Steve Vroman, who has an incomplete spinal cord injury, during one of the exercise sessions at ANS with Jim Lynskey. The handheld CK200 device is being tested for its ability to strengthen paralyzed muscles and to promote recovery of function in muscles that are partially paralyzed.

TO WALK AGAIN

By Melissa Crytzer Fry

When actor Christopher Reeve – best known as Superman – suffered a spinal cord injury during an equestrian event, his real-life body, without its on-screen superhero abilities, simply couldn't repair itself.

But what if it could … with the help of science and engineering?

That's what researchers in the Ira A. Fulton School of Engineering are working to achieve. Their plasticity studies and the development of computational algorithms are laying the groundwork for new therapies and rehabilitative devices aimed at repairing lost nervous system function.

Ranu Jung and James Abbas, Ira A. Fulton School of Engineering professors and co-directors of the Center for Adaptive Neural Systems.

Individuals with spinal cord injuries, Parkinson's Disease, cerebral palsy and orthopedic injuries are already benefiting from the research of Ranu Jung and James Abbas, ASU engineering professors and co-directors of the Center for Adaptive Neural Systems.

"With partial spinal injuries, some communication between the brain and spinal cord remains," explains Jung. "There will be some recovery, but we're trying to answer: How much? How fast will it occur? How will it occur? Our studies indicate that locomotor skills can be modulated and improved with rehabilitative therapy."

To better understand this neuroplasticity – the ability of the nervous system to change or repair itself with experience – Jung works with rodent models that have partial spinal cord injuries. "For 15 minutes a day, they receive neuromuscular stimulation therapy," says Jung, of the technique that electrically stimulates nerves and innervates partially paralyzed muscles, thus imitating regular muscle movement.

After a week of therapy, the animals' gait and patterns of movement are tested while walking on a treadmill. "In preliminary studies, after only one week, they are showing improvement," says Jung. "When we see functional improvement, we know something is happening in the nervous system. Is it changes in connectivity between regions of the spinal cord and brain, changes in the morphology of the neural cells, or changes in the molecular neurochemistry?"

To address such questions, Jung and other researchers pay close attention to spinal reflexes, connectivity of the spinal neurons with those in the brain and the shape of the spinal neuron cell bodies and dendrites – the receptive branches that radiate from neurons. They also gather experimental data about the electrical signatures of damaged spinal cord neurons.

The data is used to create computer models that can be employed to ask questions about the role of neuron shape and electrical signatures under normal circumstances versus after injury. "If we knew more about the cells, then we could predict how changes in dendritic branches affect integration of information," explains Jung. Understanding the sequence of reflexes and neural control is also helping them design computer algorithms for programming electrical stimulation devices to provide daily rehabilitation therapy.

CK200 customizes neuromuscular stimulation to activate muscles in the subject's thighs to cause knee extension.

Because the musculoskeletal system is so intertwined with neural and motor tasks, the research team is also researching changes in muscle composition and examining the bones of rodent subjects, using 3D-laser scanning. The results are being used to develop computational models of the musculoskeletal system. "This will allow us to see how muscles contract, based on the muscle's fiber type, and how the change in the fibers after injury affects muscle contraction," explains Jung.

Supported by the National Institutes of Health, this comprehensive experimental and computational modeling effort will allow the research team to investigate the role of complex interactions among an impaired central drive, spinal reflexes and musculoskeletal changes – all geared toward the design of appropriate rehabilitation therapies.

"We know the body is trying to repair itself," explains Jung, indicating that her group's studies are simply aimed at expediting that process. "The question is, can we use a device to provide electrical stimulus to the nerves and give back some of the lost neural control so the body can use it – to fool it into thinking it's still there – and to get it to repair and reorganize itself."

Jung believes the answer is "yes." Her team has already made the first step with the creation of computational algorithms currently being tested in rehabilitative devices used by individuals suffering spinal cord injuries.

James Abbas, co-director of the Center for Adaptive Neural Systems, is vice president and co-founder of customKYnetics. The Versailles, Ky.-based company has developed the CK200 with support from the National Institutes of Health and in partnership with the Center for Adaptive Neural Systems and Banner Good Samaritan Medical Center.

Steve Vroman uses the handheld CK200 with Jim Lynskey and Jamie Stovall (middle).

Impacting the Future

The Center for Adaptive Neural Systems is committed to investigating the effects of trauma and disorders of the nervous system. In its efforts to replace damaged or lost functionality and to repair the nervous system, the center is also participating in the following research projects, among others:

- **Adaptive Electrical Stimulation for Locomotor Retraining.** In this NIH-funded project, computer algorithms that are automatically customized for each person are being developed for use in electrical stimulation therapy for individuals with spinal cord injury.
- **Force Modulation Training in Children with Cerebral Palsy.** This NIH-funded project involves bio-feedback training whereby children with cerebral palsy participate in virtual reality simulations to improve joint control, resulting in improved standing and walking abilities.
- **Neuromorphic Control System for Powered Limb Splints.** In partnership with a spin-out company, Advensys LLC, this U.S. Army-funded project is evaluating an intelligent control system for powered lower limb orthoses designed for use in acute-care combat settings to provide functional bipedal mobility to injured soldiers.
- **Active MEMS Neural Clamps.** In this NIH-funded project Microelectromechanical System (MEMS)-based neural electrodes that could actively clamp onto the spinal roots are being developed to provide a novel approach for recording distributed neural activity from the peripheral nervous system.