***Using the constraints of emerging markets to create high-performance, low-cost assistive devices***

Speaker: Amos Winter, PhD

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Amos Winter’s talk covered development in three different technologies: the Leverage Freedom Chair, high-performance low-cost prosthetic knees, and High-performance low-cost prosthetic feet.

Leverage Freedom Chair (LFC):

This technology uses levers to enable 80% faster and 40% more efficient motion, and is capable of producing 50% more torque then a normal wheel chair. The levers are removable for indoor use.

The initial motivation for the LFC was for use in rural areas of developing countries where access to paved trails is limited and rough terrain makes long-distance travel difficult. Normal wheelchairs are unable to perform on rough terrain and are impractical for long distances. Existing products for long distance travel, such as hand-powered tricycles, are inadequate for the rough terrain experience and cannot be used inside. Analysis of the need, and current struggles of wheel chair residents of developing countries revealed the follow design requirements: the chair must be small and mobile enough for indoor use, it must be practical for long distances & rough terrain, and it must be easily reparable anywhere.

The initial design showed improved drivetrain performance. The speed of the LFC can be defined as a function of hand speed, diameter of Wheels, and lever length. The use of levers showed a 3:1 improvement in mechanical advantage, which is better then what is achieved by conventional mountain bikes. The drivetrain was packaged on conventional wheelchair structure in order to maintain lumbar support required. The power requirements were determined by considering drag, rolling resistance and gravity. Using conservation of energy, chair speed was derived as function of rolling resistance and incline angle. Given the terrain requirements, peak stall pushing torque was determined. Using both factors the ideal lever length for continuous use and rough terrain use was established. The design was constrained by commonly available parts in developing countries.

Multiple iterations were constructed, improving with feedback from end users as well as data collected (speed, exertion, efficiency, etc.) using DAQ during everyday use. Once a successful product for use in developing markets was designed. The LEC was reverse innovated up to wealthy markets. The new product specialized for US markets, the Freedom Chair, differed from the LEC in terms of improve transportability. This product is intended to act as a recreation device rather then a “standard-use” wheelchair, thus needed to be able to become compact enough to fit in a standard car trunk for transport.

High performance –Low cost Knees

Current low cost products in the developing market result in visually impaired gait which can have both metabolic costs and perpetuate the stigmatism associated with disability. Conversely, high cost active prostheses in wealth markets have much better performance. This lead to the motivation to define the relationship between mechanincal design of a passive knee and desired physiological performance. In a passive system, you need to predict toque profile required since it is unable to actively adjust.

To define this relationship abled-bodied kinematics were analyzed, and an adjusted ground reaction force (grf) for amputees was calculated based on differences in limb mass. The result was a curve defining torque change as function of leg mass required to achieve the ideal able-bodied kinematics. The device includes an early stance flexion spring, a late stance damper, and a swing damper. During heel strike the grf passes through back of knee, only engaging the early stance path. They are currently working on achieving early stance flexion that occurs in abled-bodied gait, but is often lost in amputees. In late stance, the latch connecting the spring opens allowing late stance flexion.

Through speaking with amputees about daily activities, difficulties they have with current passive prosthesis, and what improvements would be most valued it was found that in developing countries sitting cross legged would be highly valued. And improvements were made to enable this functionality.

High performance low cost Feet

This project is focused on improving the Jaipur foot to be mass-manufacturable. Similar to developing prosthetic knees, the aim is to determine connection between mechanical design and biomechanical performance.

Initially roll over shape was analyzed as design objective, however, limitations were realized. First, it does not provide angular constraint; different limb angles do not effect roll over shape. Further, roll over shape provides little insight into how the mechanical design of foot effects performance. Finally, it does not provide information on time dependence and how speed of gait effects performance.

A new parameter, lower leg trajectory error (LLTE), was defined based on able-bodied grf data, reaction forces and torques at the knee, and the deflection of prosthetic foot. From this limb placement throughout gait can be calculated giving a time and geometry constrainted insight into prosthesis stiffness required for more physiological gait. Preliminary gait testing data replicated abled-bodied gait data well for both loading and limb trajectory. Ankle angle was found to differ greatly, indicating that design of this device can be more flexible and is not necessarily constrained by ankle angle replication for realistic natural gait.