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

K.M. Jagodnik1,2, W.K. Thompson1, C.A. Gallo1, L. Crettsi3, J.H. Funk4, N.W. Funk4, G.P. Perusek1, C.C. Sheehan4, B.E. Lewandowski1
1NASA Glenn Research Center, 21000 Brookpark Rd., Cleveland, OH 44135
2Baylor College of Medicine, 1 Baylor Plaza, Houston, TX 77030
3Georgia Southern University, 21211 St. NW, Washington, DC 20052
4ZIN Technologies, 6745 Engle Road, Airport Executive Park, Cleveland, OH 44130

INTRODUCTION & MOTIVATION

- Extended spaceflight typically results in the loss of muscular strength and bone density due to exposure to microgravity.
- Resistive exercise countermeasures have been developed to maintain musculoskeletal health during spaceflight.
- The Advanced Resistive Exercise Device (ARED) is the “gold standard” of available devices; however, its footprint and volume are too large for use in space capsules employed in exploration missions.
- The Hybrid Ultimate Lifting Kit (HULK) device, with its smaller footprint, is a prototype exercise device for exploration missions.
- This work models the deadlift exercise being performed on the HULK device using biomechanical simulation, with the long-term goal to improve and optimize astronauts’ exercise prescriptions, to maximize the benefit of exercise while minimizing time and effort invested.

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 exposed to reduced gravity and analog environments
- Ultimately providing timely input to mission architecture and operations decisions in areas where clinical data are lacking

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 Spacelift
- 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?

ON-PAGE FIGURE:

HULK DEADLIFT EXERCISE RESULTS

Kinematics Results: Joint Angles for Differing Deadlift Cadences

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

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 10 recorded muscles are each affected differently by varying load 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

3. High-Gravity Resistive Overload Device, Concept of Operations, ZIN Technologies, Cleveland, OH.

PARTNERS

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EXERCISE HARDWARE

Hybrid Ultimate Lifting Kit (HULK)3

OpenSim Biomechanical Deadlift Model

- Linear Ultimate Lifting Kit, with its smaller footprint, is a prototype exercise device for exploration missions.
- This work models the deadlift exercise being performed on the HULK device using biomechanical simulation, with the long-term goal to improve and optimize astronauts’ exercise prescriptions, to maximize the benefit of exercise while minimizing time and effort invested.

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