Ankle exosuit for community walking aims to give post-stroke wearers more independence

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Designed for independent use in community settings, the new exosuit could help stroke survivors improve their gait outside of the lab and during their daily routines. Credit: Walsh's Biodesign Lab / Harvard SEAS

Every 40 seconds, someone in the United States has a stroke. According to the U.S. Centers for Disease Control and Prevention, that totals about 795,000 strokes each year. More than 80 percent of stroke survivors experience gait challenges, often relating to a loss of control over ankle

movement. As survivors progress into the chronic stage of stroke, most continue to walk slower and less efficiently.

An agile, untethered, and easy-to-use ankle exosuit could change that. Designed for independent use in community settings, the new exosuit could help stroke survivors improve their gait outside of the lab and during their daily routines. A proof-of-concept study suggests the community-use ankle exosuit could help stroke survivors improve their walking propulsion and boost their overall walking confidence and ability while ambulating around their own homes, workplaces, and neighborhoods. The work, led by Conor Walsh's team at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS), is published online in *Annals of the New York Academy of Sciences.*

Recent studies have proven that post-stroke study participants can improve their walking speed, distance, propulsion, and gait symmetry with the help of an assistive robotic exosuit, but those studies have all occurred in labs or clinical settings.

"We saw an opportunity to leverage wearable technology to rethink how we approach physical therapy and rehabilitation" says Walsh, senior author on the paper and the Paul A. Maeder Professor of Engineering and Applied Sciences at SEAS. "If we can shift some of these clinical services from the clinic to the home and community, we can improve access, reduce costs and deliver better care. It is exciting to see the fields of engineering and physical therapy come together to make this happen."

For over a decade, Walsh's Biodesign Lab at Harvard has been developing assistive and rehabilitative exosuit technologies for various applications. Some of that technology has already been licensed and commercialized by ReWalk Robotics and been given breakthrough status by the U.S. Food and Drug Administration. To design an ankle exosuit meant for use in the community, Walsh's team need to simplify

the exosuit's mechanical components and make it easy for wearers to control.

"In the past, our ankle exosuits had two active actuators—one that helped with dorsiflexion to keep the wearer's toes up, and another to help with plantarflexion, propelling the foot and body away from the ground," says Richard Nuckols, a former postdoctoral fellow in Walsh's lab at SEAS, and co-first author of the paper.

Instead of an active dorsiflexion actuator, the new exosuit contains a passive material that flexes and performs like a spring, helping the toes stay up during the foot's swing phase and preventing the wearer from catching their toes on the ground. "By replacing an active actuator with a passive actuator, the exosuit is inherently safer; in the case of an unexpected power loss or controller failure, the default state will keep the users toes up and reduce risk of a trip and fall," Nuckols says.

"We also developed a mobile app to enable wearers to easily interact with the device and remotely check in with our team," says Chih-Kang Chang, a Ph.D. candidate in Walsh's lab and a co-first author on the paper. "The app allows wearers to turn the device on themselves and tell the exosuit when they want to start walking."

In addition, the team incorporated sensors to allow for remote monitoring of the wearer's progress over time. "We are collecting data while people are walking in the exosuit, and measuring how they improve their gait over time," Chang says. "Going forward, this information could be a really powerful aspect of using this exosuit for long-term rehabilitation in partnership with a physical therapist."

"These sensors—located on the foot, shank, and pelvis—are converted using a machine-learning algorithm into estimates of propulsion, helping us understand how well people are generating proper ankle mechanics

and how effectively they are walking," Nuckols says.

"Collecting the amount of data needed to train a typical machine learning model from individual wearers is extremely challenging, given the limited ability to walk for extended periods of time post-stroke," says Daekyum Kim, a postdoctoral fellow in Walsh's lab, and co-first author of the paper. "The key advantage of our approach is that it leverages walking data gathered from multiple individuals to better tune a machine learning model to each user."

To test the community ankle exosuit, Walsh's team partnered with the labs of Lou Awad and Terry Ellis from Boston University's Sargent College of Health & Rehabilitation Sciences. They recruited four participants to use the device in their own community settings for four weeks, walking independently three to five times each week. All participants safely completed the study and reported no safety issues. Due to individual variability in response (participants with lower baseline walking propulsion saw more benefit from wearing the exosuit), therapeutic benefit was not observed across the whole group. But two of the participants improved their propulsion by an average of 27 percent. They also walked an average of 4,000 steps further in the week after the study than they had walked in the week before the start of the study.

"I was 33 when I had my stroke. As a result of the stroke, I have diminished sensitivity on my entire left side," says Bryant Butler, 51, one of the study's participants. "Walking is a challenge. I can't feel my toes very well when I am walking, and I have difficulty bending my leg. I frequently scuff the toe of my shoe, and sometimes I trip."

During the study, Butler used the exosuit on Boston's Commonwealth Avenue Mall, walking 20 to 30 minutes at a time several days a week.

"The experience of walking with the exosuit was liberating, because I no

longer had to expend so much mental energy when going from one place to another," he says. "The exosuit gradually corrected my gait with every step. I learned how my leg muscles, knee, and toes should feel when I walk without it. [Even] when I wasn't using [the exosuit], my walking improved, because the device taught me how to better compensate for the shortcomings of my left leg post-stroke."

Butler adds: "The device became an extra piece of clothing—[except for the] wires and a battery pack—that I wore for a specific purpose. Most of the time, I forgot it was there. The exosuit nudged me into being a better walker. It inspired me to walk more, and to enjoy it."

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