INFLUENCE OF LOAD PROFILE ON BIOMECHANICS OF THE SQUAT AND DEADLIFT

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INTRODUCTION

- Long duration space travel will expose astronauts to extended periods of reduced gravity
- Astronauts will use resistive and aerobic exercise regimes to minimize loss of bone density, muscle mass and aerobic capacity
- Astronauts will exercise on a flywheel based device on the second Orion Exploration Mission (EM2)
- The effect that a flywheel load profile has on biomechanics is unknown when compared to an actual or simulated free weight profile
- This evaluation will compare the differences in lower body kinematics and kinetics between the flywheel and free weight profile

OBJECTIVES

- Compare the effect of exercising using the strength training free weight profile to the inertial resistance flywheel profile
- Create biomechanical models to simulate the exercise motion to account for variables associated with exercising and to predict and assess spaceflight health and performance risks in reduced gravity and analog environments
- Present joint angles and moments for a known set of kinematics and loads for multiple test subjects
- Present results for squat exercising while wearing a harness and deadlift exercising while using a handheld T-bar

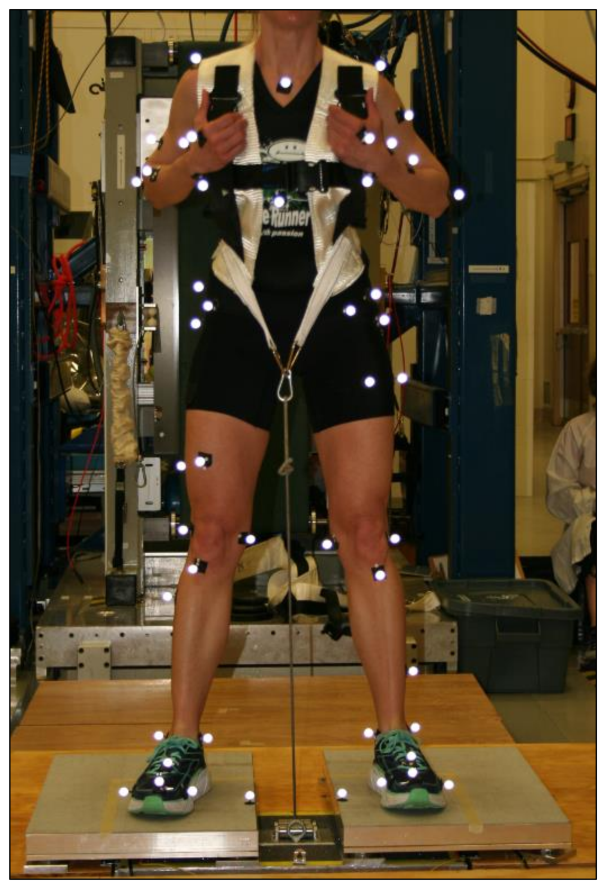
TEST SUBJECT DATA COLLECTION AND OPENSIM MODELING

- During the March-April, 2017 timeframe, four test subjects were instrumented with reflective markers for motion capture using the BTS Bioengineering (Brooklyn, NY) Smart-DX 12 camera system
- A base OpenSim model was scaled to each subject based on their anthropometrics and motion capture while in a static pose
- The OpenSim Full Body Model[2] was modified by adding two joints to the model along the spine and neck to compensate for bending of the torso while performing a squat or a deadlift
- Force balance methodology was used to optimize the harness and T-bar DART cable force vectors by reducing residuals
- Ground reaction force vectors (green arrows) are applied to the model at their load point

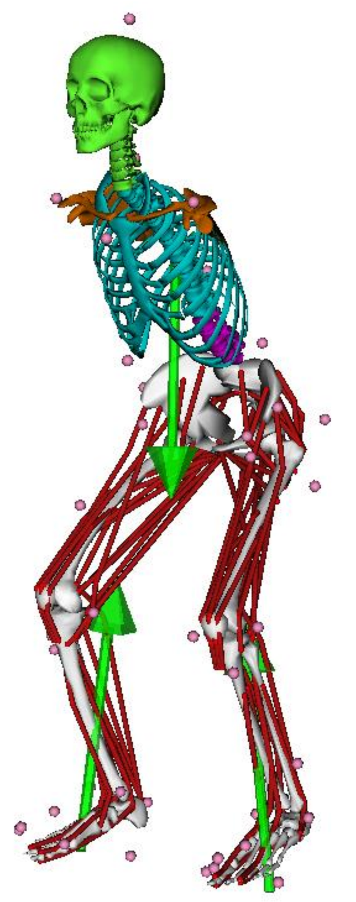
S01	Subject 01	95%	Male	113	kg	188	cm
S04	Subject 04	10%	Female	51	kg	164	cm
S05	Subject 05	50%	Male	86	kg	176	cm
S06	Subject 06	50%	Female	68	kg	170	cm

Model Scaling — Match the model to the subject's anthropometric measurements → **Inverse Kinematics (IK)** — Compute the joint coordinates that best replicate the marker position history → **Inverse Dynamics (ID)** — Determine the net forces and torques at each joint based on the kinematics

OpenSim Analysis Work Flow



Test Subject on Force Plates with Motion Capture Markers Performing a Harness Squat



OpenSim Model of Squat Exercise with DART Harness Load Applied

DART EXERCISE DEVICE HARDWARE

Device for Aerobic and Resistive Training (DART)

- Developed by TDA Research, Inc., Wheat Ridge, CO
- Computer controlled servomotor controls the cable tension
- Regenerative braking stores power generated in a capacitor
- A compression load cell measures the cable tension force
- Strength training profile simulates exercising with free weights
- Flywheel profile provides resistance using simulated inertia
- Outer dimensions: 24" length x 14" width x 8.5" height

VERIFICATION & VALIDATION

- Ensure root mean square (RMS) marker positions are within OpenSim[1] guidelines: <0.25 cm RMS, <0.5 max marker error
- Compare modeling results with reported measurements in the literature made under similar loading conditions
- Conform to NASA-STD-7009A standards to assess credibility[3]

ACKNOWLEDGEMENTS

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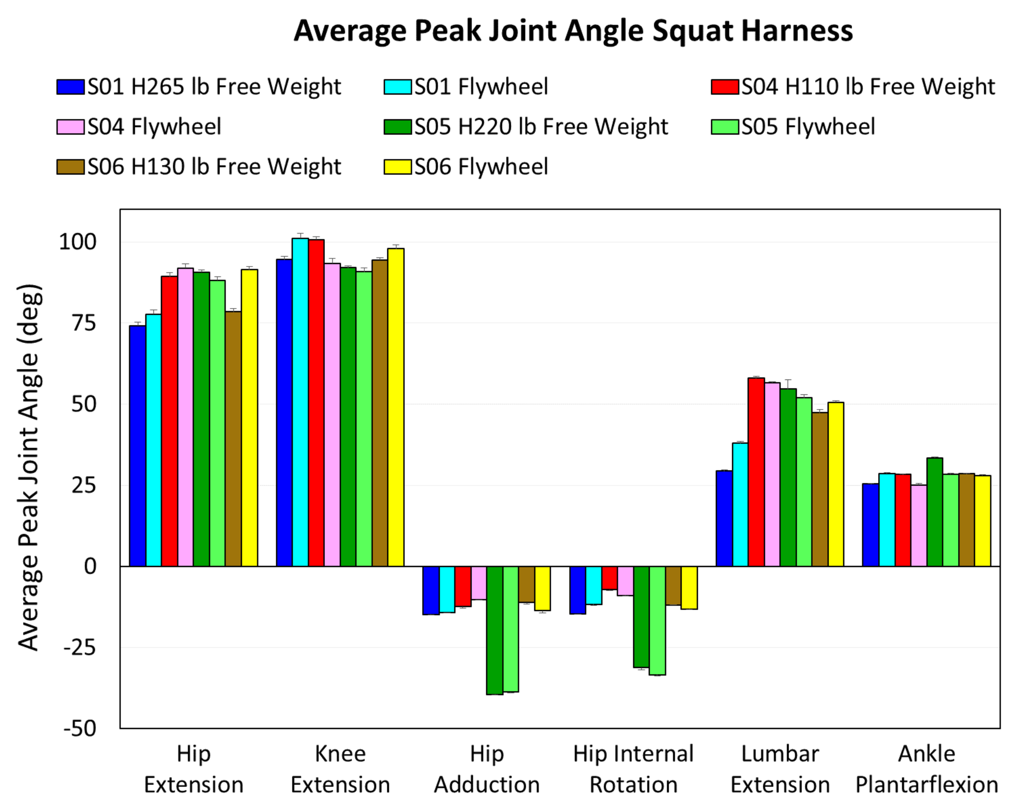
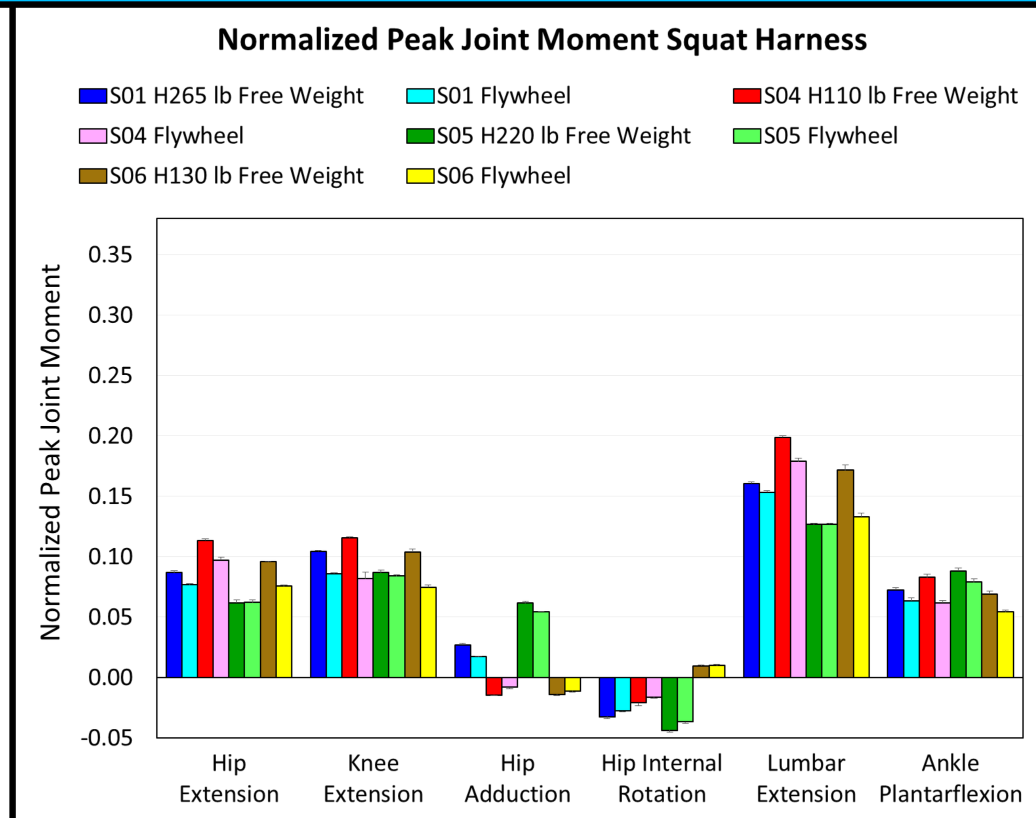
3. NASA-STD-7009A: Standard for Models and Simulations, 2016. NASA: Washington, DC.

RESULTS DISCUSSION

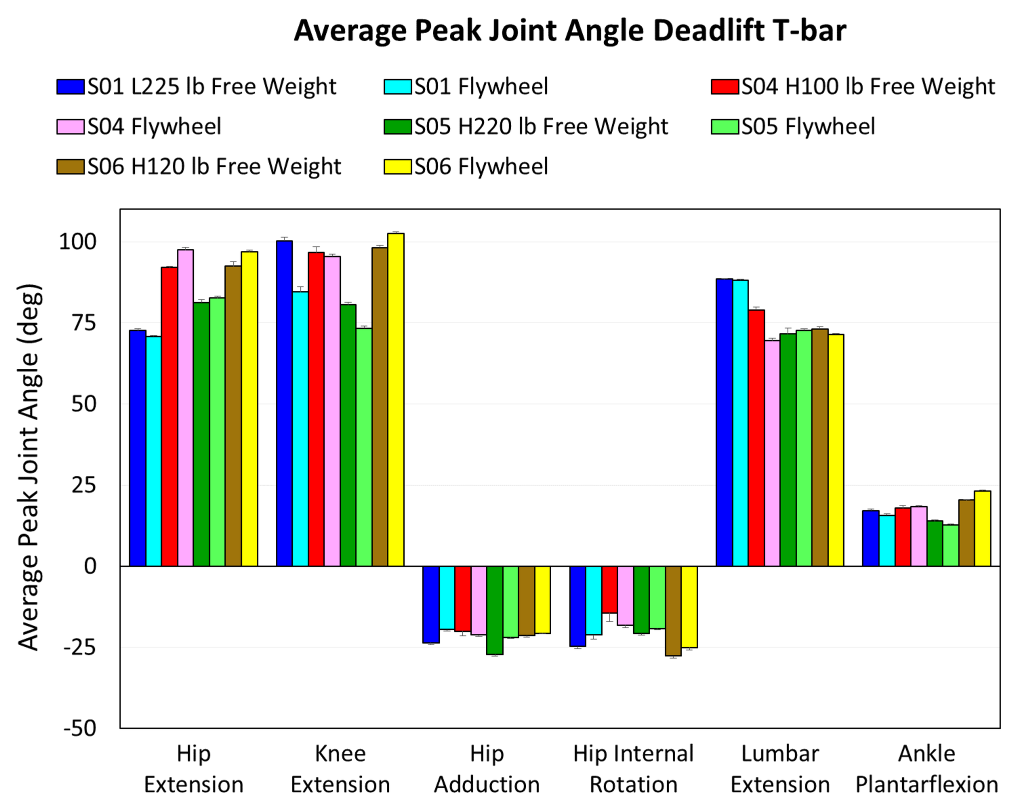
- Peak joint angle was greater at the hip during both the squat and deadlift for the flywheel profile rather than with the free weight profile
- Normalized peak joint moments were greater during squat with the free weight profile rather than with the flywheel profile for all subjects
- Normalized peak joint moment and joint angle were greater at the knee for deadlift with the free weight profile rather than with the flywheel
- Normalized peak joint moment was generally greater at all joints with the free weight profile for both squat and deadlift
- The normalized moments averaged over the four subjects were greater at the hip and lumbar for the deadlift flywheel profile and for the squat free weight profile
- The results displayed substantial variability between subjects

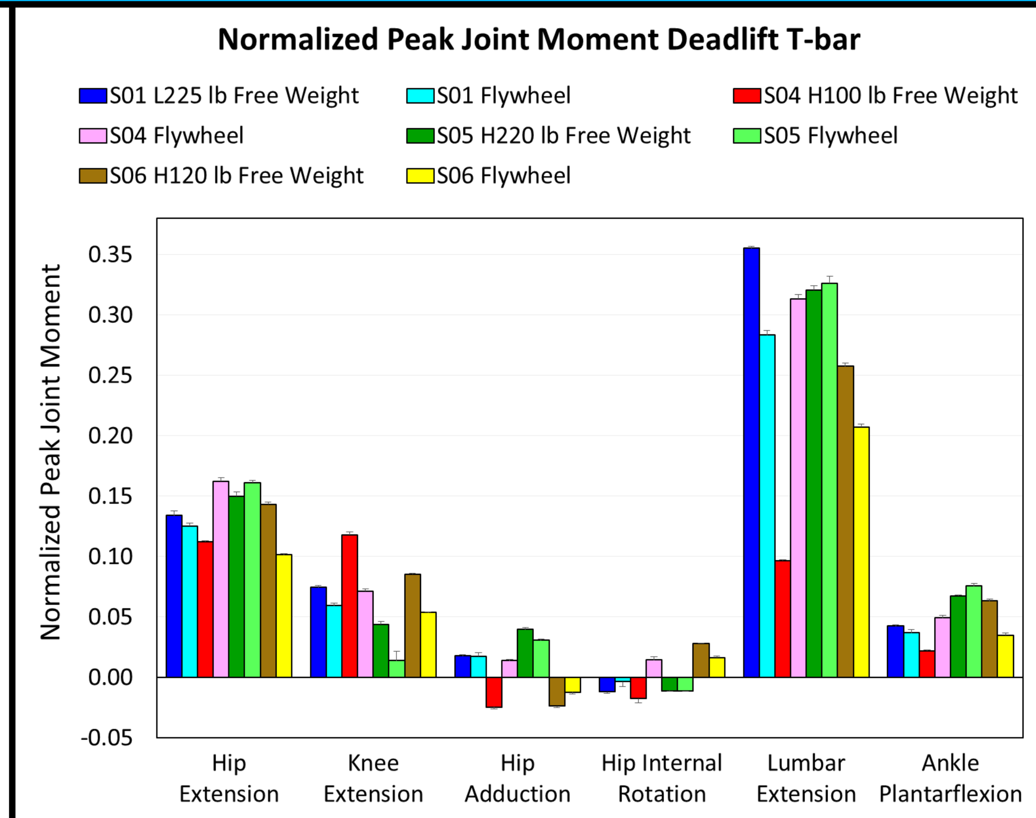
SQUAT RESULTS – FREE WEIGHT vs. FLYWHEEL EACH SUBJECT





DEADLIFT RESULTS – FREE WEIGHT vs. FLYWHEEL EACH SUBJECT





SQUAT & DEADLIFT FOUR SUBJECT AVERAGE – FW vs. FLYWHEEL