Kinematic Effects of Sloped Surfaces on Shank Angle for Persons with Drop Foot

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Introduction

- Drop Foot: passive equinus or excessive ankle plantarflexion in swing phase (Perry)

- Orthotic Treatment
  - Traditional: Ankle Foot Orthosis (AFO)
  - Alternative: Functional Electrical Stimulation (FES) of peroneal nerve

http://www.alimed.com
Functional Electrical Stimulation (FES)

- **Peroneal Nerve Stimulators (PNS)**
  - First described in 1961 by Liberson
  - Must control timing of stimulation → want stimulation at toe off

- **Types of PNS Regulators**
  - Heel sensor (Liberson 1961)
  - EMG sensors (Lyons 2002)
  - “Natural” sensor – sural nerve (Haugland 1995)
  - Tilt sensor (Dai et al, 1996)

http://www.walkaide.com
Tilt Sensor

Dai et al, 1996

Start Stim

Dai et al, 1996
Shank Angle & Phases of Gait

- $f_s(-)$: Heel Strike (Initial Contact)
- $f_s=0$: Mid-Stance
- $f_s(+)$: Toe-off (Pre-swing)
Purpose

- Describe differences in shank angle when walking on inclined/declined surfaces compared to a flat surface.

- Determine if tilt sensor FES control is reliable on inclined/declined surfaces.
Hypothesis

- Shank angle at toe off will be significantly different on inclined/declined surfaces compared to a flat surface.

Dai et al, 1996
Methods: Subjects

- Inclusion criteria:
  - Unilateral drop foot
  - Own and use a Walk Aide
  - Over 18 years of age
- n=7
  - Gender: 3 Female, 4 male
  - Average Age: 59.04 yrs (STD=11.42)
  - Dx: 4 Multiple Sclerosis, 2 CVA, 1 TBI
  - Time using Walk Aide: 2 mos to 2 yrs
Methods: Protocol

- Vicon motion analysis system
- Standard Lower Extremity marker set
- Walk Aide setup “as is”
- Walking speed self-selected
Methods: Equipment

- Flat surface
- Two stationary ramps
  - Wood
  - Modular Design
  - 8’ Length
  - 4.8° and 9.6°
Results
Shank Angle at Toe Off

Grade of Slope, degrees

Shank Angle, degrees

-10 -5 0 5 10

Subject 1
Subject 2
Subject 3
Subject 4
Subject 5
Subject 6
Subject 7
Shank Angle at Toe Off

* indicates significant difference from 0 degree condition (p<0.05)
**Conclusion**

✓ Hypothesis
   - Shank angle at toe off IS significantly different (lower) on inclined surfaces compared to a flat surface.

✗ Hypothesis
   - Shank angle at toe off IS NOT significantly different on declined surfaces compared to a flat surface.
Discussion: Shank Angle

- **Key Finding:** Shank angle at toe off is significantly reduced for both inclined surfaces compared to a flat surface.

- **Clinical Application:** Does this affect stimulation?  
  YES
% Dorsiflexion in Swing

R² = 0.9959

Grade of Slope, degrees

% DF in Swing
Limitations and Future Research

- **Limitations**
  - Short ramps → limited strides observed
  - Did not directly monitor performance of Walk Aide

- **Future Research**
  - Monitor operation of the FES device on different sloped surfaces.
  - If stimulation is reduced on sloped surfaces, determine if this is detrimental to patients.
  - Smart sensors? → Cikajlo et al, 2008
References

- Cikaljo I, Matjacic Z, Bajd T. Efficient FES triggering applying Kalman filter during sensory supported treadmill walking. *Journal of Medical Engineering & Technology* 2008;32:133-144.
Questions?

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http://www.vimeo.com/
Step Length vs Speed

- **Step Length** vs **Speed**

\[ R^2 = 0.7706 \]
Shank Angle at Toe Off

Subject Shank Angle, degrees

- Flat
- 4.8deg Up
- 9.6deg Up

Subject

- 1
- 2
- 3
- 4
- 5
- 6
- 7

Shank Angle at Toe Off
Shank Angle at Heel Strike

Grade of Slope, degrees

Shank Angle, degrees

Subject 1
Subject 2
Subject 3
Subject 4
Subject 5
Subject 6
Subject 7
Shank Angle at Heel Strike

Grade of Slope, degrees

Shank Angle, degrees

* indicates significant difference from 0 degree condition (p<0.05)
% Dorsiflexion in Swing

Grade of Slope, degrees

% DF in Swing

R² = 0.8358

R² = 0.8358
Outline

- Introduction/Background
- Purpose
- Hypothesis
- Methods
- Results
- Discussion