How Robots, Beds, and Sandals Are Helping Keep Astronauts Healthy in Space

Galen Kreutzberg
RWTH Aachen University
Mentors: Kyle Hackney, Ph.D. and Andrea Hanson, Ph.D.
Exercise Physiology and Countermeasures Lab
Introduction

• BSE BioMed Engineering, University of Michigan ‘13
• Third tour at JSC
  ▫ - Digital Astronaut
  ▫ - Neurolab
  ▫ - Exercise Physiology and Countermeasures Lab
• European Astronaut Center
  ▫ Crew Medical Support Office
• MS BME/Tissue Engineering, RWTH Aachen ’15
  ▫ - “Musculoskeletal injury and healing in reduced gravity environments”
Project Objectives

- **Assessment of Skeletal Muscle Morphology**
  - Mentor: Dr. Hackney
  - Train for skeletal muscle size assessment techniques
  - Perform data analysis for ongoing studies
    - X1 Exoskeleton
    - Bed Rest CFT70

- **Evaluation of Portable Load Monitoring Devices**
  - Mentor: Dr. Hanson
  - Evaluate XSENS ForceShoe™ load accuracy
  - Assist with flight certification pathway
  - Develop method for Center of Pressure estimation
  - Develop method for using ForceShoe™ in 3D Motion Capture data collection
X1 Exoskeleton

Background

• **Purpose:** Assess X1 ankle’s potential as an exercise countermeasure device
• **Problem:** Soleus muscle exhibits the most single fiber strength loss and atrophy during missions
  ▪ Current Countermeasure: ARED Standing Heel Raises
• **Proposal:** With knee at 90° flexion, plantar flexions against resistive load may more directly target soleus
X1 Exoskeleton

Method

- Ten subjects (5 male)
- Fit with X1 powered ankle
- Custom testing chair
  ▫ Hip and knee at 90° flexion
- Concentric-Eccentric resistance exercise
- Left and right legs randomized and counterbalanced:
  ▫ 1:1 torque ratio
  ▫ 1:1.2 torque ratio
- 5 sets of 10 plantar flexions per leg
X1 Exoskeleton

Method

- fMRI scans of both calves
  - Pre-exercise
  - Immediately (< 3 min) post-exercise
- Analyze scans to evaluate
  - Muscle CSA (cm$^2$)
  - Individual muscle activation (T2 signal intensity)
Results

- Repeated Measures ANOVA on CSA and T2
- Resistance Exercise (both 1:1 and 1:1.2) increased:
  - CSA
    - Soleus (21.1 to 22.0 cm², $p = 0.003$)
  - T2 signal intensity
    - Soleus (6.6%, $p < 0.001$)
    - Medial Gastroc. (3.7%, $p = 0.006$)
    - Whole Calf (4.1%, <0.001)
- Eccentric overload did not enhance activation pattern
Discussion

- Resistive exercise in the X1 ankle significantly targeted the soleus
- Eccentric overload did not enhance the activation pattern
- Support further development of the X1 as a countermeasure for soleus degradation during missions
Background

- **Purpose:** Assess effect of exercise on Intermuscular Adipose Tissue (IMAT) volume

- **Problem:**
  - IMAT significantly increased after 4w of reduced activity* 
  - This could promote contractile dysfunction, leading to strength loss

- **Proposal:** Evaluate changes in IMAT volume throughout 70d Bed Rest (exercise, control)

*Manini et al. 2007
CFT70 Bed Rest

Method

- Exercise protocol
  - 6d/week
  - Aerobic (treadmill, cycle) and resistance (weights)
- fMRI scans of left leg (thigh and calf)
- 3 scans during 70d Bed Rest
  - Pre (BR-6), Mid (BR36), and End(BR69)
- Medical Image Processing, Analysis and Visualization (MIPAV) program used to quantify IMAT, total muscle, and subcutaneous adipose tissue volume
Results

- TBD
Discussion

- TBD
Background

• Purpose: Evaluate the XSENS ForceShoe™ as a potential portable load sensing device

• Problem:
  ▫ ARED force plates:
    ▫ Offline
    ▫ Flex

• Proposal: Utilize ForceShoe™ for:
  ▫ Ops: Monitor loads during ARED exercise
  ▫ Research: Monitor daily loads, collect tri-axial forces, derive CoP
  ▫ ARED Kinematics

How Robots, Beds, and Sandals Are Helping Keep Astronauts Healthy in Space

XSENS ForceShoe™

Image: XSENS

How Robots, Beds, and Sandals Are Helping Keep Astronauts Healthy in Space
Methods

- HILT Test – Assess load sensing accuracy
  - 5 subjects (2 male), 5 trials (4 static, 1 dynamic)
  - Wearing ForceShoe™, standing on force plate
  - Determined the % absolute difference in load values
Methods cont.

- **Wired vs Wireless – Assess difference in data quality**
  - 3 trials (unloaded, body weight, dynamic) per mode
  - Looked for significant difference in signal noise
Methods cont.

- ARED Motion Capture – Assess CoP accuracy
  - 1 subject, 2 trials
  - Inverse kinematics vs ForceShoe™ calculation
XSENS ForceShoe™

Results

- HILT – TBD...
- Wires – No significant difference in data quality
- ARED – TBD...
Next Steps

- Kinematic analysis with ARED MoCap data
  - Compare Kistler force plate vs ForceShoe™ GRF used in joint torque calculations
- Software
  - Run LabVIEW executable on SSC with ISS Software load
  - Attempt to use SSC Bluetooth radio to communicate with XBus Master
Acknowledgements

Mentors
• Kyle Hackney, PhD
• Andrea Hanson, PhD

ExPC Lab
• Roxanne Buxton
• Erin Caldwell
• John Dewitt, PhD
• Kirk English, PhD
• Emma Hwang, PhD

NSBRI
• Amanda Hackler, EdD
• Ron McNeel, DrPH

• Linda Loerch
• Nate Newby
• Brian Peters, PhD
• Lori Ploutz-Snyder, PhD
• Jessica Scott, PhD
• Noel Skinner

NASA
• Judy Hayes
• SLSSI Team

This work is partially funded by National Space Biomedical Research Institute via NASA cooperative Agreement NCC 9-58