**Evaluation of Suited and Unsuited Human Functional Strength Using Multipurpose, Multiaxial Isokinetic Dynamometer**

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| Prepared By: | Fred Aghazadeh, Ph.D., P.E. |
| Academic Rank: | Associate Professor |
| University & Department: | Louisiana State University<br>Industrial Engineering Department<br>Baton Rouge, LA 70803 |
| NASA/JSC | |
| Office: | Habitability and Environmental Factors Office (HEFO)<br>Habitability & Human Factors Office<br>Anthropometry and Biomechanics Facility (ABF) |
| JSC Colleague | Sudhakar L. Rajulu, Ph.D. |



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## ABSTRACT

The objective of the planned summer research was to develop a procedure to determine the isokinetic functional strength of suited and unsuited participants in order to estimate the coefficient of micro-gravity suit on human strength. To accomplish this objective, the Anthropometry and Biomechanics Facility's Multipurpose, Multiaxial Isokinetic dynamometer (MMID) was used. Development of procedure involved selection and testing of seven routines to be tested on MMID. We conducted the related experiemts and collected the data for 12 participants.

In addition to the above objective, we developed a procedure to assess the fatiguing characteristics of suited and unsuited participants using EMG technique. We collected EMG data on 10 participants while performing a programmed routing on MMID. EMG data along with information on the exerted forces, effector speed, number of repetitions, and duration of each routine were recorded for further analysis. Finally, gathering and tabulation of data for various human strengths for updating of MSIS (HSIS) strength requirement, which started in summer 2003, also continued.

## INTRODUCTION

Extra-Vehicular Activities (EVA) are necessary part of being aboard International Space Station and the Space Shuttle. For EVA activities, astronauts must wear a pressurized suit called Extra-Vehicular Mobility Unit (EMU). Due to the pressurization and the bulkiness of the suit material, the EMU has been known to limit motion and impede generation of force. In order to determine the effect of suit on the strength and fatigue of the astronauts, several studies have been performed. The previous studies investigated such subjects as, effects of EVA gloves on performance, measurement of various strength variables whiled wearing EMU, determination of work and fatigue characteristics of suited and unsuited participants during isolated joint motions, etc.

However, the previous work on EMU focused solely on isolating individual joints and hence, lacks data on functional strength capabilities and limitations of a suited crewmember. The objectives of the planned summer research consisted of three parts;

**Part I.** Development of a procedure to determine isokinetic functional strength of suited and unsuited participants in order to estimate the coefficient of micro-gravity suit on human strength using the Anthropometry and Biomechanics Facility's Multipurpose, Multiaxial Isokinetic Dynamometer (MMID).

**Part II.** Develop a procedure to assess the fatiguing characteristics of suited and unsuited participants using the EMG methodology.

**Part III.** Continue the gathering of data for various human strengths for updating of MSIS strength requirement.

## METHOD AND PROCEDURE

### Apparatus

The initial stage of the project involved familiarization with the apparatus used in this project. This included obtaining the manual from the manufactures and writing of a JPA (Job Performance Aid) for the use of the equipment. The apparatus used in this project was Multipurpose, Multiaxial Isokinetic Dynamometer (MMID). The Multipurpose Multiaxial Isokinetic Dynamometer (MMID) is capable type of dynamometer used for measuring and stressing muscles in the arms, legs, and trunk. It monitors both strength and limb position in 3-D space. It is a new generation of physical fitness device capable of being used here on Earth as well as in the weightlessness of space. The key components of the MMID are the eight active modules. The modules reel in or spool out cable in unison to achieve a desired trajectory of the end effector. The MMID is capable of achieving complex, six degree-of-freedom motions by using all eight active modules. With all eight modules maintaining a given position, the end effector can be rigidly fixed in space. Other advantage of the machine is the fact that each module is light (7 pounds) and requires almost minimum volume when stored (7 x7x7 inches).

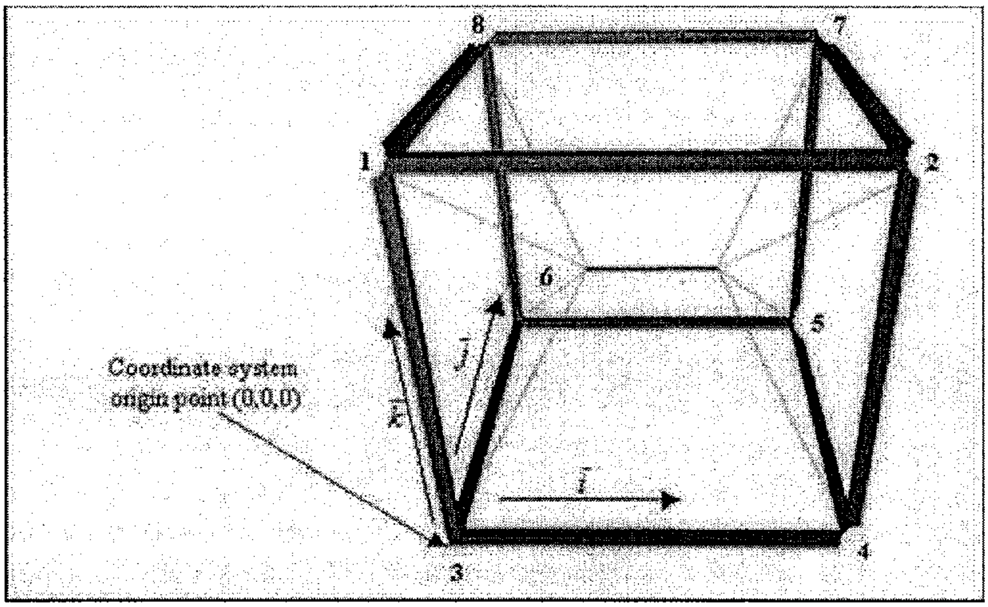


Figure 1: System Configuration and Coordinate Conventions

A diagram of the MMID system in its typical configuration is shown in Figure 1. This Figure shows the cubic configuration, the coordinate system origin point and orientation, and a typical end effector configuration (a bar). In this case, there are eight cables attached to eight points on the end effector, four points on each end. This configuration enables a comfortable balance between range of motion and force generating capability. Figure 2 illustrate one of the eight modules (pods). The module is small and may be mounted with ease.

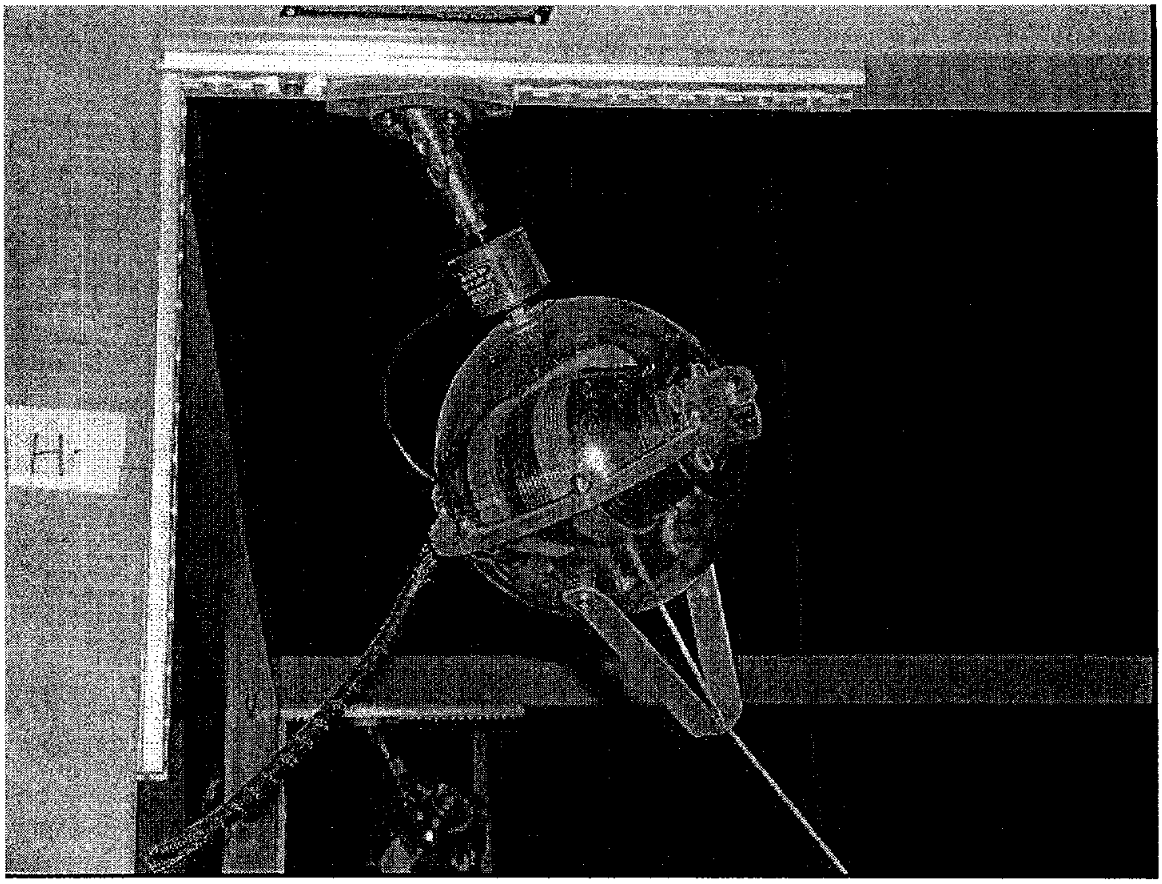

Figure 2. An Illustration of a Module (Pod)

Some measurement capability of MMID are listed below and shown in Figure 3 (Real-time Display Window) and Figure 4 (Real-time Information Display Window):

- Continuous recording of effector position in X,Y,Z axis
- Continuous recording of force (lbs), speed (in/s), acceleration ($in/s^2$), deceleration,($in/s^2$), and moment.

The apparatus is capable of measuring forces for the following routines:

Programmed Routines
Squat
Bench Press
Incline shoulder Press
Vertical Leg Press
Calf raises

Lat Pull-down (Latissimus dorsi)
Military Press
Bent-over Row
Butt Blaster
Inclined Leg Press
Triceps Press-down
Standing Curl
Cup Lift
Roto-swirl
Leg Curl
Seated Curl
Seated Curl
Inverted Push-up
Single Pod Pull
Bowl Move

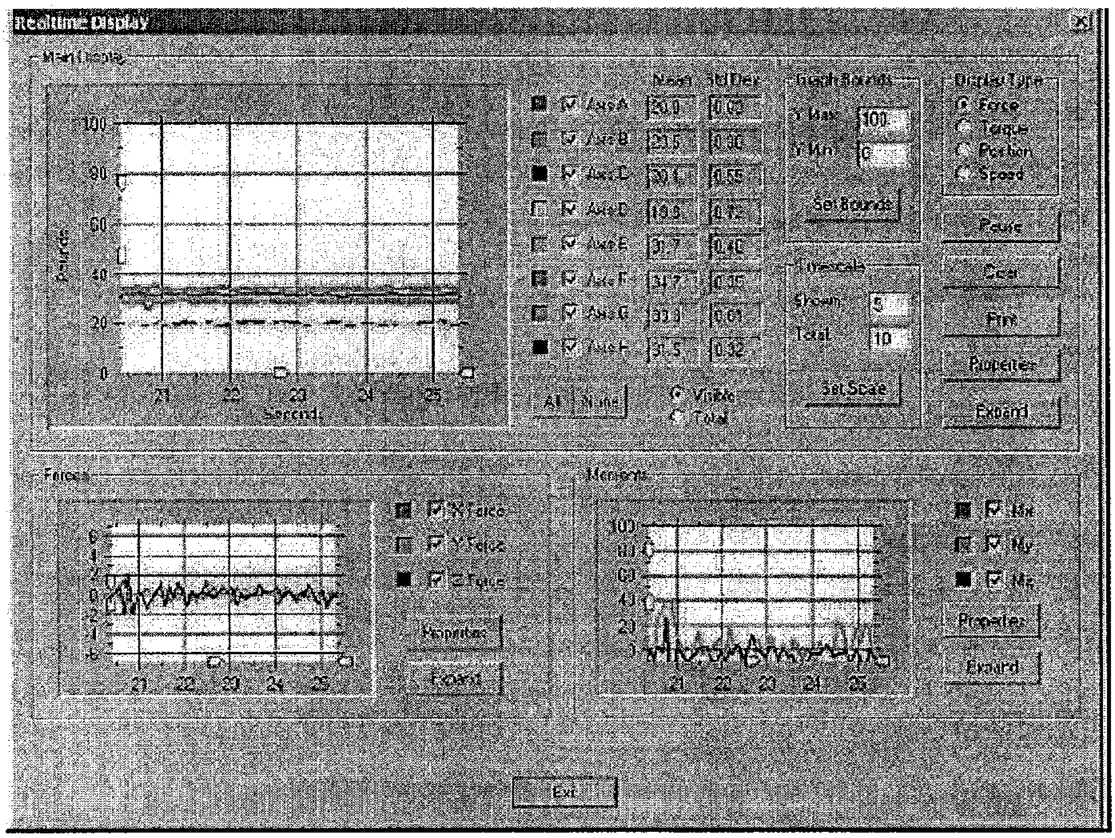


Figure 3. Real-time Display Window


Figure 4: Real-time Information Display Window (Force in lbs.)

**Procedure Development**

**Part I.** In order to develop a procedure to determine isokinetic functional strength of suited and unsuited participants, we selected the routines, and specifications for each routine. This was done through trial and error, and was based on usability of the routine and capability of the measuring devise. The selected routines and their specifications are listed in Table 1.

Table 1. Specifications of Routines

| **Strength Test Positions & Specs** | X-axis Position (inch) | Y-axis Position (inch) | Z-axis Position (inch) | Speed (in/s) | Acce-Leration ($in/s^2$) | Decele-Ration ($in/s^2$) | Min Move force (lbs) | Max registered Force (lbs) | Max move Force (lbs) |
|---|---|---|---|---|---|---|---|---|---|
| 1. Sitting lat pull down | 46 | 49 | 66-48 | 10 | 10 | 20 | 20 | 150 | 180 |
| 2. Sitting Mil Press | 46 | 54 | 66-48 | 10 | 10 | 20 | 20 | 150 | 180 |
| 3. Sitting Push | 46 | 36-63 | 46 | 10 | 10 | 10 | 20 | | |
| 4. Sitting Pull | 46 | 63-36 | 46 | 10 | 10 | 10 | 20 | | |
| 5. Open Hatch | 46 | 46 | 26-66 | 10 | 10 | 10 | 20 | | |
| 6. Standing Curl | 46 | 46 | 39-53 | 10 | 10 | 20 | 20 | 120 | 150 |
| 7. Standing Triceps Press | 46 | 46 | 53-39 | 10 | 10 | 10 | 10 | 100 | 120 |
| | | | | | | | | | |
| **Fatigue Test** | | | | | | | | | |
| 1"/sec | 46 | 36-63 | 46 | 1 | 1 | 1 | | | |
| 5"/ sec | 46 | 36-63 | 46 | 5 | 5 | 5 | | | |
| 10"/sec | 46 | 36-63 | 46 | 10 | 10 | 10 | | | |

## Experiment Protocol for Parts 1 and 2

Once the routines were specified, we proceeded with the experimentation and data collection phase. The experiment involved 10 male and 2 female participants. The subjects were instructed to move the effector (bar) by pushing, pulling, raising, etc as fast and as hard they were able to do it without jerking the bar. They were told to build the speed and force gradually. The participants tried each routine a few times and became familiar with the routine. They were asked to perform the routine continuously till they were instructed to halt the routine.. The exerted force was monitored till values for three trials that were within 10 percent of each other were obtained. A rest period of 3 to 4 minutes between routines was used. The experimental order was randomized and is shown in Table 2.

The second part of this project was about determination of the fatiguing characteristics of participants using the EMG methodology. We used trial and error method to select a routine that was based on usability of the routine and capability of the measuring devise. The selected routine was the push-pull routine at speeds of 1, 5, and 10 inch/s. We selected the triceps muscle for electrode location. The EMG recording devise was the Bagnoli-2 EMG System (DelSys Inc., Boston, MA). This is a handheld, battery-operated 2-channel EMG system. Prior to the data collection, a surface electrode was placed on the right triceps muscle and a base EMG was recorded. The participants were asked to sit on the MMID bench and push the effector as hard and as fast they could without jerking the bar. The participants repeated the routine at the prescribed speed of 1, or 5, or 10 inch/s for 400 seconds. The order of trials was randomized. Table 2 shows the experiment order. It was observed that as the muscles fatigued, the exerted force did not change accordingly. The participants complained about fatigue in the hand and fingers. Data was collected and recorded for analysis in the future.

**Table 2. Experiment Protocol**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Subject Name and Number | | | | | | | | |
| Gender | | | | | | | | |
| Height | | | | | | | | |
| Weight | | | | | | | | |
| Age | | | | | | | | |
| **Strength Test Positions and order** | | | | | | | | |
| 1. Sitting lat pull down | 1 | 7 | 6 | 2 | 3 | 2 | 7 | 4 |
| 2. Sitting Mil Press | 2 | 2 | 2 | 3 | 6 | 6 | 2 | 6 |
| 3. Sitting Push | 3 | 3 | 3 | 4 | 1 | 5 | 5 | 1 |
| 4. Sitting Pull | 4 | 4 | 7 | 6 | 5 | 3 | 3 | 3 |
| 5. Open Hatch | 5 | 5 | 1 | 1 | 2 | 1 | 6 | 5 |
| 6. Standing Curl | 6 | 6 | 4 | 5 | 4 | 4 | 1 | 7 |
| 7. Standing Triceps Press | 7 | 1 | 5 | 7 | 7 | 7 | 4 | 2 |
| | | | | | | | | |
| **Fatigue Test** | | | | | | | | |
| 1"/sec | 3 | 3 | 2 | 1 | 3 | 2 | 3 | 2 |
| 5"/ sec | 2 | 1 | 1 | 2 | 2 | 3 | 1 | 1 |
| 10"/sec | 1 | 2 | 3 | 3 | 1 | 1 | 2 | 3 |

## SUMMARY AND FUTURE WORK

Part I included development of a procedure to determine isokinetic functional strength of suited and unsuited participants in order to estimate the coefficient of micro-gravity suit on human strength using the Anthropometry and Biomechanics Facility's Multipurpose, Multiaxial Isokinetic Dynamometer (MMID).

For this part of the project a detailed procedure was developed and tested. In addition, strength data for 10 male and 2 female unsuited participants were collected. The data includes strength data for seven routines at pre-determined X,Y, Z, coordinates, speeds, accelerations, decelerations, and resistive forces. The predetermined routines were "Lat Pull-down (Latissimus dorsi)," "Sitting Military Press," "programmed routines of Sitting Push, Sitting Pull, and Open Hatch," "Standing Curl," and "Standing Triceps Press."

Work to be completed includes:

A. Analysis of collected data to determine the functional strength capacity of participants.

B. Collection of the same data for suited participants.

C. Analysis of the suited data to determine the coefficient of micro-gravity suit on human strength.

Part II was about the development of a procedure to assess the fatiguing characteristics of suited and unsuited participants using the EMG methodology. After many trials and errors, we found that the push-pull routine at speeds of 1, 5, and 10 inch/s was the practical test for this part. EMG signal of the triceps muscle was recorded at 1000 hz. for 400 seconds for 10 male participants. Work to be completed includes:

A. Analysis of the collected data to determine the relationship among variables of generated force, effector speed, number of repetitions, and EMG signals.

B. Collection and analysis of the data for suited participants.

Part III was continuation of task of gathering of data for various human strengths for updating of NASA-STD-3000 Man-System Integration Standards (MSIS) strength requirement. At the present time about 190 references related to different human strengths have been located and documented. The following is a list of journals and the number of references collected from those Journals.

| *Journal Name* | *Number of References* |
|---|---|
| Ergonomics | 20 |
| Research Quarterly | 15 |
| Applied Ergonomics | 04 |
| Journal of Biomechanics | 06 |
| International Journal of Industrial Ergonomics | 03 |
| Spine | 01 |
| Hand | 01 |
| Human Factors | 04 |
| Scandinavian Journal of Rehabilitation Medicine | 02 |
| Clinical Biomechanics | 04 |
| Clinical Orthopedics & Related Research | 03 |
| American Industrial Hygiene Association Journal | 05 |
| Proceedings of Human Factors | 15 |
| Journal of Applied Physiology | 13 |
| Archives of Physical Medicine & Rehabilitation | 07 |
| American Corrective Therapy Journal | 05 |
| Aviation Space and Environmental Medicine | 03 |
| Aerospace Medicine | 02 |
| Physical Therapy | 07 |
| Journal of Sports Medicine and Physical Fitness | 03 |
| Medicine and Science in Sports | 05 |
| Scandinavian Journal of Rheumatology | 02 |
| Journal of Hand Surgery | 04 |
| Journal of Bone and Joint Surgery | 04 |
| American Journal of Occupational Therapy | 03 |
| Engineering in Medicine | 02 |
| Journal of Orthopedics Research | 03 |
| Journal of Anatomy | 04 |

Future work to be conducted includes:

A. Locating and documenting of additional sources
B. locating and collecting hard or electronic copies
C. Summarizing sources, extracting useful data, tables etc., and building an annotated bibliography
C. Tabulating sources into sections related to:
  - Strength in micro-gravity and hyper-gravity conditions
  - Strength of various limbs
  - Isokinetic strength data
  - Isometric strength data
  - Static strength data vs. functional strength
  - Strength in IVA (Intravehicular Activity) and EVA (Extravehicular Activity) suits