The effects of toe joint stiffness and toe shape on bipedal walking

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How can toes improve gait?

**Known**

- Toe joint dynamics impact performance

**Unknown**

- Which toe parameters most influence walking performance? (e.g., joint stiffness, shape)

**Objective**

- Systematically characterize effect of various toe parameters on walking using adjustable prosthesis

**Vision**

- Optimize toe joint dynamics in prosthetic feet to aid users

Stiffer toe, later Push-off

- Data collection and processing
  - 10 subjects walked at 1.0 m/s
  - Wore simulator boots with adjustable prostheses
  - 5 toe shapes randomized
  - 6 toe joint stiffnesses randomized
  - Collected and analyzed bilateral, lower limb kinematics & kinetics
  - Evaluated Center-of-Mass (COM) Push-off & Collision work

- Future: more sweeps & metabolics
  - Testing other toe parameters (e.g., length, range of motion, etc.)
  - Metabolic study
  - Analogous testing with transtibial prosthetic users

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Toe stiffness, not shape, affected COM work

- Stiffer toe caused up to 50% more Push-off
- Stiffer toe caused up to 25% less collision
- Little change with different toe shape

9/10 subjects did not prefer $\infty$ stiffness toe

- But why? Increased Push-off generally considered beneficial

Toe joint stiffness affected knee & hip power

- Knee
  - Zero stiffness $\rightarrow$ less knee flexion
  - Little change
- Hip
  - 0 Nm/deg
  - 0.25 Nm/deg
  - $\infty$ Nm/deg
  - Stiffer toe $\rightarrow$ decreased power, but less smooth

Which toe parameters most influence walking performance? (e.g., joint stiffness, shape)