BIOMECHANICAL MODELING OF THE DEADLIFT EXERCISE ON THE HULK DEVICE TO IMPROVE THE EFFICACY OF RESISTIVE EXERCISE MICROGRAVITY COUNTERMEASURES

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INTRODUCTION & MOTIVATION

- Extended spaceflight typically results in the loss of muscular strength and bone density due to exposure to microgravity.
- BTS Bioengineering Smart
- Characteristics of the deadlift exercise in microgravity: What exercise parameters are necessary to maintain skeletal health, and can exercise hardware be designed to provide these?
- What is the minimum exercise regimen needed to maintain fitness levels for tasks?
- Ultimately providing timely input to mission architecture and operations decisions in areas where clinical data are lacking.

PROJECT VISION

NASA's Digital Astronaut Project Vision
The Digital Astronaut Project (DAP) implements well-vetted computational models to predict and assess spaceflight health and performance risks and to enhance countermeasure development by
- Partnering with subject matter experts to inform Human Research Program (HRP) knowledge gaps and countermeasure development decisions
- Modeling and simulating the adverse physiological responses to reduced gravity and analog environments

RISKS & GAPS

Human Research Program Risks/Gaps Addressed
Risks:
- The Risk of Impaired Performance Due to Reduced Muscle Mass, Strength, and Endurance
- The Risk of Bone Fracture
- The Risk of Early Onset Osteoporosis Due To Spaceflight

Gaps:
- What exercise protocols are necessary to maintain skeletal health, and can exercise hardware be designed to provide these?
- What is the minimum exercise regimen needed to maintain fitness levels for tasks?
- What is the minimum set of exercise hardware needed to maintain those fitness levels?

MOTION CAPTURE

- BTS Bioengineering Smart-D
- 12-camera motion capture system used
- Recorded data are digitized to translate physical data into biomechanical model in OpenSim®

EXERCISE HARDWARE

Hybrid Ultimate Lifting Kit (HULK)3
- Compressed air and piston assembly provides direct resistance
- Servo motor provides an eccentric overload
- Load cells in cables for load history
- Offers a wide variety of resistance exercises

MODELING METHODS

OpenSim Biomechanical Deadlift Model
- Human Data: 2 human subjects performed 26 deadlift trials; load, load configuration, cadence and stance were varied across trials
- Deadlift model consists of modified versions of existing lower extremity4 and upper extremity5 OpenSim models
- Deadlift model is scaled to the test subjects
- Model is based on subject's anthropometrics and motion capture data while in static pose and exercising
- HULK resistance load applied to model as a force at the bar ends
- Ground reaction force from force plates applied to model at the feet

DISCUSSION

- Inverse kinematics compiled for subset of deadlift trials; joint angle analysis reveals similarities and differences between experimental conditions to inform exercise prescriptions.
- EMG can be used to compare muscle activity for different exercise parameters; these results can yield non-obvious conclusions about how exercise design affects the activity of specific muscles.
- The 16 recorded muscles are each affected differently by varying loading conditions; employ this knowledge to assist in designing exercise prescriptions to achieve effective activity for a wide range of muscles.

VERIFICATION & VALIDATION

- Ensure that root mean square (RMS) marker positions are within OpenSim® guidelines
- Joint errors are within 2 degrees of experimental values
- Employ NASA-STD-7009 standards to assess credibility
- Compare deadlift modeling results with ground-based 1g deadlift exercise studies published in the literature

CHALLENGES & LIMITATIONS

- Investigate consistency of EMG data over different data collection sessions
- Include more human subjects for a more representative and general data set
- Collect additional trials to achieve more confidence in results

FUTURE WORK

- Further develop deadlift model to include shoulder stability
- Investigate developing deadlift model to improve efficiency
- Continue performing inverse kinematics (IK) analyses
- Determine dynamic properties of the deadlift using inverse dynamics (ID) analysis
- Perform static optimization (SO) to determine net forces of muscle groups

REFERENCES


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HULK DEADLIFT EXERCISE RESULTS

Kinematics Results: Joint Angles for Differing Deadlift Cadences

EMG Results: Effect of Deadlift Parameters on Upper Back Muscle Activity

EMG Results: Effect of Loading Condition

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