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ADVANCING EXERCISE BIOMECHANICS MONITORING TECHNIQUES FOR DEEP SPACE MISSIONS

Abstract

Prioritizing astronaut health and conditioning is crucial for successful human spaceflight exploration. Concerns about bone and muscle atrophy are vital, as astronauts can experience up to a 30

The current gold standard for biomechanics data collection uses a complex infrared marker-based motion capture (MoCap) system (Vicon, Englewood, CO), involving specialized cameras and reflective markers placed at key anatomical landmarks to capture motion data. While precise, these systems are bulky, complex, and stationary, posing challenges in confined environments like the ISS. n contrast, IMUs offer a lightweight, portable solution and are widely used in gait research. However, their application in exercise biomechanics is less common due to challenges in accurately tracking multijoint movements.

This study introduces two 5-IMU setups: one positioned on subjects' thighs (2), shanks (2), and pelvis (1) for lower-body exercises, and another on the torso (1), forearms (2), and upper arms (2) for upper-body exercises. Subjects are fitted with both an IMU setup and a plug-in gait reflective marker set (39 markers) to enable simultaneous data collection from inertial measurement units and MoCap system. Motion data were collected with 5 subjects, while they completed the following exercises: barbell squat, deadlifts, heel raises, bent-over rows, reverse chops, and overhead press. A MATLAB pipeline was developed to integrate IMU data into OpenSim (NIH Center for Biomedical Computation, Stanford) biomechanical models, enabling inverse kinematics analysis to extract critical joint kinematics (e.g., knee flexion for squats), which serve as the primary metric for assessing astronauts' safe and proper exercise performance. Next, several statistical metrics such as root-mean-square, mean, mode, and standard deviation were used to compare the IMU and MoCap output angles in each exercise per subject. Preliminary results indicate that IMU-based data collection is comparable to MoCap systems in accuracy while offering advantages such as simplified setup, reduced crew readiness time, lower margin for error, and smaller physical footprint. These attributes are crucial for integrating effective exercise monitoring systems into spacecraft environments for deep space missions.