Good Vibrations

A new treatment under study by NASA-funded doctors could reverse bone loss experienced by astronauts in space.

November 2, 2001: "Use it or lose it."

Author: Patrick L. Barry

The familiar mantra of fitness buffs applies as much in space as it does on Earth -- perhaps more so. The bones and muscles of astronauts, freed from the familiar strains of gravity, can weaken alarmingly. Muscles atrophy relatively quickly, while bones lose mass during prolonged exposures to weightlessness.

Reducing muscle atrophy requires exercise -- and lots of it. Astronauts in space spend about two hours each day working out with the aid of exotic devices that rely on springs, elastic, and harnesses to provide resistance and mimic body weight.

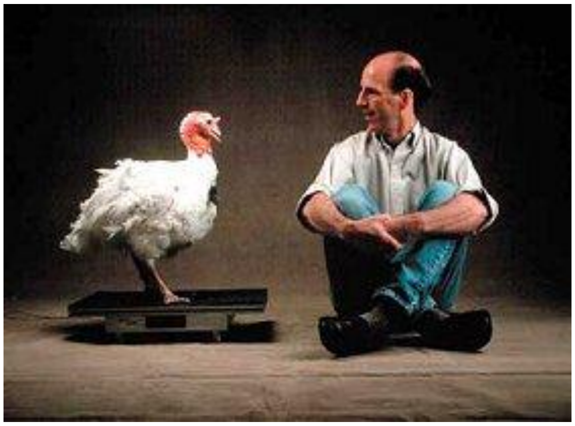
Unfortunately, such "countermeasures" have not solved the problem of muscle or bone loss. It's an ongoing problem for astronauts -- and for researchers!

Above: The proper type and amount of exercise is a key to maintaining muscles and cardiovascular fitness in space. But the workouts astronauts have tried so far haven't yet solved the problem of bone or muscle loss. Image courtesy Johnson Space Center.

But now, perhaps, there could be a solution -- at least for bones: NASA-funded scientists suggest that astronauts might prevent bone loss by standing on a lightly vibrating plate for 10 to 20 minutes each day. Held down with the aid of elastic straps, the astronauts could keep working on other tasks while they vibrate.

The same therapy, they say, might eventually be used to treat some of the millions of people who suffer from bone loss, called osteoporosis, here on Earth.

"The vibrations are very slight," notes Stefan Judex, assistant professor of biomedical engineering at the State University of New York at Stony Brook, who worked on the research. The plate vibrates at 90 Hz (1 Hz = 1 cycle per second), with each brief oscillation imparting an acceleration equivalent to one-third of Earth's gravity. "If you touch the plate with your finger, you can feel a very slight vibration," he added. "If you watch the plate, you cannot see any vibration at all."



Although the vibrations are subtle they have had a profound effect on bone loss in laboratory animals such as turkeys, sheep, and rats.

Left: Vibration plates such as this one were used for experiments on bone loss involving turkeys, sheep, and rats. Pictured with the turkey is researcher Dr. Clinton Rubin. Photo credit: Cary Wolinsky. This image originally appeared in a National Geographic feature article "Surviving in Space."

In one study (published in the October 2001 issue of *The FASEB Journal*), only 10 minutes per day of vibration therapy promoted near-normal rates of bone formation in rats that were prevented from bearing weight on their hind limbs during the rest of the day. Another group of rats that had their hind legs suspended all day exhibited severely depressed bone formation rates -- down by 92% -- while rats that spent 10 minutes per day bearing weight, but without the vibration treatment, still had reduced bone formation -- 61% less.

These results show that the vibration treatment maintained normal bone formation rates, while brief weight bearing did not.

Clinton Rubin, a professor of biomedical engineering at SUNY Stony Brook and principal investigator for the study, cautions that more experiments are required before scientists can be sure that vibration therapy is effective for people. "Animals are different than humans," he notes. And even among humans there are important variables, like nutrition and genetic make-up. What works for post-menopausal women (who often suffer from osteoporosis) might not work for astronauts in space.

In a recent "Phase I/II" clinical trial of vibration therapy, researchers applied the treatment to 60 post-menopausal women. Studies using adolescent girls with very low bone density and children with cerebral palsy are also underway.

"The early results from the research with post-menopausal women are very encouraging -- but they are preliminary. To determine efficacy, we will need a larger scale clinical trial that runs for a longer period of time," Rubin says.

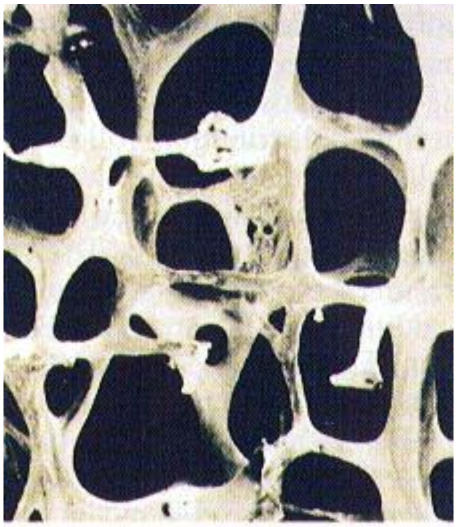
A broader "Phase III" clinical trial is currently being organized, which will provide a strong indication of the treatment's effectiveness for the general population of osteoporosis sufferers.

Right: The primary weight-bearing bones -- highlighted here in purple -- are also the ones most susceptible to weakening in space. Picture from Human Physiology in Space, a curriculum supplement for secondary schools. (Lujan and White)

Whether astronauts would benefit from a vibration-plate regimen is a question that can only be fully answered by conducting experiments in space, Rubin says. Such tests have been proposed, but none are scheduled yet.

Rubin hopes that future experiments will reveal not only *whether* vibration therapy works, but also *why*. It's a bit of a puzzle because the treatment doesn't comfortably fit within the framework of conventional wisdom: Currently, most bone researchers believe that the stresses placed on bones by, *e.g.*, bearing weight or strong physical exertion, signal the bone-building cells through some unknown chemical trigger to fortify bones. According to this thinking, the remedy for bone loss in space should be exercises that duplicate stresses on our muscles and skeletons experienced during a daily and active life on Earth.

Unfortunately, without the pull of gravity it is very difficult, if not impossible, to duplicate loads routinely experienced by our muscles and bones on Earth. The regimen of exercise that astronauts perform in space has shown some promise as a countermeasure, but not enough to protect long-voyaging astronauts from injury or bone fracture when they are re-exposed to gravity -- either here on Earth or on some other planet.



Rubin suggests that perhaps it's not only a few, large stresses placed on the skeleton that signal bone formation, but also many smaller, high-frequency vibrations applied to bones by flexing muscles during common activities such as standing or walking.

Muscles may appear to pull steadily and constantly when flexing -- like the pull of a stretched spring. But muscle contraction is more complex than that. Individual muscle cells in most skeletal muscles can't provide a sustained pull -- they can only apply a quick "twitch." To create a constant pull, the brain activates groups of muscle cells within a muscle (called "motor units") in a rapid, repeating pattern.

Above: The interior of bones isn't completely solid. Instead, it consists of a web of mineral filaments -- called "trabeculae" -- and cells (not shown in this micrograph). These trabeculae provide structural rigidity while minimizing weight, like the steel cross-members in a crane or a highway sign. Image courtesy NASA Quest .

You can feel these subtle patterns by squatting and resting your hands on your thighs -- the slight trembling of your thigh muscles is the sequential contraction of the muscles' motor units. The frequency of such contraction ranges between 10 and 100 Hz. In comparison, the experiment with rats used a 90 Hz vibration, and the experiments with humans are using 30 Hz vibrations.

"Our hypothesis is that a key regulator of bone mass and morphology are the mechanical stimuli that come out of muscle contractions," Rubin says. "So instead of these big, intensive deformations of bone, it's basically lots and lots of little ones [that provide a major stimulus for bone growth]."

"While exercise in space may generate some of these signals, we believe that microgravity essentially extinguishes these signals during the great majority of the day, as postural activity is [markedly reduced compared to here on Earth]," he says. "The vibration treatment generates a much larger signal in this frequency range, and we believe that 10 minutes per day of this higher frequency signal is sufficient to provide a maintenance signal to bone."

Above: When future astronauts return to Earth after a long voyage to Mars and back -- all in reduced or zero gravity -- they will need strong bones to once again stride across their home planet. Vibration therapy might be the key. Painting by Pat Rawlings.

"This is a real departure from the accepted theory of how mechanical signals control bone, and it is certainly controversial," Rubin says.

Nevertheless, it might work. Good vibrations -- unexpected and controversial -- could be the key to healthy bones on Earth and beyond.