Low-cost prosthetic feet for underserved populations
A comparison of gait analysis and mechanical stiffness

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Background and Motivation

- Lower limb loss is an ongoing cause of disability throughout the world.
- Despite advancements in prosthetic technologies, there are numerous underserved populations in need of effective low-cost prosthetic foot options.

Figure 1. The three tested low-cost feet. Top Left: SACH foot, Top Right: Niagara foot, Bottom Left: Jaipur foot.

Methods

- 8 Below the Knee Amputee Subjects were recruited for force plate and motion capture testing.
- The subjects wore the SACH, Niagara, and their own foot while walking at their preferred speed on a treadmill.
- The SACH, Niagara, Jaipur, and a Carbon Fiber foot were tested on an Instron to measure the energy return during push-off.
- 5 independent measurements were recorded and averaged.
- The biomechanical and mechanical data were analyzed and compared with Visual 3D and Matlab.

Research Objective:

Evaluate the biomechanical performance of popular low-cost prosthetic feet with gait analysis and mechanical testing.

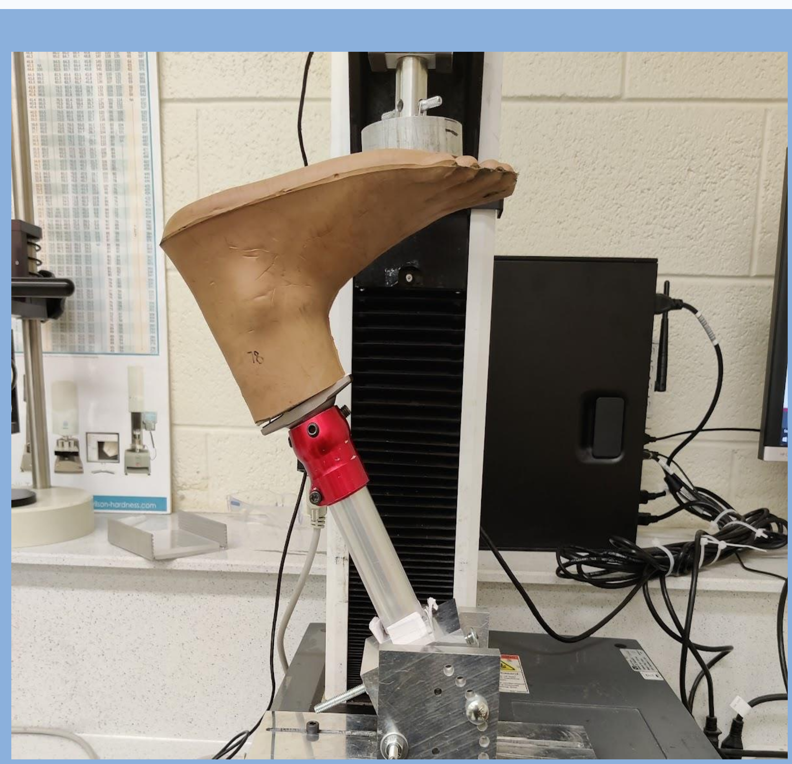

Figure 2. Mechanical testing set-up. Prosthetic feet (Jaipur foot shown) were mounted via pylon and pyramid adapter to a custom mount allowing for angular adjustments.

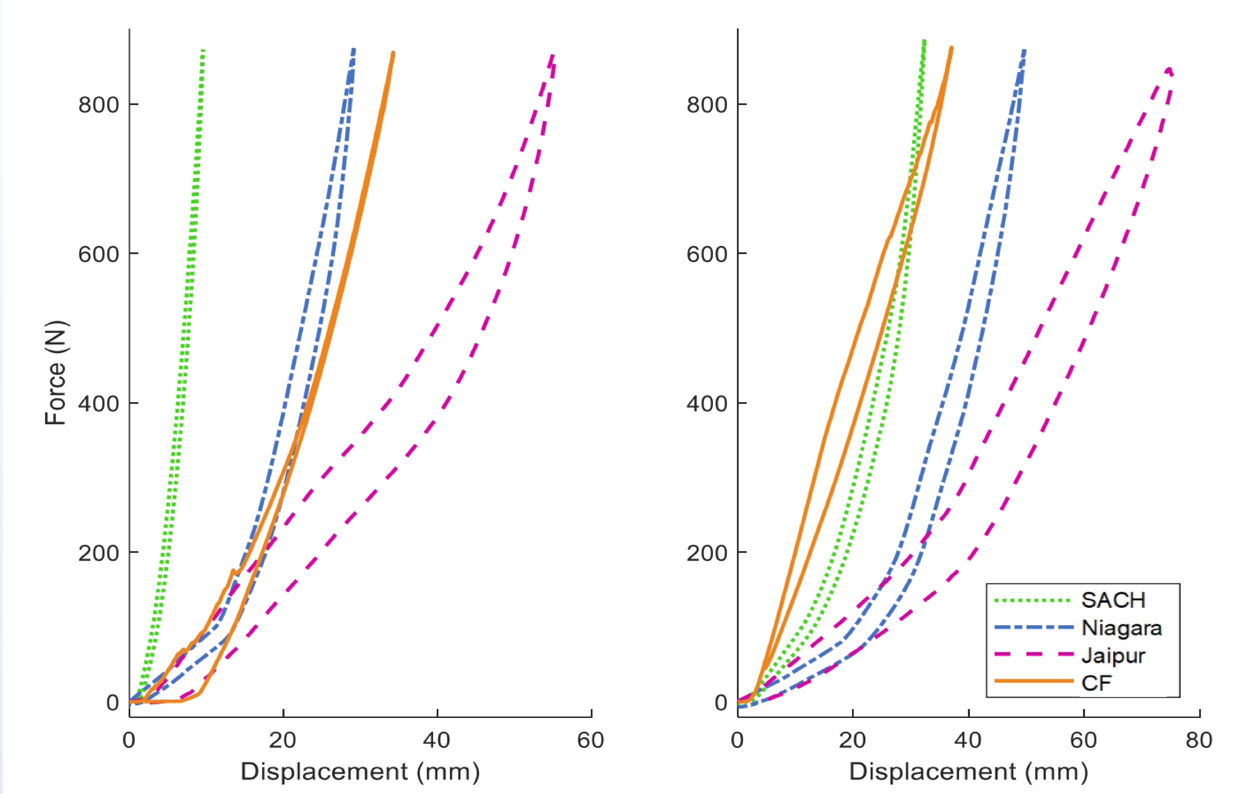

Figure 3. Force-displacement curves from the mechanical testing. Left: Data collected from the feet angled at 25° from the horizontal. Right: Data collected from the feet angled at 35° from the horizontal.

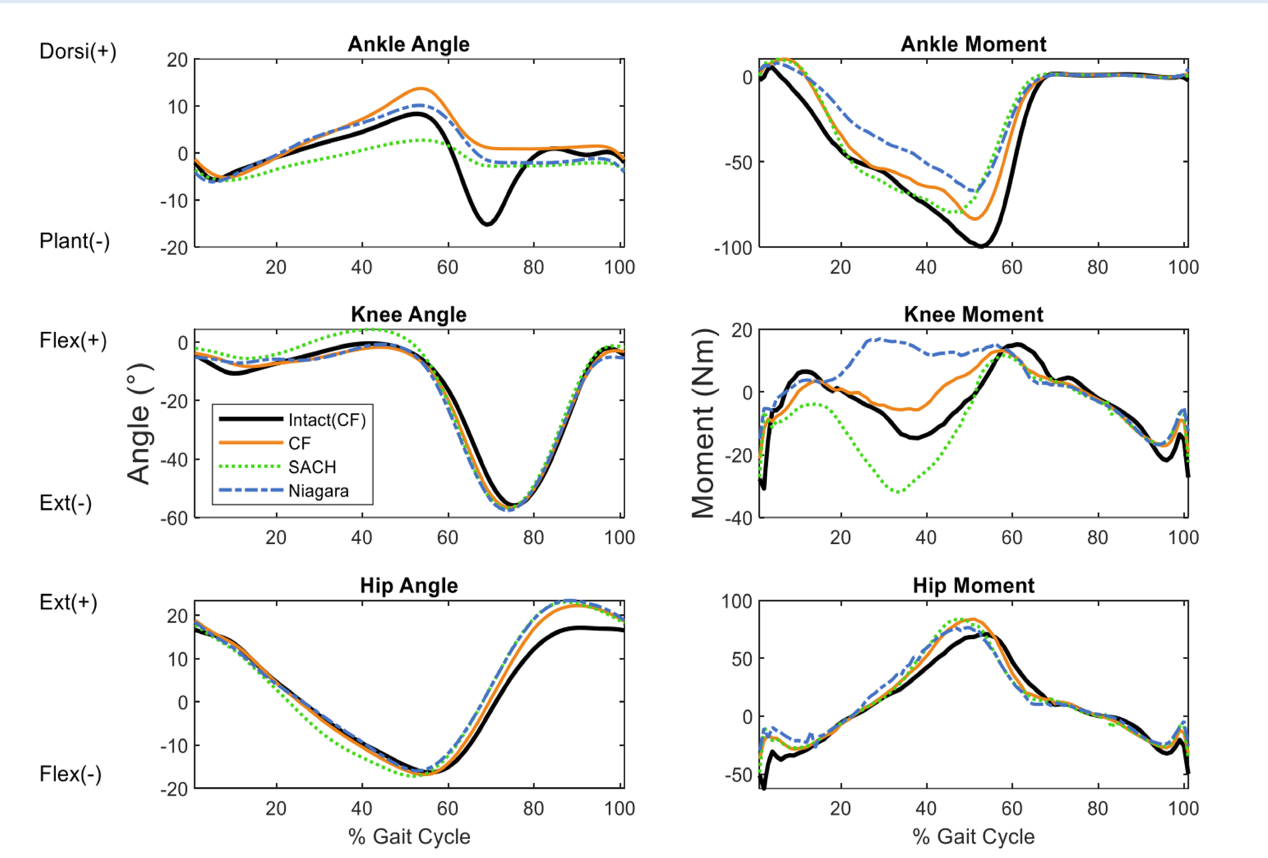

Figure 4. Ankle, knee, and hip joint angles (left column) and moments (right column).

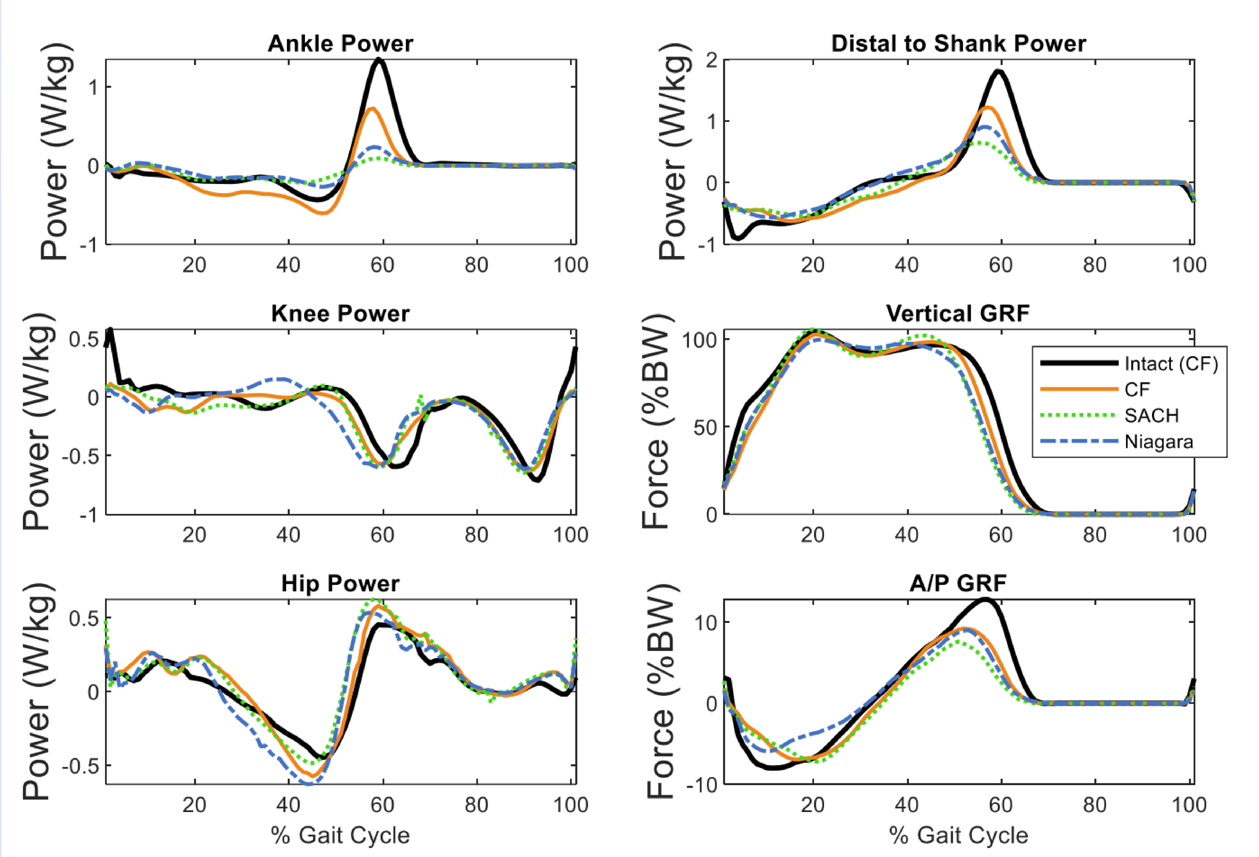

Figure 5. UD, knee joint, and hip joint power (left column) along with vertical and A/P ground reaction forces (right column).

Discussion and Conclusions

Metric analysis showed significant differences among feet in ankle motion and power as well as distal-to-shank power, with the SACH foot reduced compared to the other feet. Waveform analysis additionally revealed a knee flexion moment in the SACH foot and a knee extension moment in the Niagara and Jaipur feet. In mechanical stiffness testing, SACH had the highest stiffness, with Niagara and CF roughly similar, and Jaipur the most compliant.

There may be an optimal stiffness range for future prosthesis designs, with the SACH foot overly stiff and the Jaipur having slightly excess compliance and hysteresis. Ultimately, optimizing stiffness for gait biomimicry while maintaining cost, availability, and versatility across cultures will alleviate the effects of limb loss among underserved populations.

Significance:

The comparison of these metrics can be incorporated into the design process for developing low-cost feet.