Exoskeleton Feedback System for Combatting Muscular Atrophy in Space

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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.
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

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

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

Mod-X1 Joint torque sensors + Treadmill Force Plates

Muscle-Joint Inverse Dynamics [Li et al.]
Muscular Skeletal Geometry

Application/Reduction of Resistive Torques
Application/Reduction of Horizontal Resistance from Treadmill Load Bands

Individual Muscle Performance Protocol
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

- 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?