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Effect of STS Space Suit on Astronaut Dominant Upper Limb EVA Work Performance

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ABSTRACT PAGE

"EFFECT OF STS SPACE SUIT ON ASTRONAUT DOMINANT UPPER LIMB EVA WORK PERFORMANCE", M. G. Greenisen, Ph.D., Anthropometric Lab, NASA, SP22, Johnson Space Center, Houston, Texas 77058.

The purpose of this investigation was to evaluate STS Space Suited (3.7 PSID) and unsuited dominant upper limb performance in order to quantify future EVA Astronaut skeletal muscle upper limb performance expectations. Testing was performed with subjects standing in EVA STS foot restraints. Data was collected with a CYBEX Dynamometer enclosed in a waterproof container. Control data was taken in one "g". During one "G" testing weight of the Space Suit was relieved from the subject via an overhead crane with a special connection to the PLSS of the suit. Experimental data was acquired during simulated zero "g", accomplished by neutral buoyancy in the Weightless Environment Training Facility. Unsuited subjects became neutrally bouyant via SCUBA BC vests. Actual zero "g" experimental data was collected during parabolic arc flights on board NASA's modified KC-135 aircraft. During all test conditions subjects performed five EVA work tasks requiring dominant upper limb performance and ten individual joint articulation movements. Dynamometer velocities for each tested movement were 0 degree/second, 30 or 60 degree/second and 120 or 180 degree/second, depending on the test, with three repetitions per test. Performance was measured in foot pounds of torque. Testing continues.

INTRODUCTION

This report represents an "in progress review" of an ongoing Space Biomechanics research project with NASA JSC, Directorate of Space and Life Sciences. The study was conceptualized and initiated during a NASA-ASEE Faculty Fellowship, Summer 1985. This research continued full time at NASA JSC, September 1985 - August 1986 under a university academic year sabbatical leave and a second NASA-ASEE Faculty Fellowship award. Since August 1986 the study has been supported by a Lockheed - NASA Contract, number NAS9-15800 dated 18 August 1986.

The basis of this report is extracted from documentation prepared for a Weightless Environment Training Facility (WETF) Test Readiness Review Board (TRRB), which was held on August 21, 1986. The TRRB approved the use of the Cybex Dynamometer for experimental procedures in the WETF. Essentially, the TRRB documentation is presented in total.

This documentation summarizes the engineering effort and experimental design evolution from June 1985 to date. The study will continue through the Summer 1987. A final report on the results of this study will be published with the Summer 1987, NASA-ASEE Faculty Fellowship final reports from NASA JSC.

RESEARCH CONCEPT

This investigation is evaluating STS space suited and unsuited dominant upper limb performance in order to quantify future EVA upper limb work performance expectations. Data is being generated by Mission Specialist Astronauts. Data is collected during one control and two experimental environments.

To standardize testing, all data is being collected with a Cybex dynamometer enclosed in a nitrogen charged waterproof container pressurized to 4 psid, mounted on a dedicated stand. The stand meets all test environment attachment specifications and also serves as the anchor point for astronaut STS foot restraints.

Control one-g data is collected in the Anthropometric Measurement Laboratory (AML). During one-g testing, weight of the space suit is relieved from the subject via an overhead crane specially connected to the PLSS of the suit.

Experimental data is acquired during simulated zero-g accomplished by submerging the subjects and Cybex in the Weightless Environment Training Facility (WETF). Suited subjects become neutrally bouyant (NB) through standard WETF ballast weighting system techniques. Unsuited subjects become NB via SCUBA BC vests.

Actual, zero-g experimental data is collected during parabolic arc flights on board NASA's modified KC-135 aircraft. A gravity meter measures actual negative "g" level attained. During all dedicated test conditions, subjects perform five EVA work tasks requiring whole dominant upper limb performance and ten individual joint articulation movements of the same limb. Dynamometer velocities vary depending on the test. However, 0 degree/second is utilized during all tests to determine levels of inertial forces which may be manually exceeded by STS suited astronauts.

Data generated by a prototype hand held force measuring unit from Scott Science and Technology is also being compared to Cybex results during selected protocols of this study. This hand held unit is not waterproofed and will not be part of the Cybex WETF testing at this time.

The efforts of this study, to date, have focused on the design engineering and fabrication of the required hardware, plus evolution of the research experimental design. Principal Investigator familiarization with KC-135 parabolic flights and NASA WETF SCUBA qualification has also occurred. Research pilot data has been collected with the instrumentation on four KC-125 zero-g flights. Two flights were with unsuited and two flights were with suited astronaut subjects. During these flights the instrumentation functioned without problems.

Collection of data began the first week of November from three STS suited astronauts which submerged in the WEFT. The Cybex dynamometer, enclosed in the waterproof container, performed without problems as the test article. After testing, the underwater container was unsealed and inspected. No evidence of water leakage into the container was found, thereby, documenting the success of the engineering design.

There is inadequate data, as of this date, to realistically present any findings. However, two areas of interest have surfaced based on the available data: 1) the range of motion available at the wrist joint of the current STS Space Suit, especially during wrist extension could impact on EVA work performance. This condition could influence future EVA tool design; 2) the current EVA knob does not seem to be effective in its design requirement to receive and transfer skeletal muscle force by suited EVA astronauts.

Astronaut testing will continue during 1987. Six zero-g flights are scheduled for February and March. WETF and one-g testing will continue as a comparison to the zero-g testing.

The impact of this study is to provide data in support of STS EVA work requirements, EVA crew training requirements, and Phase C of Space Station. In addition, should the prototype force measuring unit prove successful, the mass and dimension complexities of the Cybex could be eliminated, thereby facilitating future studies.

Specific Underwater Experimental Use of Cybex Dynamometer

The attached Hazard Analysis Report describes the safety design engineering aspects of the Cybex Dynamometer pressurized waterproof underwater container and electronic safety controls.

The underwater use of the Cybex will be to determine astronaut STS space suited and unsuited dominant upper limb EVA work related performance as measured by foot pounds of torque. The following dominant upper limb movements, with corresponding velocities will provide the neutrally bouyant (stimulated zero-g) aspect of the data required for this research.

1) EVA ratchet wrench crank
   0^{o} -sec
   60^{o} -sec
   180^{o} -sec

2) EVA ratchet wrench push and pull
   0^{o} -sec
   60^{o} -sec
   180^{o} -sec

3) EVA knob turn
   0^{o} -sec
   30^{o} -sec
   120^{o} -sec

4) EVA handle turn
   0^{o} -sec
   30^{o} -sec
   120^{o} -sec

5) Wrist flex and extend
   0^{o} -sec
   60^{o} -sec
   180^{o} -sec

6) Elbow flex and extend
0^{o}-sec
60^{o}-sec
180^{o}-sec

7) Shoulder joint flex and extend
0^{o}-sec
60^{o}-sec
180^{o}-sec

8) Forearm rotation (pronation and supination)
0^{o}-sec
60^{o}-sec
180^{o}-sec

9) Shoulder joint horizontal flexion and horizontal extension
0^{o}-sec
60^{o}-sec
180^{o}-sec