Motivation

- 879,000 Americans will be living with lower limb loss by 2020\(^1\)
- 50% fall each year\(^2\)
- Inability to balance on one limb for > 5 seconds = \(\uparrow\) injurious fall risk\(^3\)
- People with lower limb loss can rarely balance on their prostheses\(^4\)
- Passive exoskeletons can tune muscle-tendon dynamics\(^5\)
- Tuning biology with passive exoskeletons to \(\uparrow\) balance is unexplored

Hypotheses

1. Optimal exo will be a pure damper (vs. spring or spring+damper)
2. Optimal exo will maximize biological dissipation

Approach

- Developed model of balancing on a prosthesis (Fig. 1)
- Across combinations of prosthesis stiffnesses, hip exo stiffness & damping:
  - Found lowest push causing fall in < 5 seconds
  - Studied biological & exo energy absorption/dissipation around exo optimum

Results & Implications

- Optimal hip exo was function of prosthesis stiffness (Fig. 2 A-F)
  - Optimal exo = pure damper for 500-600 Nm/rad prostheses (Hyp 1 √)
  - Optimal exo had stiffness component for prostheses > 600 Nm/rad (Hyp 1 X)
- Biological energy dissipation was not maximized with the optimal exo
  - \(\downarrow\) exo damping from optimal = in \(\downarrow\) push for failure, but \(\uparrow\) biological energy dissipation/absorption (Hyp 2 X; Fig. 2 G)
  - \(\uparrow\) exo damping from optimal = fall soon after push
  - \(\uparrow\) exo damping from optimal = fall later after push (Fig. 2 H)
- Tuned passive hip exoskeletons can \(\uparrow\) balance
  - Optimal exos \(\downarrow\) minimum push for fall by 3.9-20.2% from no-exo condition, depending on prosthesis stiffness

References