

# New System Monitors Tiny 'Earthquakes' in Bones to Prevent Fractures

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Researchers are applying the same basic technique seismologists use to measure earthquakes for a new medical technology that promises to prevent stress fractures by detecting the formation of tiny cracks in bones.

The crack formation generates waves similar to those created by earthquakes. Researchers at Purdue University and the University of Toledo have collaborated to create a prototype device that could be used to monitor the formation of these "microcracks" in bones that can lead to hairline stress fractures unless detected in time.

"The goal is to create a wearable device that would alert the person when a stress fracture was imminent so that they could stop rigorous physical activity long enough for the bone to heal," said Ozan Akkus (pronounced Ah-Koosh), an associate professor in Purdue's Weldon School of Biomedical Engineering.

The system records "acoustic emission data," or sound waves created by the tiny bone fissures. The same sorts of acoustic emissions are used to monitor the integrity of bridges, other structures and mechanical parts like helicopter turbine blades.

"I asked, why not use the same approach to study stress fractures?" Akkus said.

Such a technology could help prevent serious stress fractures in

racehorses and those who perform in situations that cause undue stress to bones, such as soldiers, athletes and dancers. The system could be especially useful in preventing fractures in U.S. Army recruits undergoing basic training.

"Strenuous military exercises subject soldiers to prolonged physical activity in which relatively small forces are repeatedly exerted on bones," Akkus said. "The forces are not initially strong enough to break a bone, but it's the repetition that poses the most danger by causing microscopic cracks to accumulate over time and eventually result in stress fractures."

The cracks form when collagen fibers in bone fail, producing sound waves that cause a rippling motion on the skin's surface.

"This is the same thing that happens during an earthquake, but on a microscopic scale and at a higher frequency," Akkus said. "Instead of an earthquake-size opening, these cracks are about a tenth of a millimeter wide."

Accumulating cracks sometimes cause "spontaneous fractures" that occur without warning, afflicting the young and old alike, including athletes and elderly people suffering from osteoporosis.

A major factor in the crack formation is the dynamic process bones use to continually rebuild themselves. When bone is damaged, specialized cells bore tunnel-like holes to remove the damaged tissue and then fill in the resulting cavity with new bone.

"Bone is a very smart material because it can detect and repair damage," Akkus said. "That's what keeps your bones young. The repair process digs tunnels and fills them, digs tunnels and fills them. There is a continuous renewal, but it takes longer to refill the holes than it does to

dig them, so there is always some porosity, which increases the stress locally in the most porous portions of bone."

Hard physical activity without rest increases the stress in these porous areas that are under repair.

"The localized stress in the porous portions then becomes very high, and this can result in a complete stress fracture," Akkus said.

One reason it's difficult to diagnose the hairline fractures is because they are caused by the gradual accumulation of microscopic cracks, which are not detectable with conventional imaging technologies.

"It's really hard to measure stresses in bone without cutting open the bone to study it," Akkus said. "And there is very little warning because you don't have horrible pain. You might have some discomfort, but you can keep exercising or whatever activity you are doing."

From 1 percent to 20 percent of U.S. basic training recruits experience stress fractures in the femur, commonly referred to as shin splints, depending on the service branch and type of training, with the highest incidence in women recruits. In horse racing, 70 percent of young thoroughbreds experience fractures, Akkus said.

The researchers are developing the monitoring technique by studying crack formation in pieces of bone from human cadavers that are placed in a machine that continually bends the bone until it cracks.

Akkus is working with researchers at the University of Toledo to develop a wearable prototype that will record crack-formation data, which could be downloaded to a portable digital assistant, or PDA, for review by medical professionals. Such a device could immediately alert the person by sounding an alarm, and the data could then be scrutinized

by a doctor.

"All of the technology is available, and the sensors exist off the shelf," he said. "We just have to modify them to work with our system."

Sensors made of a "piezoceramic" material generate electricity when compressed by a force, such as the vibration created by seismic waves resulting from crack formation.

"Recently, flexible polymer-based sensors have appeared on the market, and these could be incorporated into athletic apparel, such as running shoes and exercise tights to monitor areas most susceptible to fractures," Akkus said. "Ultimately, we would like to do real-time monitoring of damage activity and learn how to distinguish between a small crack and a more structurally threatening defect.

"There are different types of cracks that occur, and it's important to be able to distinguish among them so that we can determine how serious the damage is."

To distinguish the difference between the various types of cracks, researchers are integrating "pattern recognition" software and earthquake models, working with Robert Nowak, a Purdue professor of earth and atmospheric sciences. The multidisciplinary research involves biomedical and electrical engineering, veterinary medicine, and earth and atmospheric sciences.

"One challenge will be to learn when damage is serious enough that you should stop exercising," Akkus said. "You don't want to give a professional athlete a premature warning."

Bones most affected are those in the feet, legs and hips, particularly the ball-and-socket joints that connect the legs to the pelvis.

Source: Purdue University

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