ARIZONA STATE UNIVERSITY
STORIES OF SCHOLARSHIP AND CREATIVE ACTIVITY

Stimulated to heal

by Melissa Crytzer Fry

Shelley Savage considers herself lucky. Despite having to rely on a wheelchair for the past 15 years, she knows that things could have been worse—possibly much worse. Savage was a passenger in a car accident during her college years. She broke her neck at the C6 vertebra.

The break was classified as an incomplete spinal injury. "Incomplete" means that some nerves are still connected above and below the injury site. For Savage, that equates to upper body control and some sensation throughout her lower torso.

"I was completely paralyzed for the first three months, so I know what a complete spinal injury is like," says the optimistic 38-year-old. "I am very grateful to have gotten some movement and feeling back in my body. It's still tough sometimes. But I'm able to have more independence and freedom."

Savage has never given up hope for a cure. She'd be lying, though, if she said the road has been easy.

"It's frustrating and discouraging. Once you become paralyzed, you're basically written off. You're told 'This is it. Don't expect much.'"

In addition, Savage says that physical therapy is only offered early after the injury. She also learned that reduced activity after a spinal cord injury can also lead to other complications. At age 30, she developed osteoporosis-related bone loss, despite a desire to remain actively engaged in physical therapy.

"You really have to fight for follow-up physical therapy," she explains. "Sometimes the only way you get the therapy is if you injure yourself."

Even then, therapy is offered at only a limited number of clinics. Most of that is on bulky and unaffordable exercise equipment.

James Abbas and Ranu Jung are working to change that scenario. Abbas and Jung are bioengineering professors at Arizona State University. They are co-directors of ASU's Center for Adaptive Neural Systems. Their research is focused on the use of electrical stimulation to contract paralyzed muscles.

Abbas and Jung are designing adaptive technology that actually interacts with the nervous system. The goal is to create devices that promote recovery and reorganization of the nervous system after spinal cord injury.

In one study, the ASU researchers are testing a hand-held muscle stimulator. The device is called CK200. It was developed by customKYnetics, Inc., a commercial partner working with the ASU engineers. Abbas is co-founder and part owner of the company. His efforts are focused on testing and understanding the company's products.

The CK200 is about the size of a paperback novel. It uses electrical stimulation to activate the muscles. Adhesive electrodes connected to the CK200 are placed on the skin. When activated, current passes through the electrodes and into the muscle, causing a muscle contraction.

"The idea is really based on a simple therapeutic principle. Do something. Be active. That's the best way for muscles to re-learn how to work," Abbas explains.

Participants in the ASU study had both complete and incomplete spinal cord injuries. Each person each received a hand-held CK200 unit for home use over the course of three months. After completing initial evaluations at ASU, they returned monthly for additional readings.

During each session, participants completed 60 muscle stimulations. Ankle weights were added periodically. When a subject could successfully complete three sessions without fatiguing the muscle, the weight was increased by a half-pound.

Members of the complete spinal injury group worked to stimulate the quadriceps muscles on

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each leg. The goal was to gain ability to complete standard leg lifts.

"This wasn't an aggressive therapy, although participants were getting some exercise and increased muscle strength," explains Abbas. "It was meant as an initial test of the device. We wanted to determine if it could generate smooth contractions of paralyzed muscles, and if the muscles got stronger."

The goal was different for the group with incomplete spinal cord injuries. The researchers wanted to know if participants were gaining the ability to voluntarily contract the muscles being targeted by the CK200.

"People with incomplete spinal cord injuries have great potential for relearning, which can impact their daily lives," Abbas says. "The thought is that, after repetitive muscle movement with the device, they'll eventually be able to control more and more of that movement, and hopefully wean off the stimulation."

The ASU study revealed that participants' muscles definitely got stronger through CK200 usage. Savage volunteered for the trial. She saw great gains for herself.

Early in the study, she could not complete a full set of leg extensions without ankle weights. At the end of three months, with the stimulator, she could complete the full set with five-pound ankle weights on each leg.

"I could feel the muscle tightening—the same kind of burn you feel if you've been lifting weights," Savage explains. "I wasn't even sure I had any muscle left after all these years. It was encouraging to realize that maybe the muscles weren't completely gone."

During the course of the study, the muscle mass in Savage's thighs increased by 11 percent.

"The numbers for individual participants progressed as the session went on," says Abbas. By the end of 2008, seven subjects had completed the full study. Six of those people reached the five-pound ankle weight maximum on at least one leg, with a muscle mass gain of at least 4 percent.

Researchers say that the health benefits of stimulation therapy can't be overlooked.

"Stimulation helps with the blood circulation in that region. It improves the overall health of the skin and muscles," adds Jung.

Muscle stimulation can also positively impact immune system response and hormonal response. What's more, such activity may be able to stave off diabetes and heart disease for people with paralysis, who are more susceptible to those diseases.

"Devices that use electrical stimulation exist in the marketplace. But they require someone to preset the values," explains Abbas.

For example, a physical therapist has to hand-set the controls before and after each and every desired movement. The CK200 is different. It has smarts as part of its internal computer that control the stimulation. The hand-held device continually adjusts the level of stimulation to achieve the desired movement pattern.

"It's personalized to each person who uses it," explains Abbas. It can sense when a muscle is fatigued and adjust the amount of stimulation on the next repetition—to maintain the same controlled movement.

But how does this smart technology actually work? Abbas says that CK200 uses an adaptive algorithm—a formula—programmed into the device, to compare the person's patterns of movement.

"The sensors on the skin read the movement patterns generated by the muscles," explains Jung. "The computer reviews that movement and compares it against a desired pattern of movement."

Preset with specific movement patterns, the CK200 stimulator can detect any movement errors and automatically adjust the pulses sent through the electrodes.

"The algorithm basically allows us to get the movement we're asking for," Abbas adds. He developed the basic adaptive algorithm used by the CK200.

"Initially, I was focused on programming the computer. I wasn't worried about making it smaller," Abbas continues. "But then I asked myself, 'what if we use this technology in a simple device for exercise?'" That question led to the birth of customKYnetics, Inc.

"We know the body is trying to heal itself during a spinal injury," explains Jung. "And we know neural systems can adapt—at the gene level, protein level, and cellular level. We're also trying to understand how and why that happens. And what can we do to promote that? Do stimulation devices expedite that process?"

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Results from the initial studies hint that the answer is "yes." But the ASU bioengineers know their work is in its infancy. Currently, test participants included only those with spinal injuries that occurred years ago. Future studies may reveal that the potential for recovery increases if stimulation is introduced immediately after injury.

"We had to start with stable, healthy individuals. We had to know that it was the device helping them, and not the natural recovery process seen in the first few months after injury," explains Abbas.

One thing is certain: as the studies change in design, so, too, will the evolution of portable stimulation devices like the CK200. In the future, the device may even have applications for knee injury rehabilitation, and for more aggressive therapy programs. Someday, it is hoped these devices will be accessible and available for home use.

As Shelley Savage says, "They're getting close. Any progress being made brings us one step closer to a cure." When she walks again—not *if*—Savage says her first steps will be among Europe's medieval castles.

ASU studies on neuromuscular are supported by the National Institutes of Health and Science Foundation Arizona. For more information, contact James Abbas, Ph.D., or Ranu Jung, Ph.D., ASU Center for Adaptive Neural Systems, Ira A. Fulton School of Engineering, 480.965.9521 or 480.965.9052. Send e-mail to: Jimmy.Abbas@asu.edu and Ranu.Jung@asu.edu

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Posted on March 9, 2009 10:47 AM | Permalink