MODELING AND SIMULATION EFFORTS TO SUPPORT IMPROVED COMFORT IN ARGOS

L. B. Nilsson[1], D. Frenkel[2], K. H. Lostroscio[3], L. J. Quiocho[3], C. E. Beck[3]
[1]METECS, Inc., 1030 Hercules Ave., Houston, TX 77058
[2]CACI, Inc., 2100 Space Park Dr., Houston, TX 77058
[3]NASA Johnson Space Center, 2101 E NASA Pkwy, Houston, TX 77058

BACKGROUND: The Active Response Gravity Offload System (ARGOS) provides an analog environment for extravehicular activity (EVA) testing and training. Discomfort has been observed during longer suited test sessions. While the subject's core is offloaded during surface EVA evaluations, his/her arms experience full Earth gravity and can become overly fatigued, especially during suited tests which involve reaching and prolonged arm extensions. A device (ARGOS Negation of Gravitational Effects on the Limbs: ANGEL) to offload the weight of the arms and suit sleeves is being developed by JSC's Flight Systems Branch, and here we present preliminary modeling of that device using the open-source biomechanical tool OpenSim [1,2] with an in-house developed plugin. We analyze a series of motions performed by a single shirt-sleeved subject with goals of characterizing the device, validating the model, and predicting whether reduced gravity conditions (i.e., lunar gravity (Lg) or Martian gravity (Mg)) can be accurately simulated with the device, as well as providing comfort to the ARGOS user.

METHODS AND RESULTS: To model the offload device, we augment the OpenSim human model topology with the offload mechanism components and joints, using CAD models to represent the mechanism graphically. The joint angles of the device are either obtained from (1) inverse kinematics (IK) using motion capture markers on the various components of the device or (2) calculated in the OpenSim plugin by modeling how the components configure themselves under the offloading spring tension given a particular IK-derived arm position. Given the joint angles of the device, the resulting force on the arm is computed by the plugin and applied as an external load in inverse dynamics (ID) in order to enable study of overall shoulder joint torques as well as offload achieved. We verify the calculated joint angles by using the inverse kinematic data and the forces from manual measurements of the spring both independently and integrated within the device. We found that calculated joint angles generally represent the angles measured and computed with IK, supporting a possible analysis workflow inputting human motion data and observing system behavior under varied design parameters. In two different device configurations in which the maximum applied force was 131 N, our current model accurately captured force with a difference of 2-3 N from measured loads.

Though our initial test was performed with a shirt-sleeve subject, arm weights were added to emulate the weight of the suit sleeve and the subject was positioned in a test stand with a Mark-III Hard Upper Torso (HUT) and Portable Life Support System (PLSS) mockup. Arm range of motion tasks were performed outside of the HUT, inside the HUT, and inside the HUT while using the device. A variety of other upper body tasks were completed as well.

In summary, we have developed a model to investigate and verify an upper limb offload device currently in development. We believe this model will be a valuable tool not only for device characterization but also to predict proper configurations to simulate Lg or Mg conditions, investigate range of motion concerns, predict limitations such as internal collisions and contacts, and inform future design improvements.

REFERENCES:

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