# 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.
- Resistive exercise countermeasures have been developed to maintain musculoskeletal health during spaceflight.
- The Advanced Resistive Exercise Device (ARED)[1] 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 physiologic responses to exposure 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

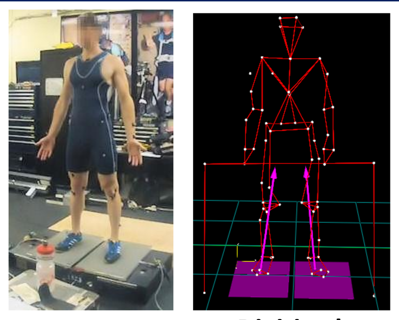
### Human Research Program Risks/Gaps Addressed

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 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?

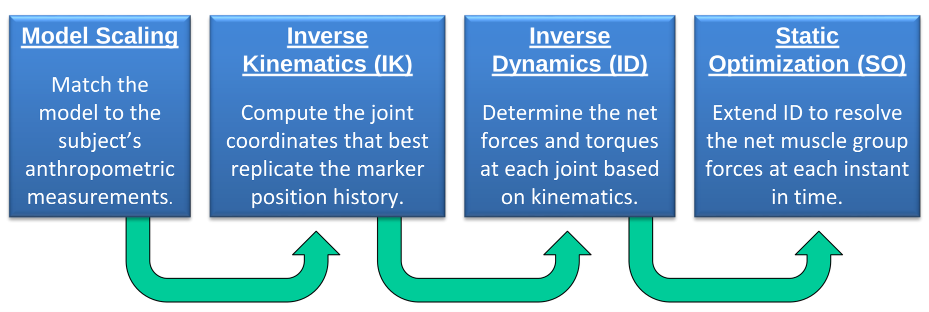
## MOTION CAPTURE

- BTS Bioengineering Smart-D 12-camera motion capture system used
- Recorded data are digitized to translate physical data into biomechanical model in OpenSim[2]



Motion Capture and Force Plates — Digitized Movement

## OPENSIM MODEL WORKFLOW




## EXERCISE HARDWARE

### Hybrid Ultimate Lifting Kit (HULK)[3]

(ZIN Technologies)

- 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

HULK Deadlift Exercise

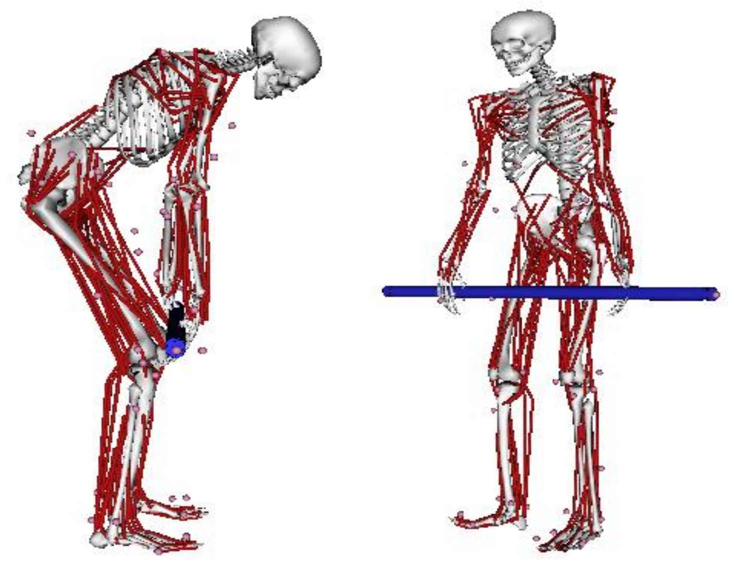
## EMG

- BTS Free EMG System: 16 wireless sensors placed according to http://seniam.org & Thought Technology Ltd. surface EMG placement guide
- DC component removal, rectify and envelop signal with RMS calculation
- Signals normalized to MVC

## MODELING METHODS

### OpenSim Biomechanical Deadlift Model

- Human Data: 2 human subjects performed 26 deadlift trials; load, load configuration, cadence and stance width were varied across trials
- Deadlift model consists of modified versions of existing lower extremity[4] and upper extremity[5] 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



OpenSim Model of Deadlift Exercise with HULK Bar Load

## ACKNOWLEDGMENTS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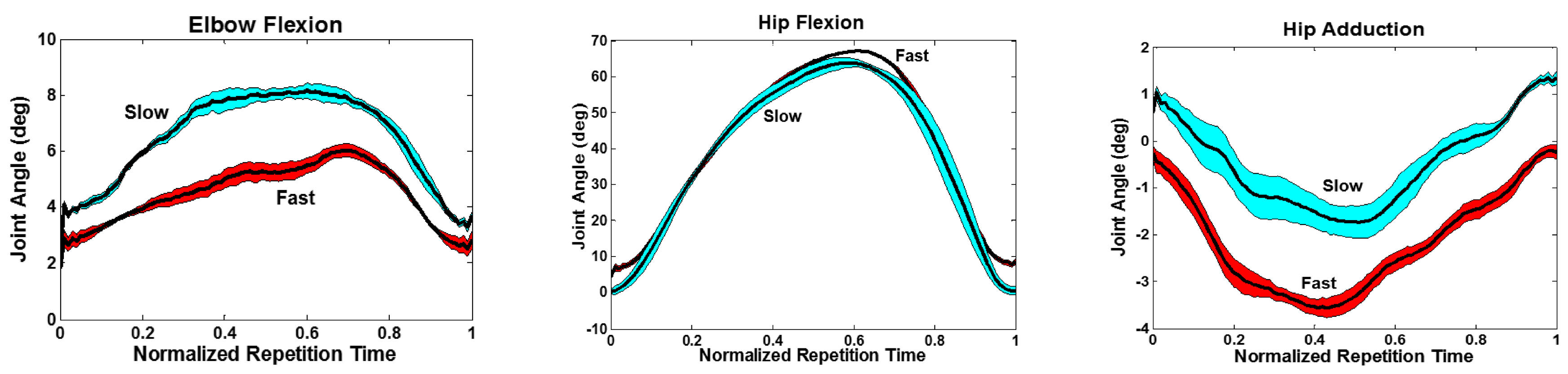
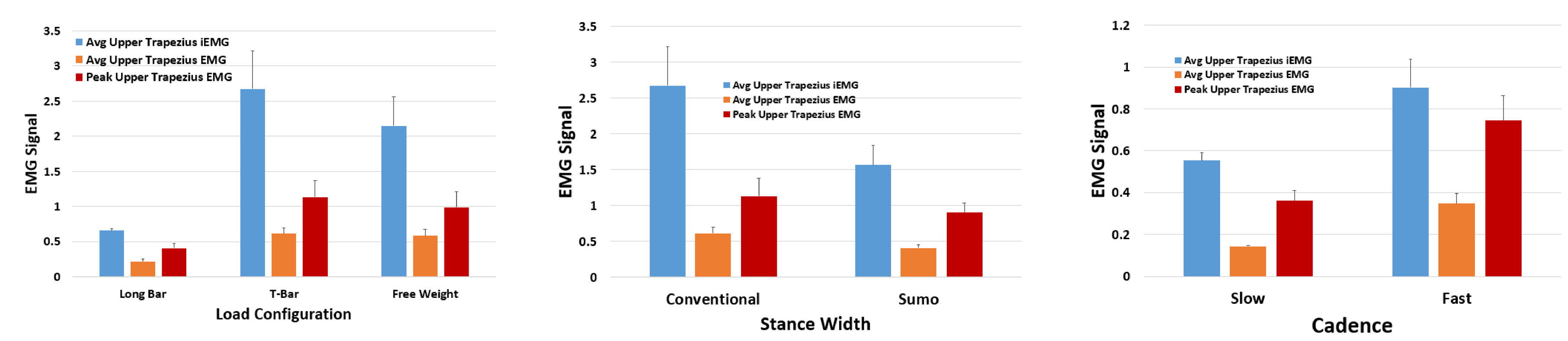
## HULK DEADLIFT EXERCISE RESULTS

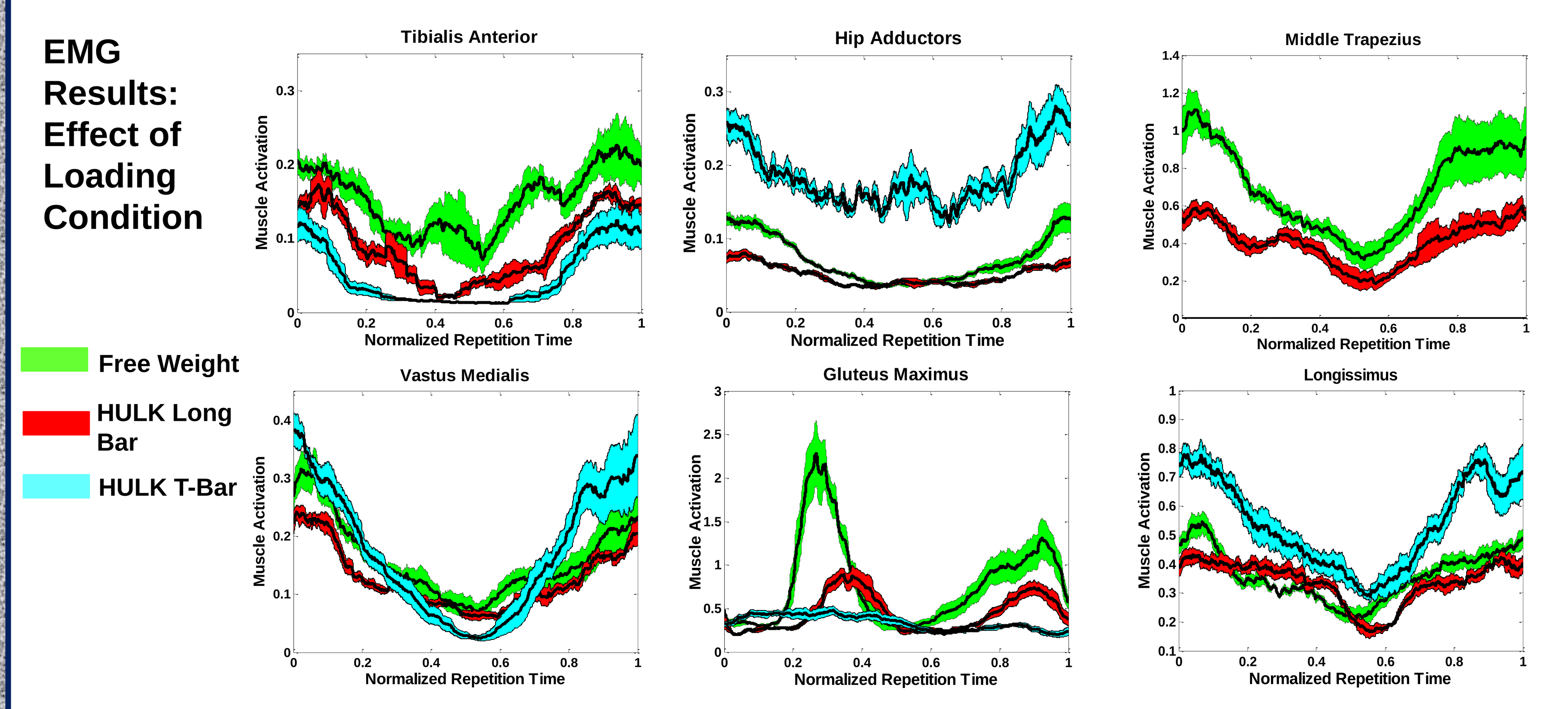
### Kinematics Results: Joint Angles for Differing Deadlift Cadences




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




### EMG Results: Effect of Loading Condition




## DISCUSSION

- Inverse kinematics completed 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[2] 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

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## PARTNERS