PORTABLE LOAD MEASUREMENT DEVICE FOR USE DURING ARED EXERCISE ON ISS

A. M. Hanson\(^1\), B. T. Peters\(^1\), E. E. Caldwell\(^1\), J. Sinka\(^1\), G. Kreutzburg\(^2\), L. Ploutz-Snyder\(^3\)

\(^1\)Wyle Science Technology & Engineering Group, 1290 Hercules Drive, Houston, TX 77058  \(^2\)National Space Biomedical Research Institute Summer Student,  \(^3\)Universities Space Research Association, 3600 Bay Area Blvd., Houston, TX 77058

BACKGROUND

The Advanced Resistive Exercise Device (ARED) was designed and built to offer crewmembers a full complement of resistance exercises. The enhanced capabilities in load capacity and hardware configuration as compared to the precursor Interim Resistive Exercise Device (iRED) allows exercise trainers to develop more comprehensive and higher intensity exercise prescriptions. The original ARED design included instrumentation to monitor the exercise loads through in-line sensors, and a force platform to monitor under foot forces. Due to failure of the data acquisition system and load cell malfunctions, no exercise loads have been autonomously recorded since 2010. The lack of real-time ARED load monitoring severely limits the science outcomes. In particular, the lack of force platform data makes it impossible to carry out science studies that are in the queue to analyze biomechanics. To address this issue, portable load monitoring technologies are being evaluated to act as a surrogate to ARED’s failed instrumentation. The XSENS ForceShoe™ will be used in a technology demonstration aboard the International Space Station (ISS) in early 2014, and tested as a portable device to measure exercise loads on ARED.

METHODS

The XSENS instrumentation was tested in two configurations. One configuration was the ForceShoe™ as purchased from XSENS. In the second test configuration, the instrumentation was removed from the shoe and used in two small force plates, each with a common base and two top plates. Each top plate was mounted over an individual XSENS instrumentation package. The XSENS shoes house six degrees-of-freedom (6-DOF) tri-axial force \(F_x, F_y, F_z\), and torque \(T_x, T_y, T_z\) sensors. In addition to the load cells, the shoes house XSENS MTx sensors that measure tri-axial acceleration and inertial parameters. The individual XSENS channels were sampled at 50 Hz, synchronized with the load cell mounted in the test stand, low-pass filtered (10Hz Butterworth), and recorded. The resultant force was calculated from the XSENS instrumentation in both the shoe and force plate configurations.

An X-Y test stand was used to apply a range of static loads to an individual sensor in both the shoe and force plate configurations. A single axis load cell (500 lb force rating) was placed in-line with the force load applicator to allow for an independent load measurement to compare to the load measured by the XSENS instrumentation. Signals from the test stand were sampled at 1000Hz, synchronized with the XSENS channels, and recorded. These data were compared to the XSENS data. Data were collected both on the ground and in parabolic flight through use of the mechanical test stand. A Kistler force plate \(F_z=1000Hz\) was used to compare results from the ForceShoes™ in a human-in-the-loop-test (HILT) on the ground.

RESULTS

In general, there was less variability in measurements at > 40 lb for both the plate and shoe in the ground data. Above a 40 lb load, the average percentage difference for the shoe measurement compared to the test stand was <5% on the ground and in flight. By comparison the average percentage difference for the force plate measures above a 40 lb load, was < 3% on the ground and in flight. In a ground human in the loop evaluation, across all subjects \((n=5)\) and trials \((n=5)\), the mean percent difference between static load measurements made with the ForceShoe™ and a Kistler force plate was < 2%.

CONCLUSION

The results of the ground, parabolic flight, and human in the loop evaluations with the XSENS ForceShoes™ demonstrate good accuracy during static load measurements. Additionally, repeated static load measurements were consistent. The COTS ForceShoe™ configuration was determined to be easier to use as a portable load monitoring device than the custom force plates using the XSENS instrumentation. Therefore, a recommendation was made to test the hardware in a technology demonstration about the ISS. NASA’s Human Research Program has funded a directed study to fly the XSENS ForceShoe™ in an in-flight evaluation to measure exercise loads during ARED exercise. The results of the flight demonstration will help researchers to determine if the portable load monitoring device is a suitable tool to provide data for research and/or operational needs.