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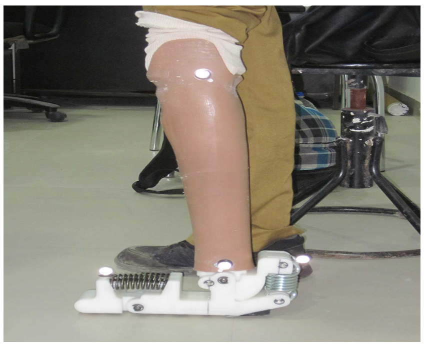
Method to Design a Better Prosthetic Foot



The Challenge: The leading available prosthetic foot, called the Jaipur Foot, only costs about $10, lasts three to five years, and meets or exceeds the performance of competing products for developing countries. However, being "good enough" still leaves room for improvement. The 24,000 Jaipur Feet that are distributed every year are hand-made, an inefficient process that also creates quality-control problems. Meanwhile, cheaper “knock-off” products hurt the nonprofit organization's reputation. Bahgwan Mahaveer Viklang Sahayata Samiti (BMVSS), the Jaipur, India-based organization that distributes the Jaipur Foot and other assistive devices, asked Katy's PhD advisor to help design a new foot that could be mass-produced without sacrificing performance. Katy made that her PhD project.

The Solution: Katy discovered that the leading design principle for the past 15 years, called "roll over shape," doesn't fully describe the gait kinematics of a prosthetic foot. (Kinematics is the branch of mechanics that deals with pure motion, without reference to the masses or forces involved in it.) Two feet with identical roll over shapes can have very different kinematics. Katy first invented a design objective called the Lower Leg Trajectory Error (LLTE). LLTE looks at the positions of the knee and lower leg at each instant during a step and measures how far they depart from the ideal kinematics. A foot that minimizes that error yields the most natural possible gait. It turned out that it’s unnecessary to faithfully replicate a natural foot. What matters is the person's lower leg, which interfaces with the foot. If the lower leg moves naturally and experiences the loads borne by an able-bodied leg, the person will walk comfortably.

Commercialization: Armed with this new analytic tool, Katy started building prototypes, and then tested them in a gait lab at Northwestern University. The results were good, but her prototypes were too bulky and had too many moving parts to be commercially viable. She spent three months at U.K.-based McLaren Applied Technologies learning optimization until she could build a one-piece prototype with no moving parts. The resulting foot can be made of low-cost injection-molded nylon or 3D-printed to sell for around $10 in the developing world, or it can be made from carbon fiber for markets that can bear a $1,000 price point. As soon as the low-cost foot is ready for production, BMVSS will replace its Jaipur Foot with Katy's design, creating instant distribution for 24,000 units annually. BMVSS doesn't have the manufacturing equipment to actually produce the feet, so Katy is also meeting with Indian materials suppliers and manufacturers and exploring whether a business should be started to distribute the technology or the technology should be licensed to an existing company. The higher-cost foot must meet various

U.S. Food & Drug Administration and International Organization for Standardization regulations, but Katy's collaboration with partners such as McLaren Applied Technologies will help navigate those potential barriers and enable a higher profit margin. Ultimately, she could develop a whole suite of prosthetic feet optimized for uses other than level-ground walking; for example, a foot for Indian amputees could allow squatting, while another one for especially active individuals could support carrying heavy loads.