. Smith is the nutritionist and manager for Nutritional Biochemistry at NASA's Human Adaptation and Countermeasures Office. He says, "Research is showing that the best way to prevent osteoporosis is to have strong bones in the first place." Weight-bearing exercises are one way of increasing bone mass. That is why astronauts exercise so much while in orbit.

NASA is currently beginning preparations for manned missions to the Moon and for moving into manned solar system exploration. Astronauts who undertake this exploration will spend extended amounts of time away from the gravity of Earth. A trip to Mars, for example, could last a year or more. This makes it even more important to find ways to prevent the adverse effects associated with spaceflight today. NASA wants to minimize these effects of long-term travel in space. Scientists supported by NASA's Office of Biological and Physical Research (OBPR) are conducting research on humans, animals, plants, and even individual cells. They are finding the causes of these effects and devising ways to minimize their impact. Scientists are also learning more about how to combat similar health conditions on Earth.

Muscle atrophy involves many subtle chemical as well as physical interactions. The basic principle is simple. Muscles adapt themselves to what is required of them. Increase the load on them by lifting weights or other exertion, and they grow larger and stronger. Reduce the load, by lying in bed or living in microgravity, and they grow smaller and weaker. When the load is increased, genes in the nuclei of muscle cells make ribonucleic acid (RNA), which **synthesizes** the proteins that make muscle fiber. Reducing the load, such as through exposure to microgravity, interrupts the protein synthesis, so that muscle fibers atrophy. Not all muscles atrophy at the same rate in microgravity. Back and leg muscles that work against Earth's gravity to stand up atrophy most quickly in microgravity. But, even among these muscles, there are differences. For example, astronauts in microgravity naturally assume a modified fetal position (legs bent at the knees and feet extended downward). In this position, the calf muscles in the back of the leg are relaxed, which speeds atrophy. However, the shin muscles are lengthened, which slows atrophy. Microgravity also has a profound effect on fast- and slow-twitch muscle fibers. Slow-twitch fibers are those that contract gradually and generate little power, but have high aerobic capacity and resist fatigue. Fast-twitch fibers contract more quickly and generate more power, but tire quickly. Both of these types of fibers undergo rapid atrophy in microgravity.

Because of muscle atrophy that takes place in reduced gravity, the astronauts' entire calf muscle function is monitored to provide an example of the changes taking place. The strength of a muscle is determined mainly by its size. The power is the amount of work that a muscle can perform in a given period of time. This is related to strength, but it also includes speed (how fast it contracts) and rate (the number of times that it contracts each minute) of contractions. A NASA-designed Torque Velocity Dynamometer (TVD) measures muscle strength and power. Torque is the force generated by the contracting muscle, and the power developed is related to the peak work capacity, such as how high a person can jump. The TVD looks something like a reclining bicycle, where one foot is strapped onto a footplate containing a force monitoring system. The system measures the amount of muscle force and the shortening speed while the astronaut attempts to extend the foot. It also mechanically extends the ankle at a series of set speeds while measuring the force. Astronauts on the International Space Station (ISS) will keep daily exercise logs while on orbit.



Strength training involves two different types of resistance exercises: isotonic and isometric. Isotonics shortens and lengthens muscles (for example, lifting and lowering a dumbbell). Isometrics fully contracts muscles without movement (such as pushing against a doorway). Both types of exercises could reduce muscle atrophy in microgravity. However, research suggests that isometrics may be more successful than isotonics in protecting slow-twitch fibers.

The researchers' studies are related to three different exercise machines: the leg cycle ergometer, the treadmill, and the interim resistance exercise device. The cycle ergometer was the first exercise device to be flown on spacecraft; it flew on Skylab and Russian Space Station Mir, and is now on the ISS. Astronauts can use this **versatile** piece of exercise equipment to cycle with their legs or their arms to gain aerobic conditioning benefits. The second device used in the exercise plans is the treadmill, which is operated in both motor-driven and self-driven modes. In order to use the treadmill in microgravity, astronauts are held on the exercise device by a harness. The harness can be used to simulate anywhere from two-thirds to all of the astronaut's weight on Earth. The third exercise machine is the interim resistance exercise device (iRED). The iRED is basically two cylinders, and inside each cylinder are 13 disks, connected to a central axle with a series of rubber connections. The astronaut sets the number of disks to be used and pulls on a cord tied to the axle. The disks create resistance in an exercise similar to lifting weights on Earth (up to 300 pounds per cylinder). This "weight-lifting" device also can be used for other exercises. A shoulder harness system can be attached so astronauts can do deep knee bends, back exercises, or heel raises. These exercise the "antigravity muscles": the calves, the thighs, the buttocks, all the back muscles—all the muscles that are used when you stand up.

With the iRED, as well as the treadmill and the cycle ergometer, astronauts are better equipped to maintain their health while in space. Studies of their physiological systems are also helping scientists learn about what is required to maintain health on Earth. Becoming highly **sedentary** is much like going to space. What you see in the sedentary lifestyle is exactly what happens when people spend a lot of time in flight and don't exercise. That's why we all need to exercise. As more of the world's population becomes less physically active because of elderly incapacitation, obesity, or illness that requires extensive bed rest, staying fit is very important. This means the knowledge that NASA is gaining through this research will have benefits not only in space, but also right here on Earth.

Much remains to be learned before astronauts first journey through the solar system to explore other planets. But, NASA's OBPR is already working on ways to keep them fit on the way to other worlds. That's why several steps on a treadmill today could help astronauts take the first steps on Mars tomorrow.

Published by NASAexplores: February 5, 2004