

ANALYSIS OF EXERCISE LOADS TO INFORM VIBRATION ISOLATION SYSTEM DESIGN

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BACKGROUND: This study was conducted with the primary interest of providing data that would inform Vibration Isolation and Stabilization (VIS) system design and performance for the European Enhanced Exploration Exercise Device (E4D). In preparation for the International Space Station (ISS) in-flight demonstration, a list of critical Human Health Countermeasures (HHC) exercises was compiled [1]. The goal of this study was to assess the ground reaction forces and moments imposed by an exercising subject in each of the six VIS Degrees of Freedom (DOFs) during a comprehensive set of these critical exercises performed on the E4D.

METHODS AND RESULTS: The ISS in-flight demonstration list of critical exercises included seated aerobic rowing, bent-over rowing, cycling, front squats, back squats, conventional deadlifts, Romanian deadlifts, heel raises, overhead presses, reverse chops, and power clean presses. At the NASA Johnson Space Center (JSC) Prototype Immersive Technology (PIT) laboratory, motion capture data were collected on critical E4D exercises for six subjects. At the NASA JSC Active Response Gravity Offload System (ARGOS) facility, additional motion capture and load cell data were collected on offloaded trials for four subjects. Select data were extrapolated to represent a 5th percentile female subject and a 95th percentile male subject.

A previous investigation comparing the forces obtained from the load cell and from motion capture based data found a satisfactory level of agreement between the two measurements [2]. The motion capture based data were analyzed for this study since it is driven by the subject's trajectory alone, automatically excluding any forces exerted on the subject by the ARGOS offloading harness.

The OpenSim [3, 4] biomechanical simulation inverse kinematics tool was used to calculate the joint angles based on the locations of motion capture markers placed at key positions on the subject's body. An OpenSim plugin was then used to obtain the forces and moments generated by the subject during each trial, with the moments computed relative to the equilibrium location of the subject's feet [5]. The force of gravity was also removed to simulate the loads generated by the exercise when performed in microgravity. The load plots for each trial were generated and visually analyzed to obtain the magnitudes of the peak loads for each exercise in each DOF. The typical period of exercise for each trial was also estimated and used to calculate the frequency for each trial. The exercise loads data was then organized in multiple ways to capture different aspects of the data. As a result of this study, we present a summary of the load magnitudes observed during these critical exercises utilizing the E4D.

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