The Effect of Transtibial Prosthesis Suspension on Residual Limb Pistoning

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Background

- Goal of prosthetic suspension is to minimize residual limb motion within prosthesis

- Poor suspension can cause: [Carroll 2006, Edwards 2000, Michael 2004]
  - Skin breakdown
  - Loss of control
  - Discomfort
  - Compliance issues
Background: Prior Research

  - Mostly static
    - Range of pistoning from 0.5 cm to 3.5 cm
  - Suspension systems
    - Supracondylar
    - Cuff Strap
    -林ers with pin and shuttle lock
    - **Knee Sleeve**
    - Suction
    - Elevated vacuum
Purpose

- Describe the effects of three suspension systems on the residual limb motion (pistoning)
  - Static simulation
  - Dynamic motion capture
Hypothesis

Elevated vacuum suspension will significantly reduce the amount of pistoning when compared to suction and knee sleeve suspension methods.
Methods: Subjects

- IRB approved protocol
- 5 subjects (3 M: 2 F)
- Age: 49.12 (40.8-57.1)
- BMI: 31.54 (27.5-35.6)
- 3 Right, 2 Left
- Time from amputation: 6.47 years (2.08-10.92)
- Cause:
  - 2 Trauma
  - 2 Vascular
  - 1 Osteomyelitis
Methods: Protocol

- Fabricate and fit prosthesis
- Dual energy x-ray absorptiometry (DEXA) scans of limb for 3 conditions for each suspension
  - No loading
  - Loaded to half body weight
  - 44.5 N distraction force [Board 2001]
- Total of 9 images per subject
Methods: Pistoning

- Limb imaged at load of half body weight (HBW) for each suspension
- Distance from tibia to prosthesis measured five times
- Average value calculated
Methods: Pistoning

- Limb imaged at 44.5 N distraction force for each suspension
- Distance from tibia to prosthesis measured five times
- Average value calculated
Methods: Pistoning

Pistonning_{\text{vacuum}} = \text{Avg (44.5 N}_{\text{vacuum}}) - \text{Avg (HBW}_{\text{vacuum}})
Results

Static Measure of Pistoning

- Vacuum
- Suction
- Sleeve

Subject 1 Subject 2 Subject 3 Subject 4 Subject 5

Pistoning (cm)

p > 0.05
Discussion: Pistoning

- Average amount of pistoning
  - Elevated vacuum: 0.99 cm (± 0.68 cm)
  - Suction: 1.34 cm (± 0.24 cm)
  - Sleeve: 1.92 cm (± 0.48 cm)

- Pistoning falls within the ranges found in literature (0.5 cm – 3.5 cm)
Discussion: Limitations

- Fabrication
  - Modifications done by outside prosthetist
  - Socket fit

- Supine DEXA scan
  - Tissue response to loading
Discussion: Clinical Relevance

- Clinically, what does this mean?
  - Elevated vacuum may minimize pistoning
  - Even if true, not necessarily the best option
    - Clinical judgment
    - “Stuff” and stiffness factors
  - Elevated vacuum may have other benefits
Further Research

- Analyze the pistoning in dynamic conditions
- Subjective feedback from subjects
- Other benefits of elevated vacuum suspension
Thank You!

- Ohio Willow Wood
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Questions??
References


Transtibial Suspension Methods

[Michael 2004]

- **Atmospheric Pressure**
  - Roll-on locking liners, vacuum assisted suction, knee sleeves, hypobaric seal with suction

- **Anatomic**
  - Supracondylar wedge, supracondylar with suprapatellar extension

- **Straps**
  - Cuff strap, waist belts

- **Hinges**
  - Thigh corset
Atmospheric Pressure Suspension 1-4

- **Indications**
  - Whenever clinically possible

- **Advantages**
  - Minimize pistoning
  - Proprioception
  - Best ROM

- **Limitations**
  - Consistent donning necessary
  - Best used with mature limb

Ohio Willow Wood Alpha Max Liners

Balogh 2008
Inclusion/Exclusion

- **Inclusion**
  - Unilateral
  - 18+ years old
  - Liner user
  - Amputation for > 1 year
  - Able to walk at variable speed
  - Current socket is less than 5 ply sock fit

- **Exclusion**
  - Dementia or inability to give consent
  - Knee flexion contracture > 15°
  - Pregnant or think they might be pregnant
Dynamic Study

[Wirta et al 1990]

- Studied 7 different PTB suspension systems on 20 adult, unilateral TT amputees
- Walked at three speeds
  - 0.76 m/s, 0.98 m/s, 1.23 m/s
- Measured pistoning of limb to be 1.91 cm (0.6-3.1 cm)
Gait Lab

- Instrumented gait lab
- Reflective markers placed on lower body
- Walk under four conditions:
  - Current prosthesis
  - Elevated vacuum suspension
  - Suction suspension
  - Sleeve suspension
- Walk at two speeds in each suspension
  - 1.2 m/s
  - 1.4 m/s
Results

Resting Position of Limb

Distance from tibia to prosthesis (cm)

Subject 1  Subject 2  Subject 3  Subject 4  Subject 5

Vacuum  Suction  Sleeve