Effects of Walking Speed on Mechanical Work on the Body Center of Mass in Transfemoral Prosthesis Users

S. Pinhey1, R. Amma2,3, H. Murata2,3, G. Hisano3,4,5, D. Ichimura3, H. Hobara3, and M.J. Major1,6

1Northwestern University, Chicago, USA; 2Tokyo University of Science, Japan; 3National Institute of Advanced Industrial Science and Technology, Japan; 4Tokyo Institute of Technology, Japan; 5Research Fellow of Japan Society for the Promotion of Science, Japan; 6Jesse Brown VA Medical Center, Chicago, USA

email: shaypinhey2021@u.northwestern.edu

INTRODUCTION

- For human locomotion, each limb performs step-to-step work on body center of mass (BCOM) to maintain forward walking [1]
- Efficient energy exchange involves alternating periods of negative and positive work that rely on physiological mechanisms to support limb collision following initial contact and push-off in late stance
- Mechanisms are impaired in transfemoral prosthesis users (TFPUs), which might explain asymmetry and increased metabolic cost [2]

Aim: To assess the effects of waking speed on step-to-step energy exchange in unilateral TFPUs

H1: Collision work on both limbs will increase with walking speed
H2: Prosthetic limb will have reduced push-off work across speeds

METHODS

Participants
25 unilateral TFPUs (19 M, 6 F, 31±10 yrs, 166±7 cm, 65.6±13.9 kg) wearing their customary prosthesis (n=15 mechanical, n=10 microprocessor knee joints)

Procedure
- A split-belt instrumented treadmill (Tec Gihan Inc., Japan) collected instantaneous ground reaction forces at 1000 Hz
- ~7 minutes treadmill accommodation
- Walk at 8 speeds (0.55–1.53 m/s with increments of 0.14 m/s) for 30 seconds
- Rest provided as requested to minimize fatigue effects

DATA ANALYSIS CONT.

BCOM work estimated during three phases of stance:
1. Collision = First double support phase
2. Midstance = Single support phase
3. Push-Off = Second double support phase

Work was then calculated across each phase for each limb and averaged across all valid steps/strides for each speed

Statistical Analysis
- Two-way ANOVA assessed the main and interaction effects of speed and limb side (sound, prosthetic) on work for each phase of walking (α=0.05)
- Next, simple main effect analysis employed if interactions were significant

RESULTS

- H1 supported: TFPUs displayed a significant (p<0.001) increase in collision work with walking speed on both limbs
- H2 supported: TFPUs displayed significantly (p<0.001) less push-off work generated by the prosthetic limb across all speeds
- Prosthetic limb midstance work was nearly unchanged across speeds, but increased almost exponentially on the sound limb after 1.11 m/s
- A significant (p≤0.033) but small increase in prosthetic limb push-off work after 1.11 m/s that may suggest some element of prosthetic foot energy return at higher walking speeds
- TFPUs gait inefficiency may be partially explained by limited ability to generate prosthetic limb power during mid and terminal stance, relying more on the sound limb to drive energy changes during forward walking
- Prosthetic limb mainly assumed energy loss during collision and support the body as it transitions over that limb which emphasizes need to assess the potential long term (overuse) effects of transfemoral prosthesis use on sound limb musculoskeletal health
- Interventions to address this asymmetry may include therapy to promote greater use of the prosthetic limb hip to generate work or prosthetic devices to aid late stance propulsion

DISCUSSION

REFERENCES