A Startup with Sole

UCSB researchers create a shoe to address a debilitating condition that affects millions

The variable-friction shoe (left) that (from left, opposite page) Tyler Susko and Elliot Hawkes created has the huge advantage of appearing to be a normal shoe, not an orthopedic device; vastly improves users ability to walk; and has additional therapeutic benefits that have resulted in a $2.3-million grant from the NIH.

Millions of people in the United States experience "foot drop" — an inability when walking to avoid scuffing the ground when bringing one foot forward through the air to take the next step. Foot drop can result from any number of causes, including spinal cord injuries, stroke, cerebral palsy, multiple sclerosis, Parkinson's disease, or even, simply, weakness associated with advancing age.

"It's a huge population," says **Tyler Susko,** associate teaching professor, undergraduate vice chair, and capstone instructor in the Mechanical Engineering Department at UC Santa Barbara. He worked on rehabilitative robots while pursuing his PhD at the Massachusetts Institute of Technology and, in 2015, began trying to find a way to help people who experience foot drop. Now, nine years later, he and associate mechanical engineering professor **Elliot Hawkes** have a startup company, called Cadense, Inc., which recently delivered its first shipment of a custom shoe that alleviates foot drop while providing multiple related benefits.

The two researchers call their invention a "variable friction shoe," a reference to the fact that the sole contains both high-friction and low-friction components. When the foot is moving forward during what's called the "swing phase" of walking, the low-friction component is elevated from the sole, so that if the foot contacts the ground, the shoe slides forward rather than stopping, which can lead to trips and falls. Once the foot reconnects with the ground as the step is completed and the weight shifts to that foot, the low-friction surface retracts, exposing the high-friction surface, which provides a stable, non-slip landing for the "stance phase" of the step, when the foot is on the ground.

The idea had its origins in Susko's PhD work, when he conducted a study in which multiple people who had walking disabilities walked on a treadmill customized so that, as their foot started to come forward, the track dropped away, allowing the leg to swing forward freely, without scuffing. After the study, one participant told Susko how good it felt to walk without worrying about scuffing and tripping and that she wished she could "take it outside of the lab." Susko started thinking about how to make that possible. It hinged on the question: *How can we do this complex thing — removing the floor of the treadmill — in the simplest way possible?* "I say so many times to my students that the one fundamental principle of mechanical design is to keep it simple," Susko notes. "Anything you design should be as simple as possible."

Getting to simplicity is, of course, a complex undertaking. The vision for a shoe became a mechanical engineering undergraduate capstone project in 2015, Susko's first year at UCSB, with students designing a robot shoe that was too complicated, too heavy, and too reliant on things that could fail to function. "The thing we learned from that was not to make a robot shoe," Susko laughs.

At that point, Susko was joined by Hawkes, an expert in soft-material robotics and biomechanics who had just been hired by UCSB. At the time, Hawkes was working to create a wearable device to improve running performance. He designed a simple, one-dollar rubber band tied between the legs that made runners seven-percent more efficient.

Creating it involved, first, carefully analyzing the forces runners applied to an instrumented track, then determining how to modify those forces ideally, and finally, designing the simplest device possible to achieve those modifications. Hawkes says that he brought a similar process to the walking project: "I remember vividly examining the forces that occur during impeded walking, and devising a variety of ways to modify them, all of which failed, before we identified the variable-friction concept."

But going from concept to a shoe that would work for hundreds of thousands of steps was not a straightforward task. The team continued to work on the project with a second set of students, one of whom, **Erinn Sloan** (BS '17, MS '18), continued the project as the subject area for her master's degree. They were buying shoes — HOKA eventually gave them some — cutting them up, and trying different things. "We could hack a shoe and get a new concept the next day," Susko recalls.

Eventually, Hawkes, Susko, and Sloan patented the variable-friction shoe. "In 2019, we had a preliminary shoe, and it looked promising," Susko said. "People using it walked faster, with no instruction. Some people walked twenty to sixty percent faster. We also looked at people's 'gait strategies,' such as swinging their foot wide to get it forward. With the shoe, they no longer did that, and because the leg was moving straighter, they went faster."

Susko's intention, however, was to "develop a rehabilitation device that people could use to repair and retrain their brains," so he was not satisfied with a shoe that simply assisted walking. A grant from the California NanoSystems Institute at UCSB made it possible to locate a shoe designer and find a manufacturing facility to produce the first prototypes, which were beta-tested in 2022.

Several people in the initial trial used the shoe as an assistive device and immediately improved their gaits. Then, in a longer trial, they discovered the shoe's rehabilitative effects."We found one man who had suffered a stroke eleven years before," Susko says. "Usually, there is no natural recovery at that point, but using the shoe, he ended up walking three times faster than when he started. His calf muscle got so big that he had trouble fitting it inside his AFO [ankle foot orthosis, the standard of care for foot drop]. We thought, *So, there's muscle contraction and increasing muscle tone*, which was really interesting evidence, so we presented that to the National Institutes of Health (NIH)."

"Assistance is one thing," Hawkes adds, "but rehab is a whole other level. It means that they could graduate out of the shoe eventually and no longer need assistance."

The result of sharing the results from their production prototype tests with NIH resulted in a $2.3-million NIH grant for a study with researchers at Northwestern University. Together, they will collaborate to run a four-year clinical trial studying the effects of using the variable-friction shoe compared to the AFO brace.

Now in production, the first order of 2,080 pairs of Cadense shoes were delivered this past March, 800 of which were pre-ordered and would be sent directly to customers. Made with standard running-shoe materials, they look like running shoes and cost $198, giving those who experience foot-drop an affordable opportunity to step into a brand-new world of possibility.