ROBO-REHAB

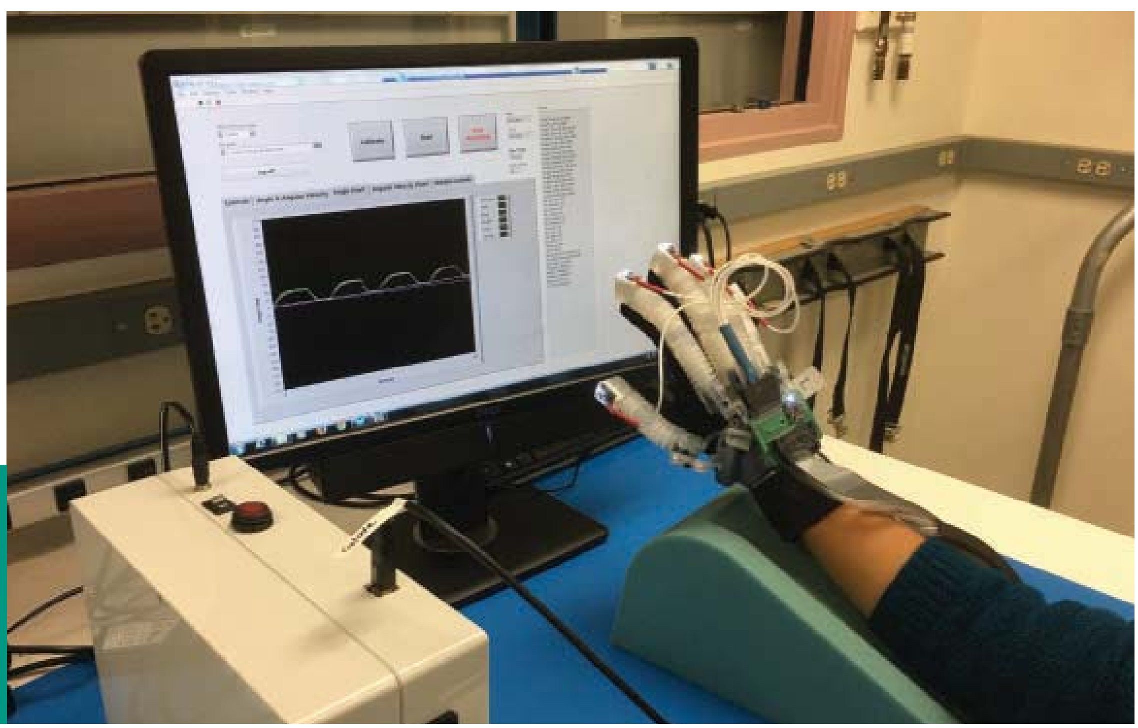
A soft robotic device being developed by researchers could give patients a quicker boost toward manipulating their fingers to hold and grasp items.

JOHN KOSOWATZ

EVERY YEAR IN THE US, 795,000 people fall victim to stroke, many of them with debilitating effect. Sometimes, the damage affects only a portion of a person's body, arms or legs, or speech. Often, it renders half of the body useless, limiting the patient's movement or control.

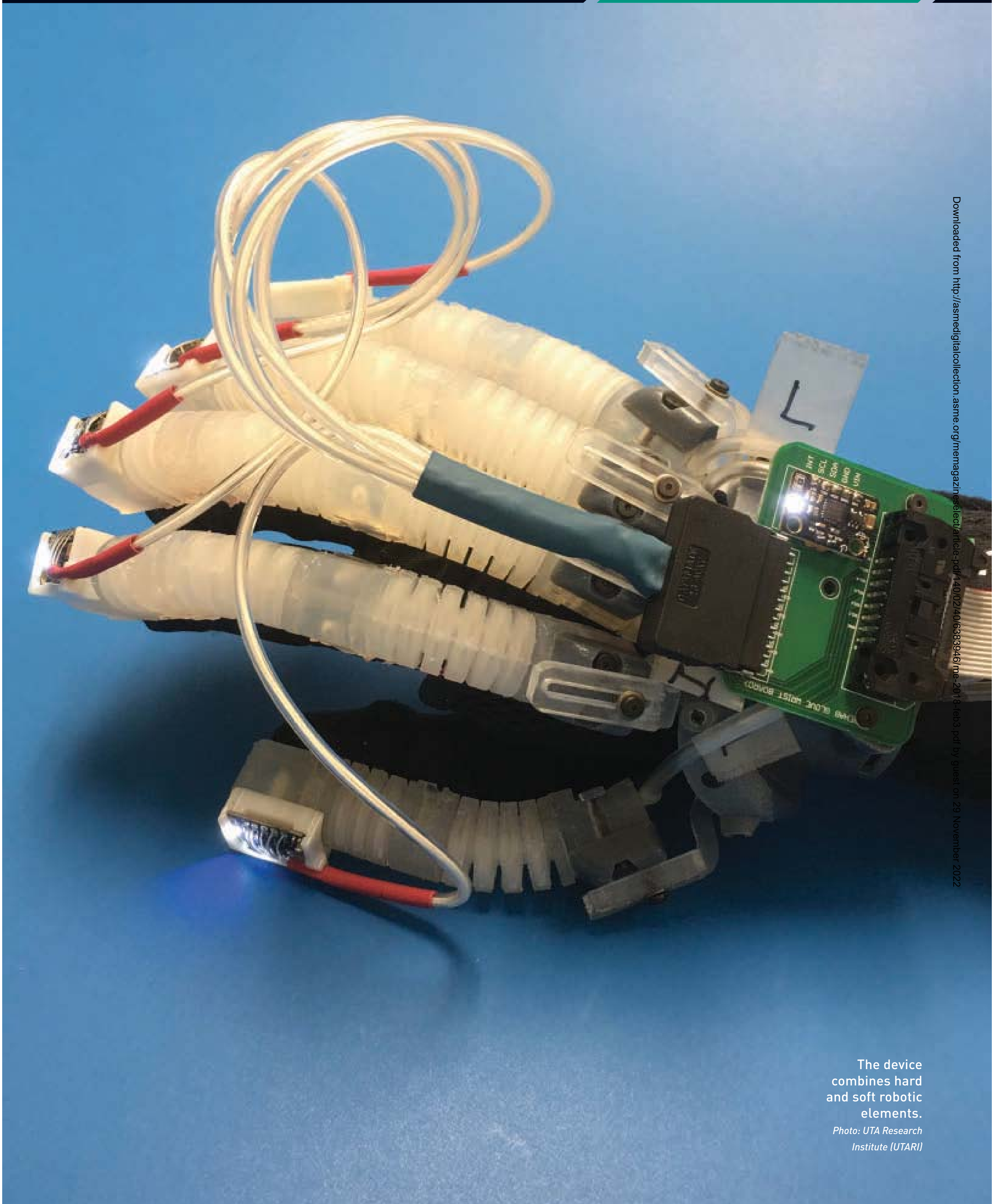
A patient's rehabilitation usually focuses on improving overall movement of arms and legs. But rehabilitating the extremities—hands and fingers—is often left for a later time. A soft robotic device being developed by researchers in Texas could change that pattern, giving patients a quicker boost in manipulating their fingers to hold and grasp items.

Rita M. Patterson, a professor of family medicine at the University of North Texas Health and Science Center, and Mahdi Haghshenas-Jaryani and Muthu Wijesundara at the University of Texas Arlington Research Center, are developing a soft robotic device for the hand, or more specifically, the fingers and thumbs.

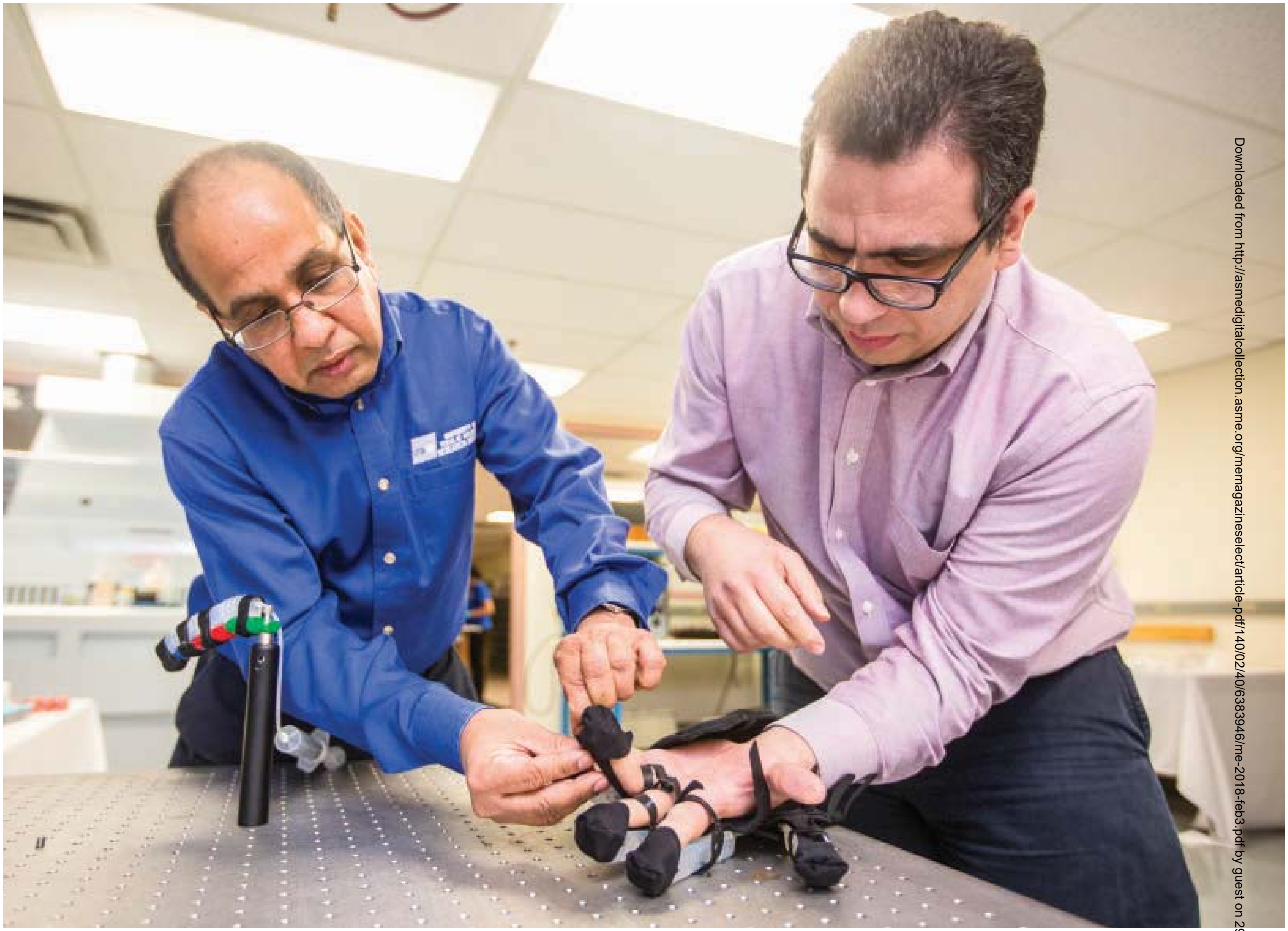


The device controls the level of force applied and sends data back for evaluation.

Photo: UTA Research Institute (UTARI)



The device combines hard and soft robotic elements.
Photo: UTA Research Institute (UTARI)



Actuator sections are placed over individual joints and connected through a glove.
Photo: UTA Research Institute (UTARI)

“We have not seen much in devices geared toward the hand,” Wijesundara said, especially with hard robotic devices. “When you really look at hand devices, they are not very dexterous.”

The specific anatomy, comprised of many small joints that produce complex motions, makes designing a hard robotic device difficult. Those available are rigid, mechanically complex, large, heavy, and costly. “There have been some successes, but the biggest limitation is providing a continuous bending motion,” Wijesundara said of soft robotics.

Patterson’s recent research uncovered 20 soft robotic devices for hands and fingers, but all are in early development phases and have limitations. She noted that over the last three years there has been a rapid increase in the development of devices for rehabilitative use. Most of those identified were continuous passive motion machines, which constantly move a joint through a controlled range of motions, and none are fully portable or operational without a technician. Most focused on flexion and/or extension of the index and middle fingers.

The team, which benefits from its members’ previous manufacturing experience, is developing a device that combines hard and soft robotic elements. Using advances in laminating materials and working with compression molding and other fabrication techniques, the team is combining the mechanics of hard robotics with soft robotics. The device relies on proprietary, bellow-type soft actuator sections that are placed over individual joints and connected through a soft and rigid hybrid structure, or glove. By attaching actuators to the joints, the device can control degrees of bending and the entire range of motion of flexion and extension, Wijesundara said.

Additionally, the device controls the level of force applied and sends data back for evaluation by a technician or therapist. The researchers say it will allow therapists to work with more people and to care for them remotely, providing portability and allowing patients to rehab without having to travel to an office.

One of the biggest design challenges is fitting the device to variable hand sizes. Eventually the team will produce the device in standard size gloves. Accommodating hand size differences within one standard size—small, medium, large—is problematic because

> **"THERE'S A DOZEN DIFFERENT PROBLEMS AND EACH REQUIRES A DIFFERENT REHAB MODE."**
>
> MAHDI HAGHSHENAS-JARYANI

actuators are placed on each joint of each digit of the hand. Placing them properly requires a stretchable frame to accommodate shortening or lengthening. That design differs from others that are currently being developed.

One of those devices is a lightweight glove developed by engineers at Harvard University's Wyss Institute and currently being tested on patients. The Wyss glove uses a continuous tube structure of Kevlar and other materials over the length of the finger, while the Texas glove uses a soft and rigid hybrid structure to hold the actuators. Patterson said the hybrid structure allows the device to individually control each joint for "applying desired motion and force, through either mechanical design or independent actuation." The Wyss device relies on the interaction between the continuous tube and the finger, impacting the finger as a whole and not individual joints.

There are other differences, including motion. The Harvard glove has one-direction action motion while the Texas glove is bidirectional, using pressure and vacuum actuation for flexion and extension. The Texas device also has sensors to track finger motion and torque applied to all the joints, and measures quantifiable therapeutic parameters, such as range of motion, stiffness, and grip strength to monitor a patient's progress and therapy.

Knowing how much force to apply, however, can be difficult to gauge. The hand has its own feedback to the central nervous system, so applying too much pressure can produce a reflex reaction. "Finding that sweet spot between mechanical input parameters and what you're applying to the hand, you have to be careful not to elicit a reflex reaction in your own system," Patterson said.

And therein lies a more basic issue. The task of designing a robotic device for the hand and fingers must take into account the needs of a range of potential patients. But there have not been any meaningful studies to determine the differences, Patterson said. "Just knowing the actual resistance of a normal hand, from a child with cerebral palsy to an adult with a stroke, it's never been documented in literature," she said. "We don't know the specs of what we're designing for."

Fleshing out those specifications is another big part of the discovery phase. The team has tested the device on individual stroke patients. But the next phase involves improving the interface between the device and controls, and fine-tuning the system to meet the varying needs of patients. Clinical trials are still in the future.

"What does the therapist want to control?" Haghshenas-Jaryani asked. "There's a dozen different problems and each requires a different rehab mode." The team is confident the device will fill a large void and eventually help both therapists and patients.

Today's standard practices for hand rehabilitation require therapists to work one on one with patients, a time-consuming process that's often restricted by a lack of qualified therapists in some areas of the country.

"This can help the therapist as an extension or helper," she said. **ME**

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