Sensitivity Analysis of Biomechanical Models for NASA's Digital Astronaut Project

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Musculoskeletal deconditioning is a side effect of human inhabitance in a microgravity environment and a major obstacle to long-term space travel. The Digital Astronaut Project (DAP) aims to evaluate exercise countermeasure devices intended for future exploration missions on their ability to provide sufficient loading stimuli and maintenance of astronaut fitness. Using open-source biomechanics software, DAP members have created computer models of exercises conducted on a prototype resistance device envisioned to fly on the Orion Multi-purpose Crew Vehicle. **PURPOSE:** As part of the verification and validation process for the DAP models, sensitivity analyses were performed as a means to understand the effects that uncertainty in model input parameters, which accrue during the model scaling process, can have on joint moment outputs of interest. **METHODS:** A split squat exercise model with a long-bar loading configuration was chosen for analysis. The inertial body segment parameters of mass and center of mass (COM) were the primary inputs under examination. Mass parameters were perturbed by 5.0 kg for the torso and 3.0 kg for femurs while center of mass for all bodies was perturbed by 0.03 m in the x, y, and z planes. Monte Carlo simulations for each perturbation were generated with the help of a probabilistic plugin appended to the software's application program interface using custom code. Pearson's R correlation coefficients were then used to quantify the relationship between inputs and inverse dynamics outputs. **RESULTS:** Lumbar extension moment was found to be highly sensitive to perturbations in the torso inertial parameters ($r_{COM(x)}=1$, $r_{COM(y)}=1$,$r_{COM(z)}= -1$, $r_{mass} =1$) whereas hip adduction ($r_{COM(x)}=1$, $r_{COM(y)}=1$,$r_{COM(z)}=1$, $r_{mass} = -1$) and hip flexion moments ($r_{COM(x)}=1$, $r_{COM(y)}= -1$,$r_{COM(z)}= -1$, $r_{mass} =1$) were highly sensitive to perturbations in the respective femurs. Pelvis perturbations did not affect any outputs of interest ($r \leq 0.01$). **CONLUSION:** The highly sensitive, highly linear correlations observed indicate that failure to accurately account for subject-specific variation in inertial parameters will directly impact DAP moments of interest. From these data it is apparent that the torso and femur require greater focus in future model development and scaling.

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