KINEMATIC SENSORS EVALUATION FOR SPACEFLIGHT EXERCISE DATA COLLECTIONS

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INTRODUCTION: On the International Space Station (ISS), exercise feedback from astronauts is very important to diagnose and mitigate any form-related injuries and ensure efficacious exercise prescriptions and systems. Going forward, exploration exercise efforts seek to gain further quantitative data of human and system performance. Currently, methods of collecting in-flight exercise data on the ISS are limited to marker-based motion capture (MoCap) where astronauts must wear reflective markers over their clothes and specialized cameras are used. The main objective of this work was to investigate the following alternative tracking options: markerless video-based MoCap and inertial measurement units (IMUs). These were compared against traditional marker-based MoCap to evaluate kinematic accuracy and inform feasible methods for future exercise data collections on the ISS, especially in support of future Vibration Isolation and Stabilization (VIS) system development.

METHODS: Three test subjects performed a variety of flight-like resistance and aerobic exercises using the Miniature Exercise Device (MED-2), Concept-2 rowing ergometer, barbell mockup, bench (e.g., for bench press, hip thruster, and cycling), and a custom structure for dips. These were intended also to represent exercises which could be performed on the multi-modality European Enhanced Exploration Exercise Device (E4D) [1]. The marker-based MoCap data, collected through a 16-camera OptiTrack MoCap system, was regarded as the gold standard to compare the data against. Passive markers were affixed to each subject according to a modified full body Plug-in Gait marker set [2] with 46 total markers. The markerless MoCap data was collected using two GoPro Hero7 cameras and one GoPro Hero11 camera. For the IMU data, a full body set of 17 Xsens DOTs were placed on the subject: 10 upper body and 7 lower body IMUs. Biomechanical modeling and evaluation was conducted through OpenSim [3] (MoCap), OpenSense [4] (IMU), OpenCap [5] (markerless), ENABLE [6] (markerless), and other modeling software. Secondary objectives included comparing the volume of equipment, reducing mass and crew set-up time.

RESULTS AND DISCUSSION: While there were issues with initial processing for the IMUs and markerless MoCap, the results aided in the understanding of each sensor, developing end-to-end processes, and identifying future needs. Some observed concerns with the markerless MoCap approaches included being cognizant of a cluttered background, number of people in field of view, camera number and placement. Some challenges with the IMUs included possible sliding, early deactivation possibly due to exercise pose, and large quantity sensor synchronization. Overall, the markerless MoCap option may be the preferred method of data collection and processing as it provides a solution for certain IMU shortcomings and may be least in equipment volume, upmass, and crew setup time.

CONCLUSIONS: While this work was mainly focused on ISS data collection, these sensor data along with continued evaluation and development efforts will help to establish best methods for exercise data collection on Gateway, for other Artemis missions, and beyond. Details on the latest end-to-end processing of the data and results will be presented, along with lessons learned and recommended sensor selection and methods.

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