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 repeatedly transitioning from low- and analog environments;
- Ultimately providing timely input to mission architecture and operations decisions in areas where clinical data are lacking.

VERIFICATION AND VALIDATION (V&V)

- Computed calculated joint angles, torque and forces with reported data
- 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

RESULTS: MUSCLE AND JOINT-ONLY MODULES

- Ground Reaction Forces (GRF) - Verification
- Compare model-predicted GRF’s with measured GRF

DISCUSSION: ACCOMPLISHMENTS AND FINDINGS

- Kinematic agreement is better during the ascent/descent phases than at the start/end of the movement
- Joint forces are more accurately reproduced in the ASM model than the DAP
- Relative muscle tensions among muscle mimics the activation patterns reported in the literature
- The 0g kinematics cannot be predicted by simply ignoring gravity and activating the VIS 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 isotonic force and recruitment of individual muscles

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REFERENCES


CONCLUSIONS

- Accurate predictions of joint angles, torques and forces in both static and dynamic conditions
- Improved muscle and joint model performance and fidelity increases with additional anatomical information
- Joint and muscle training models can inform the DAP muscle adaptation framework

FACILITIES

- LifeMOD: Indeterminate 3D dynamic analysis
- Pro-E solid models, engineering specifications, and engineering hardware verification data.
- Constructed in Msc-Adams™

METHODS: IMPLEMENTATION DETAILS

- Integration in LifeMOD
- Prior to model merge operation
  - Preset ARED exercise bar to barbell configuration
  - Align reference frames of ARED and body in virtual environment
  - Balancing of GRF’s (vs. measured GRF data) hierarchically propagates results of the modules
  - Visual inspection of model posture using Pro-E solid model files, engineering specifications, and engineering hardware verification data.
- Modeling of Contacts Between Biomechanical Module and ARED
- Adjusted parameters
  - Servo joints
  - Proportional gain
  - Derivative gain
  - Passive joints
  - Translational Stiffness/Damping
  - Rotational Stiffness/Damping
  - Muscles
  - Stiffness
  - Damping
  - Phys. Cross Sectional Area
  - Ground reaction force (GRF)
  - FID plane
  - Inertial geometry
- Joint and Muscle Training
  - Motion tracker agent
  - Residual forces applied at pelvis in transverse directions to keep the model stable during the exercise
  - Adjustable rotational and translational stiffnesses
  - GRF data and joint angle errors iteratively verify the forward dynamic simulations
  - With ARED
  - Without ARED – compare to existing biomechanical models
  - Adjust gain and stiffness/damping until model is verified

METHODS: BIO-MECH., AREDS & INTEGRATED MODULES

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

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