BACKGROUND

NASA’s Digital Astronaut Project (DAP) Vision

The Digital Astronaut Project implements well-vetted computational models to predict and assess spaceflight health and performance risks, and enhance countermeasure development, by:

- Partnering with subject matter experts to inform HRP knowledge gaps and countermeasure development decisions;
- Modeling and simulating the adverse physiologic responses to long duration spaceflight and analog environments; and
- Ultimately providing timely input to mission architecture and operations decisions in areas where clinical data are lacking.

HRP Risks/Gaps Addressed by This Effort

Risk of Muscle Atrophy: impaired performance due to reduced muscle mass, strength and endurance

- Gap M1: Can the current in-flight performance be maintained with reduced exercise volume?
- Gap M9: What is the minimum exercise regimen needed to maintain baseline levels for tasks?

Risk of Loss of Bone Mineral Density: early onset of osteopenia and bone fracture

- Quiz 7: Why need is there priority for mitigating early onset osteopenia before, during and after spaceflight? (formerly Gap R15)
- Quiz 8: How do skeletal changes due to spaceflight modify the terrestrial risk of osteoporotic fractures? (formerly Gap R7)

Verification: Is the model constructed correctly?

- Compare joint angles and displacements between the forward dynamics (driven by the trained module) and inverse dynamics (driven by MoCap data)
- Compare calculated forces, muscle tensions and joint torques with reported measurements in the literature under similar loading conditions.
- Conform to NASA-STD-7009 standards for assessing the credibility of computational models in all V&V activities.

METHODS: BIO-MECH., ARED & INTEGRATED MODELS

Biomechanical Models

- Derived from motion capture (MoCap) and ground reaction force (GRF) data acquired on the ARED ground unit using a MoCap exercise-experienced male subject
- Constructed a forward dynamics module in LifeMOD® (a plug-in to ADAMS®) using the performance of a 1-repetition maximum exercise
- Joint-only and joint/muscle configurations

ARED Device Module

- ARED is a resistance-training exercise device for the crew of the International Space Station (ISS)
- Rigid Body Dynamics module developed using Pro-E solid model files, engineering specifications, and engineering hardware verification data
- Constructed in MSC Adams

RESULTS: MUSCLE AND JOINT-ONLY MODULES

Verification: Is the model constructed correctly?

- Compare model-predicted GRF data with measured GRF

Results of V&V of ASM-im in 1g per NASA-STD-7009


discussion: accomplishments and findings

Accomplishments to date

- Completed integrated modules for the 1g squat exercise in both joint-only (ASM-i) and muscle/joint (ASM-im) configurations.
- Validated kinematics, joint forces/torques, muscle lengths and GRF
- Validated model kinematics, dynamics and GRF’s versus literature on the squat exercise
- Performed preliminary sensitivity analysis to quantify effects of perturbations to model parameters
- NASA-STD-7009 credibility assessed for 1g, estimated for 0g

Major Findings

- Kinematic agreement is better during the ascent/descent phases than at the start/finish of the movement
- Joint forces are more accurately reproduced in the ASM-im model than the ASM-i
- Relative muscle tensions among muscles mimic the activation patterns reported in the literature.
- The 0g kinematics cannot be predicted by simply ignoring gravity and activating the V&V on the ARED.

FUTURE WORK

- DAP Bone Adaptation Model
  - Provide exercise-induced loading inputs
  - Key skeletal sites: hip, spine and femoral neck
- DAP Muscle Adaptation Model®
  - Change LifeMOD muscle parameters to reflect adaptations to spaceflight
  - Quantity effects of changes to cross-sectional area, maximum isometric force and permutation of individual muscles on overall performance

ACKNOWLEDGEMENTS

This work is funded by the NASA Human Research Program, managed by the NASA Johnson Space Center. Specifically, this work is part of the Digital Astronaut Project (DAP), which directly supports the Human Health and Countermeasures (HHC) Element. The DAP project is managed out of NASA/Glenn Research Center (GRC) by DebW. Griffen, Ph.D., and Lealem Mulugeta of USRA Houston serves as the DAP Project Scientist.

REFERENCES


PARTNERS


CONTACT

http://www.nasa.gov/medSci

NATIONAL AERONAUTICS And Space Administration

WASHINGTON, DC

www.nasa.gov