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


Image: Robert Markowitz


Image: USRA

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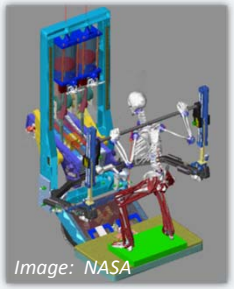
Exercise Physiology and Countermeasures Lab


Image: XSENS

Introduction

Image: UM



NEUROLAB?!

NASA JSC
Exercise Physiology & Countermeasures

Image: NASA

- 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

Image: NASA

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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

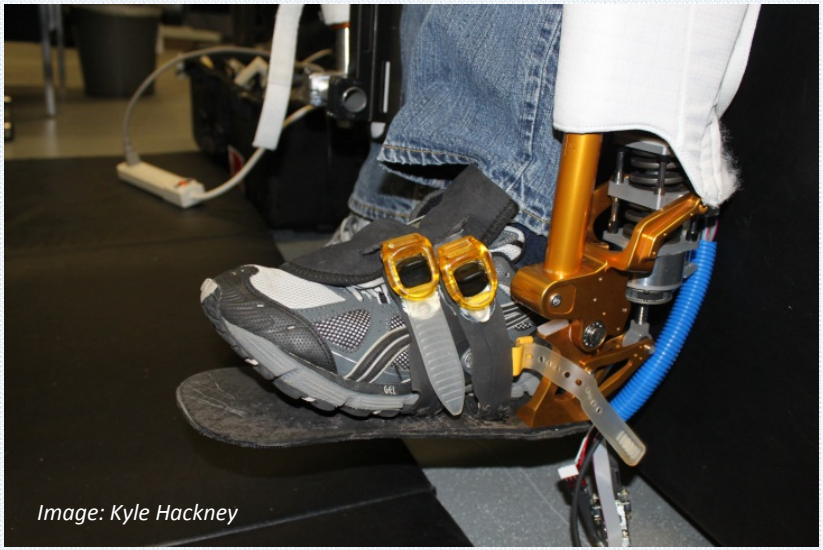

Image: Kyle Hackney

Video: Kyle Hackney

Image: NASA

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)

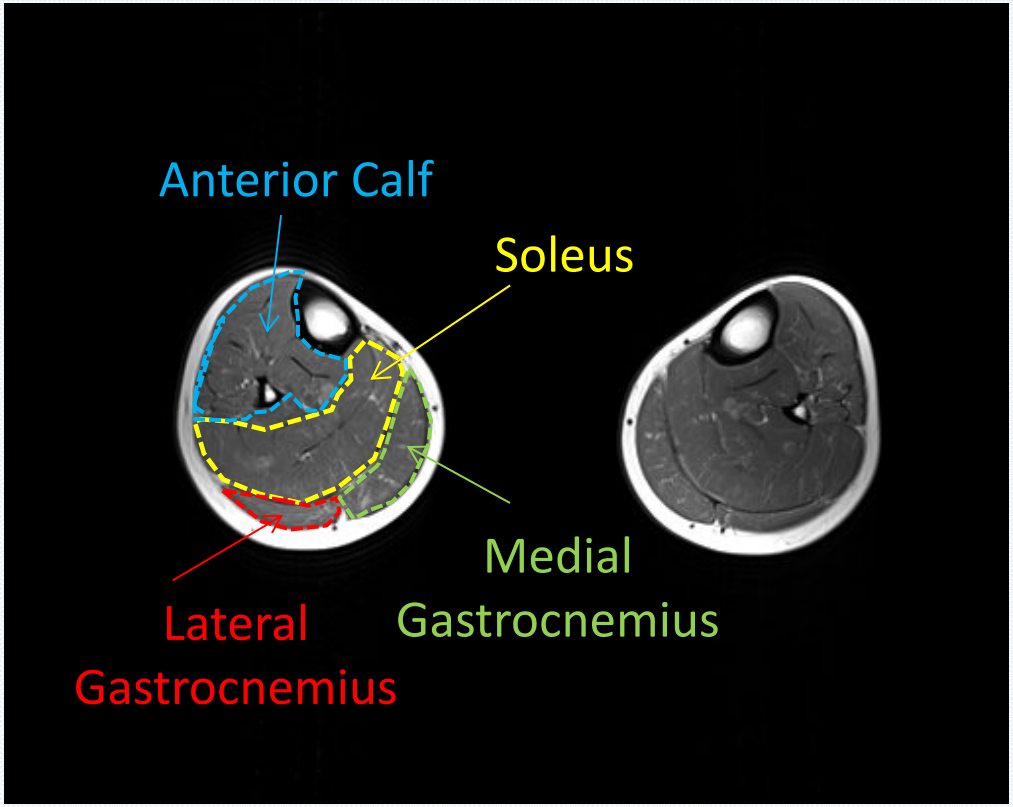

Image: NASA

X1 Exoskeleton

Results

- Repeated Measures ANOVA on CSA and T2
- Resistance Exercsie (both 1:1 and 1:1.2) increased:
  - CSA
    - Soleus (21.1 to 22.0 cm^2, 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

Image: NASA

X1 Exoskeleton

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

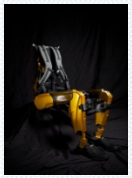

Image: NASA

CFT70 Bed Rest

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

Image: USRA

Image: NASA

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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

Image: NASA

CFT70 Bed Rest

Results

- TBD

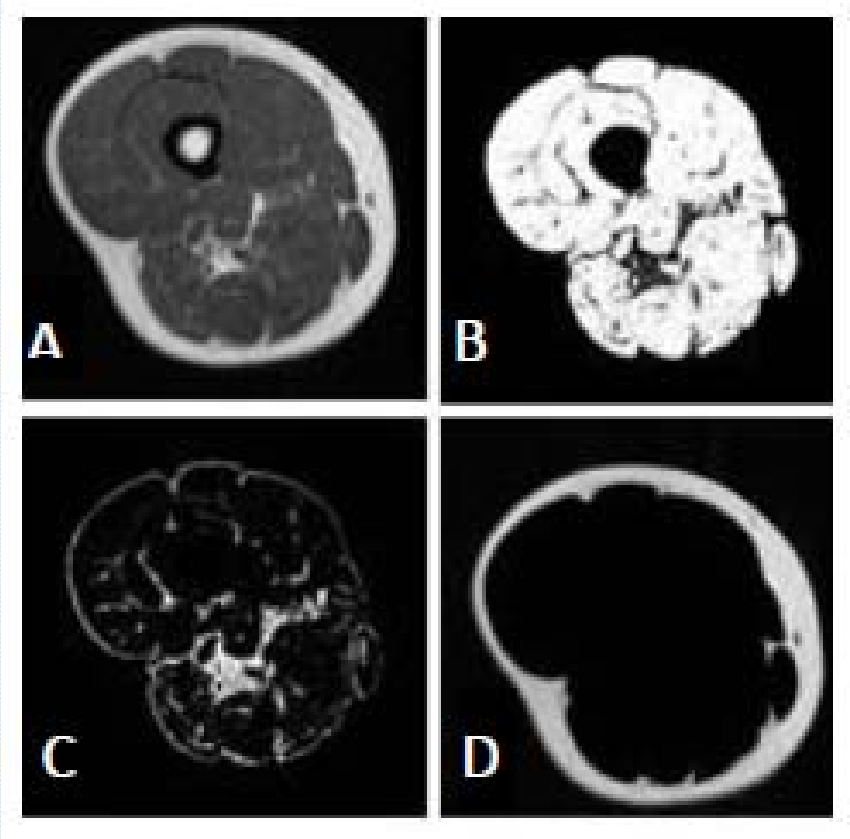

Image: NASA

CFT70 Bed Rest

Discussion

- TBD

Image: NASA

XSENS ForceShoe™

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

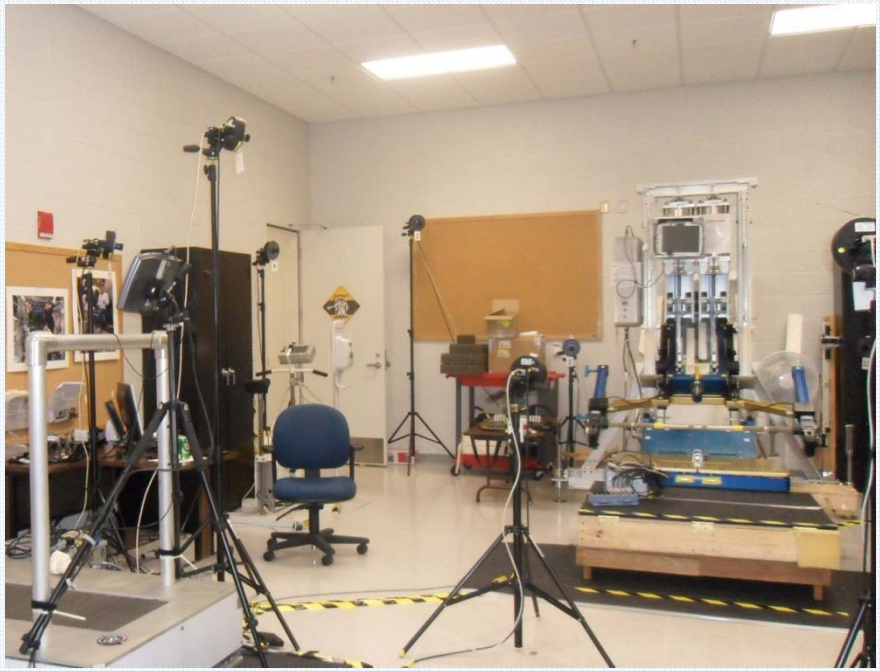

Image: XSENS

XSENS ForceShoe™

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

Image: XSENS

XSENS ForceShoe™

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

Image: XSENS

XSENS ForceShoe™

Methods cont.

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

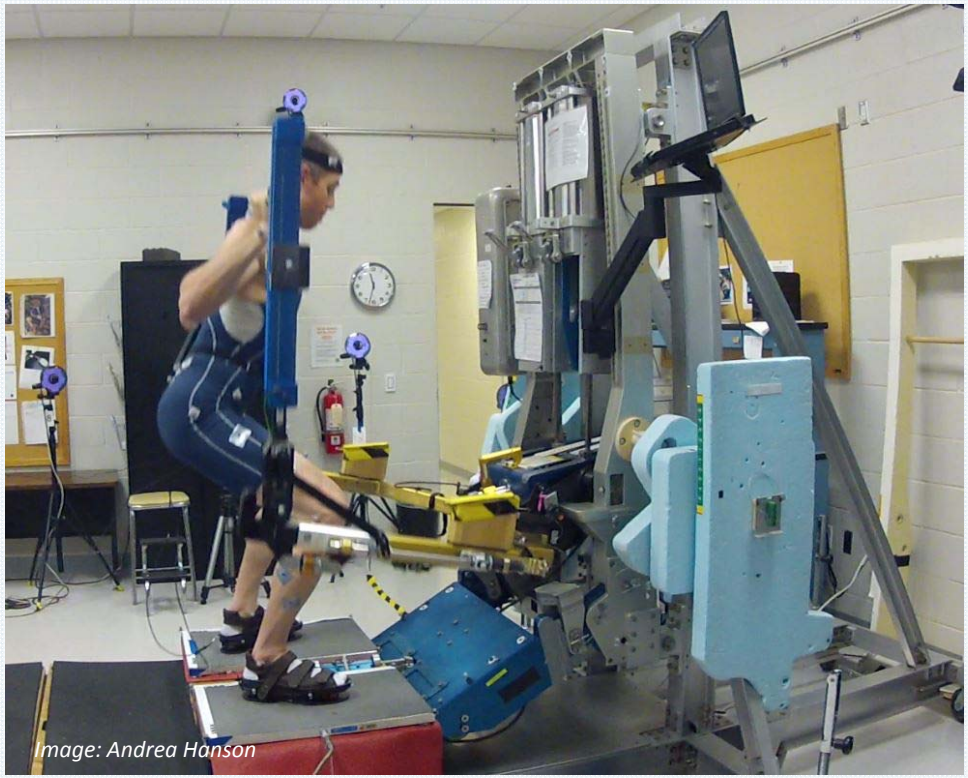
Image: Andrea Hanson

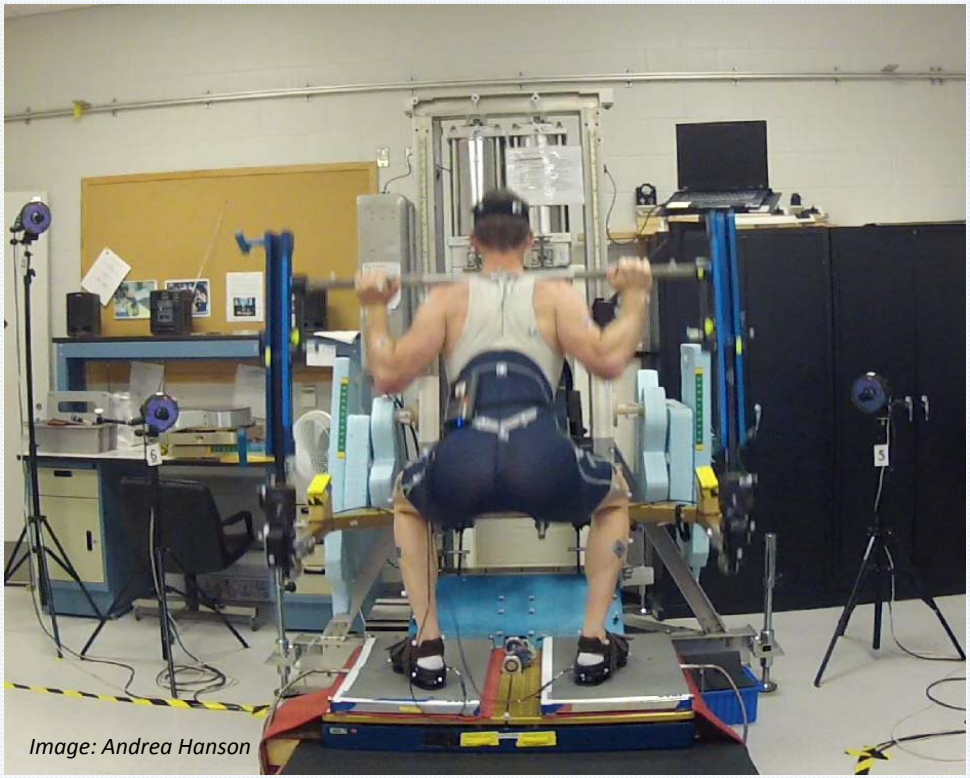
Image: Andrea Hanson


Image: XSENS

XSENS ForceShoe™

Results

- HILT – TBD…
- Wires – No significant difference in data quality
- ARED – TBD…

Image: XSENS

XSENS ForceShoe™

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

Image: XSENS

Acknowledgements

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