EMULATING CANDIDATE ANKLE-FOOT PROSTHESES TO INFORM PRESCRIPTION

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INTRODUCTION

Robotic ankle-foot prostheses can improve walking performance for amputees compared to conventional designs [1], but prescription has been hindered by their high cost and uncertainty about the degree to which individuals will benefit. The typical prescription process cannot well predict how an individual will respond to a device they have never used, as it bases decisions on subjective assessment of an individual's current activity level [2]. We propose a new approach to prescription in which individuals 'test drive' candidate devices using a prosthesis emulator while their walking performance is quantitatively assessed and results are distilled to inform prescription decisions [3].

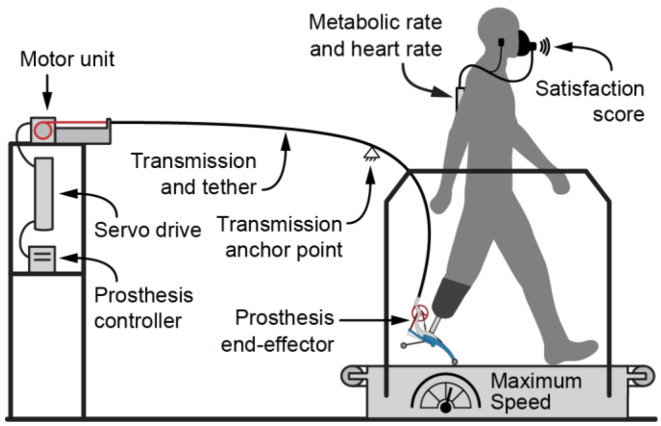

Figure 1: The emulator consists of a lightweight prosthesis actuated through a tether by a powerful motor and controller. Metabolic and heart rate, maximum walking speed, and user satisfaction are measured to assess the emulated behaviors.

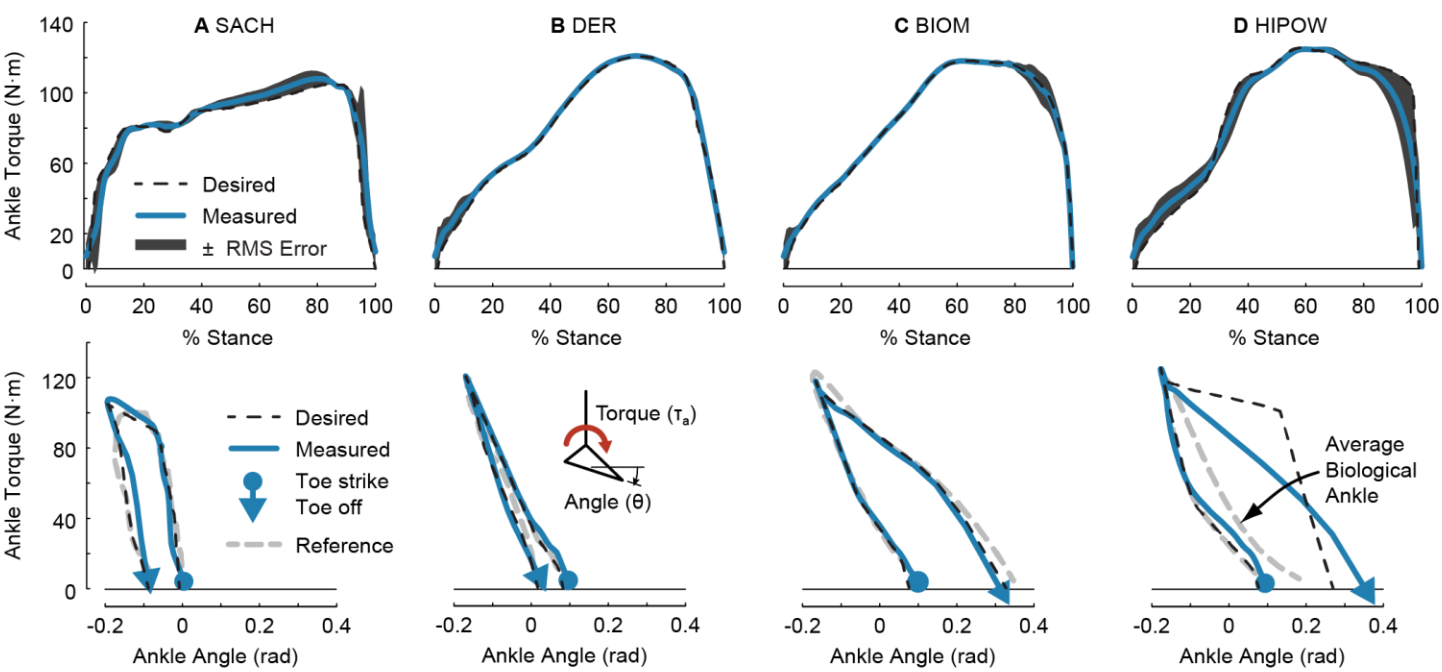

Figure 2: We programmed the behavior of **A** a solid ankle cushioned heel (SACH), **B** a dynamic-elastic response (DER), **C** the BiOM® T2 powered robotic, and **D** a conceptual high-powered robotic (HIPOW) prosthesis. Emulation was performed by joint torque control with the ankle torque vs. angle relationships of commercially-available prostheses as the reference torque. Data presented are from a single representative subject walking at 1.25 m/s on level ground over approximately 150 strides.

We propose a new approach to prescription in which individuals 'test drive' candidate devices using a prosthesis emulator while their walking performance is quantitatively assessed and results are distilled to inform prescription decisions [3]. By emulating, rather than purchasing and fitting candidate devices, behavior can be changed quickly through a software interface rather than by swapping mechanical components, so users can experience a broader range of devices than is possible using traditional approaches.

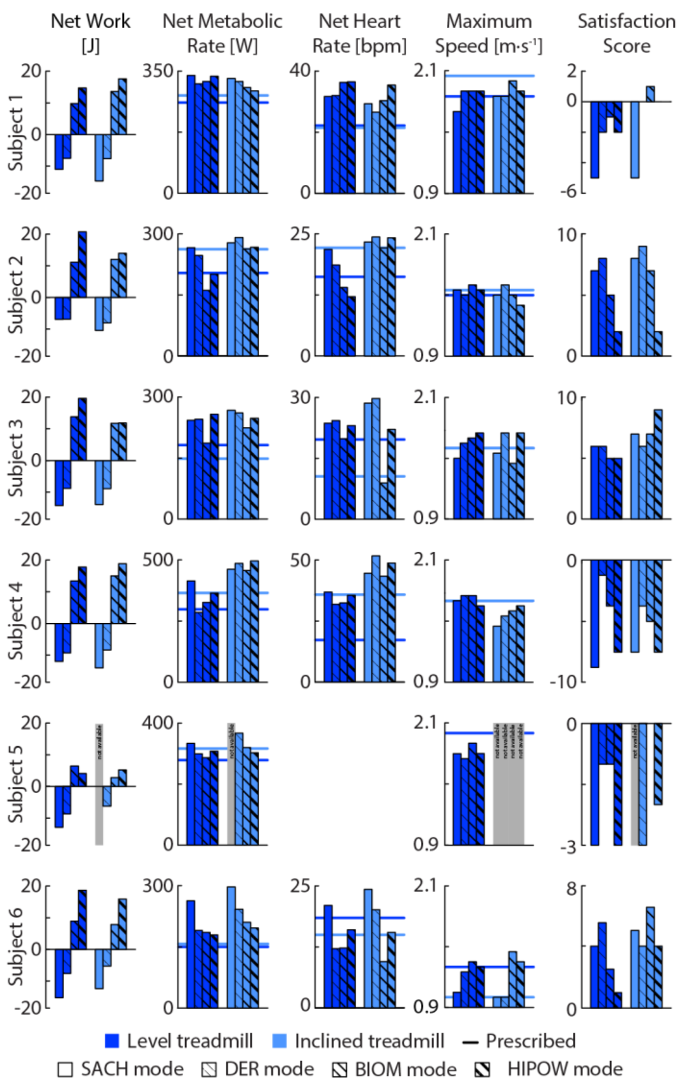

Figure 3: Walking performance outcome metrics listed for each subject across different emulator modes and two treadmill incline conditions.

METHODS

To test the viability of the approach, we developed a prototype ankle-foot prosthesis emulator (Fig. 1) and assessment protocol, leveraging hardware and methods we previously developed [4] for basic science experiments (eg. [5]), and conducted a treadmill walking experiment with 6 unilateral transtibial amputees (♂, K3, aged 49±5 yrs, 15±16 yrs as amputee, 184±15 lbs).

RESULTS AND DISCUSSION

We demonstrated an emulator that closely tracked the ankle torque vs. angle relationships of an array of commercially-available ankle-foot prostheses (Fig. 2). Average RMS torque tracking errors were between 2 and 4% of the maximum ankle torque. Users indicated that emulations were subjectively convincing representations of each device class. We demonstrated a protocol for measuring users' walking performance across emulator modes that discerned individuals' needs using simple quantitative measures (Fig. 3). All unilateral transtibial amputees we tested appeared to benefit from robotic assistance strategies to some degree but with individual subject differences. The five DER users demonstrated potential for improved walking performance and satisfaction with a robotic prosthesis, but were never able to explore this option within the conventional prescription process. The BiOM® T2 user showed benefits from robotic assistance, but only when walking uphill, and always preferred walking in the passive modes. By exploring candidate device behaviors through haptic emulation, prosthesis prescriptions could be objectively justified prior to device purchase and fitting to ensure that users reach an appropriate balance of cost and benefit.

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