Exoskeleton Feedback System for Combatting Muscular Atrophy in Space

By Christopher Forsyth and Emily Gable

Muscular Atrophy

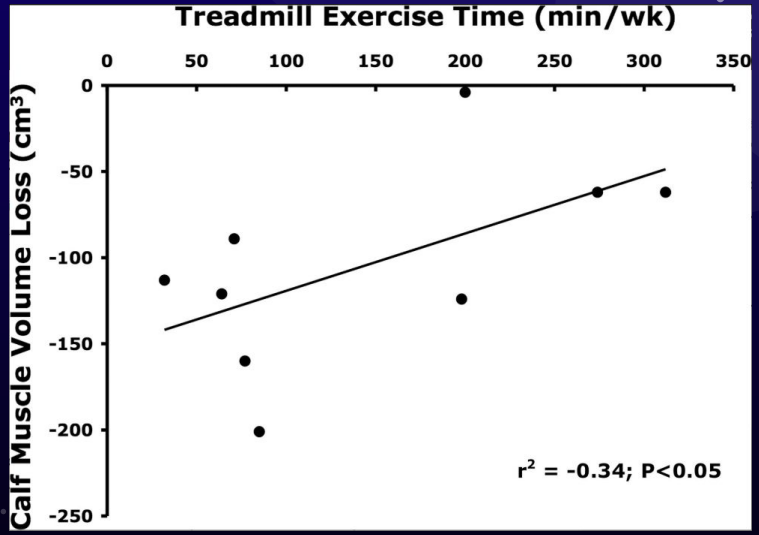
- Muscular Atrophy is the loss of muscle mass due to **inactivity of the muscle**
- When the muscle isn't used enough, protein synthesis stops and **protein degradation** takes place
- Astronauts who spend extensive time in space will often develop muscular atrophy due to the absence of gravity.

20%

Of total muscle mass is lost in space flights that last longer than 11 days (NASA)

Need for Space Exercise

- On Earth, we are constantly utilizing our muscles especially our antigravity muscles (calves, quads and the muscles in the neck)
- In order to keep up their strength, astronauts must spend at least **2.5 hours a day** utilizing countermeasures on the International Space Station (ISS)
- Despite this, **significant muscle atrophy still occurs**



Trappe et.al

Existing Countermeasures

Treadmill with Vibration Isolation and Stabilization (TVIS)

Cycle Ergometer (CEVIS)

Advanced Resistive Exercise Device (ARED)

Previous Investigations - X1 Design

- Exoskeleton designed by NASA for resistive and assistive functions
  - Designed to replace/supplement existing exercise devices.
- Four DOF's modulated by Reaction Force-sensing Series Elastic Actuators (RFSEAs).
  - These actuators are able to supply and resist torques
- Lightweight and can be worn during everyday activities
- Joint data is streamed back to Earth, giving physicians the ability to quantitatively assess effectiveness.

Previous Investigations - Exoskeleton Muscle Performance Monitoring

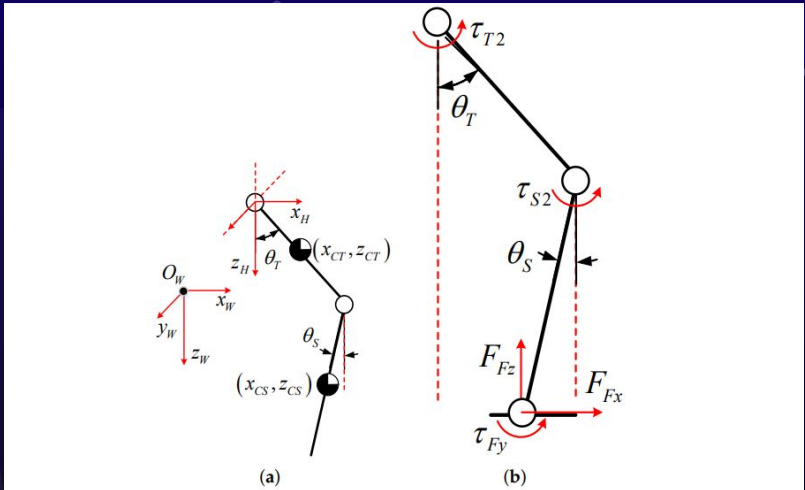


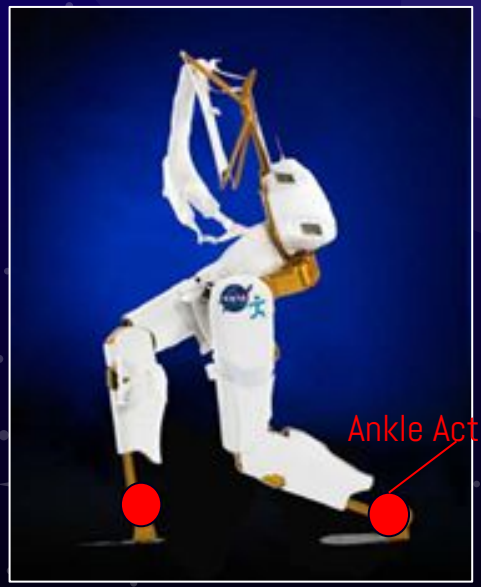
Figure 2. Dynamic model of a single leg. **(a)** Model for calculating mass-induced torques. **(b)** Model for calculating foot contact force (FCF)-induced torques.

Li, et al.

- ★ Utilizes torque sensors and to determine individual muscles forces
- ★ Inverse dynamics combines all data and tracks muscle movement and forces [Li et al.]

Proposed Research - Hypothesis

- Modification of X1 exoskeleton to include ankle actuator (mod-X1) and incorporation of mod-X1 with ISS Treadmill, creating lower-limb muscle training feedback loop, will assist in decreasing muscle atrophy better than existing countermeasures alone.



mod-X1 + Treadmill Feedback System

Application/Reduction of Resistive Torques

Mod-X1 Joint torque sensors

+

Treadmill Force Plates

Muscle-Joint Inverse Dynamics [Li et al.]

Muscular Skeletal Geometry

Individual Muscle Performance Protocol

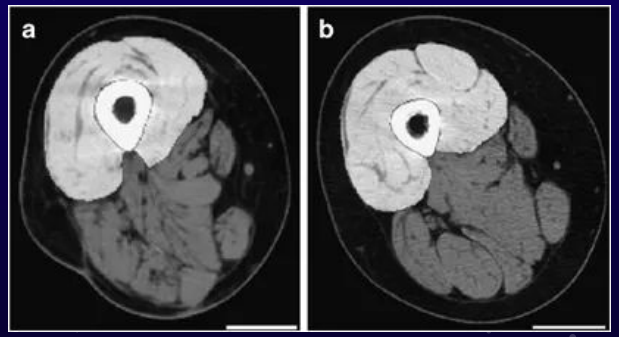
Application/Reduction of Horizontal Resistance from Treadmill Load Bands

Proposed Research - Methods

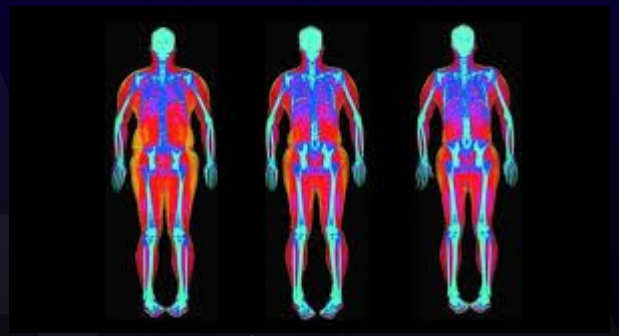
- On-Earth Study
  - 5 participants of average astronaut build
  - Confirm inverse dynamics with Zero-G Simulation using Supine Suspension Approach (ZG-SSA) and Motion Capture

Proposed Research - Methods

Muscle Atrophy MRI



DEXA bone-density scan



- 60-day bed rest study
  - Measure feedback system's ability to prevent loss of muscle mass
  - 12 subjects - 5 using mod-X1 system on ZG-SSA, 5 using existing countermeasures on ZG-SSA, 2 no exercise (control)
  - Weekly MRI imaging, bone density scans, & biopsy protein analysis - track muscle atrophy

Clinical Applications

- Physical Therapy and Rehabilitation
  - Use mod-X1 feedback system to measure muscle performance
  - Anti-Gravity Suspension system adjusted on-the-fly to achieve optimal muscle forces for rehabilitation

Future Implications

- We hope to utilize the mod-X1 in the ISS to help astronauts combat muscular atrophy while in space
- By using the real-time feedback loop and automatic adjustment system we hope to further reduce the effects of muscular atrophy and loss of muscle mass

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ANY QUESTIONS?