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Medicinal EMFs
Harnessing electric and magnetic fields for healing and health

Janet Raloff


Women at risk for osteoporosis got a daily buzz on this prototype bone-growth stimulator in a Creighton University study.
McLeod

Jan Andreason used to get slightly rattled every day—all in the name of science.

Though in her mid-50s, Andreason has the thin, fragile bones seldom found in women under 70. Hoping to fight off further ravages of osteoporosis, she had volunteered in late 1997 as a subject in a year-long trial of atreatment for the brittle-bone disease.

Participation wasn't difficult. All Andreason had to do was submit to twice-daily bouts on a 75-pound contraption installed in her guest bedroom by the Creighton University School of Medicine in Omaha, Neb. Resembling an upright bathroom scale with handlebars, the vibrating machine sent a gentle buzzing through every bone in her body.

Most mornings, Andreason read the newspaper or blow-dried her hair while putting in 10 minutes on the device. Before bedtime, she'd step on the platform for a second 10-minute buzz.

This shaky therapy may represent the future of bone health. Preliminary data from Andreason and 51 other postmenopausal recruits suggest that in some cases, the platform's vibrations may be able to halt the rapid bone loss that occurs in most older women, says Kenneth J. McLeod, a co-inventor of the device.

Even newer data from a 2-year study of sheep suggest that scientists might be able to tailor the regimen to increase the mass of the bones most vulnerable to age-related thinning.

The vibrating platform appears to work by triggering bones to generate tiny electric fields, explains McLeod of the State University of New York at Stony Brook, who directed the sheep experiments. These tiny currents may turn on genes that affect bone remodeling and growth.

The experimental osteoporosis-fighting machine represents just one technology in a wave of new applications of electric and magnetic fields (EMFs) to bone injuries and related problems. All build on decades of work by physicists and surgeons. Though much of this work remains experimental, the Food and Drug Administration acknowledges that when properly applied, EMFs can make for good medicine.

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Most news reports about EMFs have focused on emanations from power lines, building wiring, and appliances. They have chronicled the continuing controversy over whether these fields have unhealthy effects, such as perturbed sleep patterns

In a just-completed 2-year study, researchers put the hind legs of aging ewes—a model for osteoporosis in people—on this vibrating platform for a daily shake. The vibrated legs lost less bone than the animals' untreated forelegs. Depending on the frequency of the vibrations, some bones gained mass.
Simon Turner, Colorado State University

(SN: 1/10/98, p. 29), altered heart rhythms (SN: 1/30/99, p.70), and cancer (SN: 2/21/98, p. 119). Yet while these risks have grabbed headlines, EMFs have been quietly edging into medicine.

Over the past 20 years, FDA has approved EMF generators for two medical uses. The devices are used frequently to treat bone fractures that have stopped healing. EMF treatment is also increasingly being applied to fuse spinal vertebrae in people with intractable back pain.

The first inkling of potential benefits from EMFs emerged during the 1950s, McLeod notes. That's when a series of experiments showed that bone is piezoelectric, meaning that bending or deforming its crystal structure creates local electric currents. Physiologists quickly linked these currents to bone growth in studies that seemed to explain why exercise strengthens bones and immobilization weakens them. This link suggested that electric currents could be applied as therapy.

From the beginning of EMFs' ascendancy to medical respectability, Carl Brighton has been an active player. An orthopedic surgeon at the University of Pennsylvania School of Medicine in Philadelphia, he was the first doctor to treat a fracture with EMFs.

In 1971, Brighton was faced with the case of a Camden, N.J., woman whose 9-month-old ankle fracture steadfastly refused to heal. From his experiments, Brighton knew that electric fields have the capacity to knit unfused bones in animals. So, his team poked a metal pin into the woman's leg, anchored the pin to the broken bone, and hooked it up to a battery. Then, they put the leg in a cast and sent the woman home with the batteryconnected.

"Twelve weeks later, her bone was healed," Brighton recalls. The researchers' explanation was that the small current delivered by the battery to the patient's ankle—which they measured at 10 microamps—spurred specialized cells to grow new bone.

Over the past quarter century, orthopedic researchers have been refining their techniques. Brighton developed one of the earliest of those modifications—delivery of fields via electrodes placed on the skin instead of on the bone. This method remains the only one that FDA has approved for fusing spinal vertebrae, he notes.

More recent techniques enable fields to be delivered without electrodes touching the body. This is the most important therapeutic advance in recent years, suggests Arthur A. Pilla. A biophysicist at the Mount Sinai School of Medicine in New York City, he explains that the newer devices transfer a field's energy into the body from wire coiled around, but not touching, the injured area.

For EMFs to penetrate the body, the coils must carry a pulsing electric current, he explains—not the simpler direct currents associated with electrode-generated fields. In designing the waveform for these oscillating fields—their shape, amplitude, and frequency—"we were guided by measurements people were making of natural, mechanically induced voltages in bone," Pilla recalls. The waveforms of these therapeutic EMFs differ dramatically from those generated by power lines and indoor wiring.

His group won FDA approval in 1979 for the use of a pulsing EMF device for fusing broken bones. Pilla adds that the major manufacturers of EMF-generating bone-growth stimulators still rely on this basic waveform. Twenty years later, researchers still argue whether therapeutic benefits trace to the electric fields or the magnetic fields that these devices induce.

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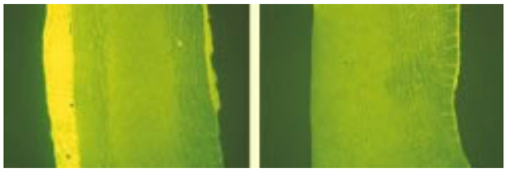

Yellow dye highlights new growth in these sections of wing bones from live turkeys. In contrast to the wing treated with coils triggering a very tiny current in bone (left), the one placed in inactive coils (right) shows no new tissue.
McLeod

To study joint disease, orthopedic surgeon Roy K. Aaron has been working with a pulsed EMF technique. He and Deborah Ciombor, both at Brown University School of Medicine in Providence, R.I. recently used it to treat a strain of guinea pigs that ordinarily begin showing signs of osteoarthritis of the knee by 1 year of age. The researchers began EMF therapy on one group of animals on their first birthday and continued it for 6 months. Another group received no treatment. At 18 months of age, most of the treated guinea pigs had relatively mild disease and a few appeared to be free of pain. All the untreated animals were crippled by the oseoarthritis.

"I was so surprised by the difference between the [treated and untreated groups] that I repeated the experiment," Aaron says. The results were the same. The data demonstrate that this treatment does not simply reduce symptoms, such as swelling, but actually modifies the development of disease, he says.

EMF therapy also helps people with established joint disease, Aaron says. This month, he's completing a clinical trial of EMF therapy for men and women with advanced osteoarthritis in their knees.

Two previous studies had found that EMFs reduce pain and swelling. EMFs also have that effect in his new trial—presumably, he says, "by changing the chemistry of the joint." Studies by his team and others indicate that these fields can increase a joint's production of natural anti-inflammatory agents, such as transforming growth factor-beta.

Not surprisingly, Aaron notes, medical supply companies are now developing products, such as a glove with coils, to deliver EMFs to arthritis-savaged joints.

Softer tissues also respond to these fields. For instance, Pilla observes that many people with bone breaks experience significant pain in muscles around their injuries. Shortly after EMF therapy begins, however, that pain disappears.

Though the mechanism remains elusive, Pilla says, the treatment seems to affect swelling, which can cause pain. If this proves true, he says, EMFs might benefit people with carpal tunnel syndrome, where swelling in the wrist pinches nerves going to the fingers.

Indeed, that's a possibility that Betty F. Sisken of the University of Kentucky College of Medicine in Lexington would like to explore. Currently, she's probing EMFs' direct influence on nerves.

In their initial studies, she and her colleagues crushed a nerve in the hind leg of rats and then treated the animals with EMFs for 4 hours daily. In one 6-day-long experiment, the treatment speeded the nerve's recovery by 22 percent. In follow-up tests—where 16 rats received EMFs for 40 days and an equal number were allowed to heal unaided—treated animals again showed an accelerated recovery.

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Despite some exploration of EMFs to heal nerves and other soft tissue, the majority of studies continue to focus on bone.

Sections of bone from healthy female rat (left) and two whose ovaries were removed 6 weeks earlier to model women who lose bone after menopause. Bone from animal treated with combined EMFs (middle) shows less loss than one from untreated rat (right). John H. Kinney, Lawrence Livermore National Laboratory

James T. Ryaby, vice president of OrthoLogic, a medical devices company in Tempe, Ariz., has been using what he calls combined fields—oscillating magnetic fields superimposed on a static magnetic field. They appear to spur bone growth more quickly than the older type of pulsed EMFs, Ryaby says.

What's more, the combined-field devices require just a small percentage of the power used by typical pulsed EMF generators. This means the combined-field devices can run on conventional batteries, Ryaby says. His company is testing such a device for fusing vertebrae in patients with back pain.

More tantalizing, says Ryaby, are the data from a just completed study with female rats suggesting that the combined fields can reverse the kind of bone loss women experience after menopause. After removing the rodents' ovaries to simulate a postmenopausal state, Ryaby's team watched the animals quickly lose bone. Six weeks later, some of the rats began receiving combined-field therapy for 30 minutes a day. Within a little more than a month, he says, the treated animals were regaining lost bone while their untreated counterparts continued to lose it.

As exciting as the data are, Ryaby says his company has no plans to develop the technology for human use. Women just aren't likely to sign up for such therapy at menopause knowing that they would likely have to continue it the rest of their lives.

Indeed, McLeod says, "a fear factor associated with EMFs clearly haunts the therapeutic field."

Because of the stigma of EMFs, McLeod and Clint Rubin have been looking for an alternative. The Stony Brook pair may have found it in the bones themselves. Over the past 20 years, they have demonstrated that during walking, jumping, or even just maintaining a balanced posture, muscles exert enough strain on bones to generate microcurrents of electricity. The discovery inspired the scientists to create a device to encourage the body to make its own electric fields for building bones.

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The resulting vibrating platform "is highly innovative but not ready for prime time," says endocrinologist Robert Marcus of the Veterans Affairs Medical Center in Palo Alto, Calif. Overall, the benefit for women taking part in the Creighton study, led by Diane Cullen, "was less than overwhelming," he says. He acknowledges, however, that certain subgroups—such as those, like Andreason, who started out with the thinnest bones—appeared to derive benefit. He's begun using the device in a pilot project.

The platform's commercial developer, Exogen of Piscataway, N.J., will fine-tune the device's frequency and the recommended treatment times before undertaking any study of a larger group in women, says Jack T. Ryaby, the company's scientific director.

McLeod says that in his newest tests with aging sheep, platforms vibrating at 90 Hz increased bone mass. This suggests that tripling the vibration frequency of the platform used for the Creighton trial might build new bone, not just stabilize loss.

Moreover, if the sheep data translate to people, he suspects that women would need just 8 minutes a day on the faster-vibrating device. "This is really exciting because 8 minutes is easy," he says.

For the larger range of problems, Pilla holds that applied EMFs will be more useful. However, medical generators today produce fields with a waveform that probably is far from optimal, he says. Though experiments aimed at improving these generators and securing FDA approval for devices with different waveforms would be costly, the payoff could be tremendous, he believes.

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To get to that payoff, scientists need to learn more about why these fields work. Many of the researchers who are developing new applications for these fields are therefore asking, What do cells of the body see in EMFs?

"These fields are too weak to power the biology or biochemistry that is active here," Pilla says. "They only deliver enough energy to trigger something"—much like a pacemaker triggers contractions in the heart.

In *Bioelectrochemistry and Bioenergetics* last February, he and his colleagues reported finding that pulsed EMFs appear to increase the binding of ions to receptors on the surface of cells. For instance, they've witnessed enhanced binding of calcium to the regulatory molecule called calmodulin. This difference may prove important in stimulation of bone-cell growth by EMFs, Pilla says.

EMFs can also increase bone cells' production of insulinlike growth factor II, according to test-tube experiments by Ryaby of OrthoLogic and his colleagues. This hormonelike molecule plays a key role in bone growth and may be regulated by calcium binding to calmodulin.

At the BioElectromagnetics Society meeting last June, Sisken's group reported on test-tube experiments showing that pulsed EMFs can turn on a gene in damaged nerves. That gene plays a role in triggering growth-related repair.

Brighton is also working to elucidate which genes are altered by EMFs. "This is to me what's most exciting," he says. "We can turn genes on and off with this stuff."

McLeod and his group tend to focus on physical effects of fields on cells. Their data indicate that EMFs may bias the movement of cell structures that are otherwise jostled by the random pushes and pulls of chemical and physical processes, McLeod says. He also finds that EMFs can alter the environment in which cells grow and move within the body. For instance, electric fields may alter the stickiness of surrounding proteins. Indeed, he argues that changes in a cell's behavior may trace as much to environmental alterations as to the cell's gene activity or membrane effects.

Changes in cellular behavior may not be limited to the fields being used in therapy today, however. Aaron, for instance, has examined effects of the 60-Hz fields generated by power lines and home wiring.

In the August *Bioelectromagnetics*, his group reports that field strengths similar to those in the home and workplace increased production of a protein that regulates proliferation and development of cells destined to become bone. The EMFs also stimulated some maturation in cells.

Aaron concludes that fields associated with electric power may exert a beneficial influence on such tissues rather than harm them.

All this basic research may add up to more effective devices and ubiquitous applications. For instance, Pilla says he believes generators might one day be miniaturized to the size of a dime and cost next to nothing.

He envisions disposable bandages incorporating a tiny EMF device that would treat problems ranging from ankle sprains to bedsores.

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Sources:

Roy K. Aaron
Brown University School of Medicine
Department of Orthopaedics
Providence, RI 02906

Carl T. Brighton
University of Pennsylvania
School of Medicine
Department of Orthopaedic Surgery
425 Stemmler/6081
Philadelphia, PA 19104

Deborah M. Ciombor
Brown University School of Medicine
Department of Orthopaedics

Providence, RI 02906

Diane Cullen
Creighton University
Department of Medicine-Osteoporosis
SJH Room 4820
Omaha, NE 68178

Deborah M. Ciomber
Brown University
Department of Bio. Med. Orthopaedics
Box G-RI
Providence, RI 02912

Kenneth J. McLeod
State University of New York, Stony Brook
Program in Bioengineering
Health Science Center
T18-030
Stony Brook, NY 11794-8181

Arthur A. Pilla
Mount Sinai School of Medicine
Department of Orthopaedics
Bioelectrochemistry Laboratory
New York, NY 10029

Jack Ryaby
Exogen, Inc.
10 Constitution Avenue
P.O. Box 6860
Piscataway, NJ 08855

Betty F. Sisken
University of Kentucky
Department of Anatomy and Neurobiology
Center for Biomedical Engineering
Lexington, KY 40506

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