Evaluation of the Mechanical Function of a Novel Lower-Limb Biarticular Prosthesis

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Introduction

- Gastrocnemius (GAS): accelerates leg into swing in late stance phase [1]
- Soleus (SOL): accelerates trunk forward [1]
- Other muscles compensate for lack of biarticular GAS function [2]

Overall Research Goals

- Develop biarticular clutched spring prosthesis that replicates functional role of GAS
  - Supply ankle power at toe-off
  - Reduce compensatory muscle forces
  - Reduce metabolic cost of amputee walking

Mechanical Design

- Thigh Cuff
- Ratcheted Clutch
- Socket
- String Potentiometer
- Pylon Strain Gauge
- Spring
- Variflex foot
- Load Cell
BP Spring Control

Clutch On

1. Pylon strain gauge detects heel strike
2. Spring produces force after length minimizes
3. Ratcheted clutch engages
4. Clutch disengages when Forces < threshold
Specific Aims

1. Evaluate the mechanical function of the Biarticular Prosthesis (BP)

2. Analyze the energetic effects of the BP on amputee gait
Methods

Walking trials:

1. Prescribed Prosthesis
2. Unrecorded acclimation with unpowered BP
3. BP with increasing spring stiffness
   - 1.85 N/mm
   - 3.7 N/mm
   - 10 N/mm
4. Unpowered BP
Amputee Model

- 80 muscles
- 19 degrees of freedom in lower body
- Residual limb and prosthesis mass properties derived from literature [4,5]
- Pin joint created in same relative position as intact ankle to replicate flexion in prosthesis

Results: Mechanical Test

Measures of Mechanical Function

- Vertical GRF
- Pylon Force
- BP Spring Force
- Clutch On-Off
- String Length

Percent Gait Cycle
Results: Ankle Moment

Average Ankle Moment

Dorsiflexion

Plantar flexion

Percent Stance Phase

Moment (Nm/kg)
Results: BP Ankle Moment

BP Spring Contribution to Total Ankle Moment

Dorsiflexion

Average: 33%

Plantar flexion
Results: Knee Kinematics

Average Knee Angle

Flexion

Extension

Percent Stance Phase

Angle (Deg)

Prescribed
BP
BP unpowered
Discussion

• BP had appropriate mechanical function
  – Software, one-way clutch, pylon strain gauge, and thigh cuff worked in concert

• BP spring marginally increased ankle plantar flexion torque
  – Greater increase desired for future prototypes

• Spring stiffness affects peak knee extension in midstance
Future Work

• Repeat protocol with additional amputee subjects

• Look at BP effect on compensatory muscle forces
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