FY13 High Performance EVA Glove (HPEG) Collaboration: Glove Injury Data Mining Effort - Training Data Overview

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Presentation Overview

• Intro/Background
• Project Objectives
• Data Request
• LSAH Data Sources
• Analysis Definitions
• Injury Prevalence & Type
• Discussion
• Future Work
Introduction/Background

- From the time hand-intensive tasks were first created for EVAs, discomforts and injuries have been noted.
- There have been numerous versions of EVA gloves for US crew over the past 50 years, yet pain and injuries persist.

<table>
<thead>
<tr>
<th>Glove</th>
<th>Description</th>
<th>Years in Service</th>
<th>First Flight</th>
</tr>
</thead>
<tbody>
<tr>
<td>A7L Gloves</td>
<td>Original Apollo gloves</td>
<td>1960's</td>
<td>Apollo 7 (1968)</td>
</tr>
<tr>
<td>A7LB Gloves</td>
<td>Modified for A7LB</td>
<td>1960's</td>
<td>Apollo 15 (1971)</td>
</tr>
<tr>
<td>2000 Series</td>
<td>EMU Modified Baseline Glove</td>
<td>N/A</td>
<td>Never Flew</td>
</tr>
<tr>
<td>4000 Series</td>
<td>Evolution of 3000 series</td>
<td>1986-2001+</td>
<td>1986</td>
</tr>
<tr>
<td>4750 Series</td>
<td>4000 Series w/ 5000 series TMG</td>
<td>1992+</td>
<td>STS-49 (1992)</td>
</tr>
<tr>
<td>Phase VI</td>
<td>Current EVA Glove Iteration</td>
<td>1998+</td>
<td>(STS-88) 1998</td>
</tr>
</tbody>
</table>
Project Objectives

• The investigation team was tasked with assisting in a glove injury assessment for the High Performance EVA Glove (HPEG) project

• To aid in this assessment, the team was asked to complete the following objectives:
  – First, to develop the best current understanding of what glove-related injuries have occurred to date, and when possible, identify the specific mechanisms that caused those injuries
  – Second, to create a standardized method for comparison of glove injury potential from one glove to another

• The overall goal of the gloved hand injury assessment is to utilize ergonomics in understanding how these glove injuries are occurring, and to propose mitigations to current designs or design changes in the next generation of EVA gloves
Data Request Constraints

• The investigation team worked with Lifetime Surveillance of Astronaut Health (LSAH) personnel to gather crew injury data
• The team requested detailed data of Extra-vehicular Activity (EVA) and Neutral Buoyancy Lab (NBL)/ Weightless Environment Training Facility (WETF) training injuries to better understand their demographics
  – 330 US crew members were reviewed for the project
  – Requested data for injuries that occurred from the elbows down to the fingernails (upper extremities)
  – Requests queried the LSAH database for anyone that performed an EVA or training run
    • Some crew completed training runs without ever performing an EVA
  – Requests looked for indication of redness, pain, or injury
  – Timeframe for recorded training data was from 1998 – 2010
Data Sources

• LSAH Training Data Sources
  – Electronic Medical Record (EMR)
  – Suit Symptom Questionnaire (SSQ)

• LSAH EVA (flight) Data Sources
  – Shuttle Post-flight medical debriefs
  – Private Medical Conferences (ISS in-flight)
  – Space Medicine Operations Team (SMOT) notes
Analysis Definitions

• **Injury**: Pain, redness, or injury reported on a crewmember’s upper extremities

• **Injury Incident**: a single event, occurrence, or case affecting a single crewmember. One recorded *incident* may include multiple *injuries*.

• **Injury Count**: the summation of multiple *injuries* within the same *incident* or from multiple *incidents*

• **Injury Incidence Rate**: the calculated number of *incidents* per 100 NBL runs (600 hrs)
Training Injury Prevalence
## Initial Assessment of LSAH Injury Data

### Training Data

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Number of Injury Incidents</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall</strong></td>
<td></td>
</tr>
<tr>
<td>Total Training Incidents Listed</td>
<td>89</td>
</tr>
<tr>
<td>Non-Applicable Training Incidents</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total Applicable Incidents</strong></td>
<td>87</td>
</tr>
<tr>
<td><strong>Training Location</strong></td>
<td></td>
</tr>
<tr>
<td>NBL Training Incidents</td>
<td>80</td>
</tr>
<tr>
<td>WETF Training Incidents</td>
<td>1</td>
</tr>
<tr>
<td>Unknown Training Location Incidents</td>
<td>6</td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>19</td>
</tr>
<tr>
<td>Men</td>
<td>68</td>
</tr>
</tbody>
</table>

Multiple injuries may have occurred to the same crew member over several training run incidents or within the same training run incident. The data above only looks at the number of injury incidents, not the number of crew affected or injury counts.
Crew Injury Distributions By Gender

![Graph showing crew injury distributions by gender]

<table>
<thead>
<tr>
<th>Crew Category</th>
<th>All Crew</th>
<th>All Training</th>
<th>All EVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men</td>
<td>282</td>
<td>183</td>
<td>119</td>
</tr>
<tr>
<td>Injured Men</td>
<td>37</td>
<td>37</td>
<td>33</td>
</tr>
<tr>
<td>% Injured</td>
<td>13%</td>
<td>20%</td>
<td>28%</td>
</tr>
<tr>
<td>Women</td>
<td>48</td>
<td>42</td>
<td>10</td>
</tr>
<tr>
<td>Injured Women</td>
<td>7</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>% Injured</td>
<td>15%</td>
<td>17%</td>
<td>40%</td>
</tr>
</tbody>
</table>
NBL Injury Prevalence

Annual Training Incidence Rate By Total Annual NBL Training Hours

Larger Size = Higher Incidence Rate
Rate based on 100 NBL Runs (600hrs)
Career Training Hours of Injured

- The following chart depicts training injuries, plotted along the timescale of career training hours
- Color indicates severity of injury (see legend)

Data Collected 2002-2004: CIRCLES
Data Collected Outside this Range: PLUS SIGNS
Training Injuries by Year

- The following graphic shows all training injury data by year, and indicates the proportion of data collected 2002-2004.
- Color indicates severity of injury (see legend).

Data Collected 2002-2004: CIRCLES \((72\%\) of incidents\)
Data Collected Outside this Range: PLUS SIGNS \((28\%\) of incidents)
Note: Training Data 2002-2004

- We found that from 2002-2004 an attempt was made to record injury data with high consistency following training runs. This included:
  - A comprehensive medical review of crewmembers’ post NBL training from July 19, 2002 to January 16, 2004 (Strauss et al. *Aviat Space Environ Med.* 2005 May;76(5):469-7)
- Of the 89 training injuries in the LSAH data, 64 were recorded between 2002 and 2004 (72%)
- There is not a noted proportional increase in training hours per year in the same data range to accompany the higher rates (see below)

**NBL Training Hrs Per Year**

![Graph of NBL Training Hrs Per Year](image-url)
Training Injury Types
Training Injury Types

- Abrasion
- Blanching
- Contusion / Ecchymosis
- Edema (swelling)
- Erythema (redness)**
- Epicondylitis
- Excess Moisture*

- Fatigue (soreness)**
- Onycholysis (fingernail delamination)
- Ganglion Cyst
- Pain**
- Paresthesia
- Subungual Hematoma

*This variable is technically not an injury but a notable variable to include in the analysis
** These variables may be considered as possible precursors to injury or were accompanied with injury and are included in the analysis
Training Injury Types

Training Injury Counts

<table>
<thead>
<tr>
<th>Injury Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>58</td>
</tr>
<tr>
<td>Erythema (redness)</td>
<td>29</td>
</tr>
<tr>
<td>Onycholysis</td>
<td>25</td>
</tr>
<tr>
<td>Fatigue (soreness)</td>
<td>7</td>
</tr>
<tr>
<td>Paresthesia</td>
<td>6</td>
</tr>
<tr>
<td>Abrasion</td>
<td></td>
</tr>
<tr>
<td>Contusion / Ecchymosis</td>
<td>5</td>
</tr>
<tr>
<td>Edema (swelling)</td>
<td>3</td>
</tr>
<tr>
<td>Blanching</td>
<td></td>
</tr>
<tr>
<td>Epicondylitis</td>
<td>2</td>
</tr>
<tr>
<td>Subungual Hematoma</td>
<td>1</td>
</tr>
<tr>
<td>Ganglion Cyst</td>
<td>1</td>
</tr>
<tr>
<td>Excess Moisture</td>
<td></td>
</tr>
</tbody>
</table>

Total Injury Count: 147
**Thumb and finger categories do not include more detailed categories such as fingertip, thumbnail, or interphalangeal joint (IP)**
Training Injury Type vs. Body Part

Injury Count

Fatigue, Abrasion, Paresthesia, Contusion, Blanching, Edema, Epicondylitis, Excess Moisture, Ganglion Cyst, Subungal Hematoma

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February 13th, 2014
Body Part vs. Training Injury Type

Injury Count

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Top 3 Injuries over Time

Note: We only have 1 injury datapoint before 2002.
Injuries by Age
Age vs. Injury Type

Age at Injury vs. Injury Type

- Erythema
- Onycholysis
- Pain

Legend:
- Abrasion
- Blanching
- Contusion
- Edema
- Erythema
- Epicondylitis
- Excess Moisture
- Fatigue
- Ganglion Cyst
- Onycholysis
- Pain
- Paresthesia
- Subungual Hematoma
Injury Distribution by Age

- 67% of all incidents occurred to those in their 40’s
- Are certain ages more susceptible to training injuries or is there something else going on?

Training Injuries by Age
Why are 40-Somethings More Affected?

- Majority of active crew ≥ 40 since 2000

1: 72% of training incidents occurred in ’02-’04 range
2: 78% of ’02-’04 incidents occurred to crew ≥ 40
Discussion

• This initial investigation of the LSAH injury data revealed that there were varying levels of reporting for injury data
  – This led to varying levels of fidelity in the resulting data
    • e.g., 2002-2004 were found to have the greatest amounts of high fidelity / high quantity training data when compared to surrounding years

• Future efforts should consider standardizing data collection methods for greater data consistency through time
Discussion

• Review of the LSAH distribution data finds that certain variables should be further investigated for strength of injury association such as:
  – **Age**
    • We know a large number of injured were in their 40’s and that crew in their 40’s are the majority of the corps, but is that age a risk to injury or just coincidence?
      – Need further investigation.
  – **Gender**
    • We know that women are a small group amongst crew and EVA eligible women, even smaller, but are they at a different risk from men?
      – Consider differences in gender anthropometry.
Discussion

– Cumulative career hrs of training exposure
  • Does risk increase with more career experience or is it the same as little experience?
    – Consider injuries by crew career hours.

– Density of training sessions prior to injury
  • Does risk increase with a higher frequency of runs over a short time period like one month?
    – Consider injuries by training 1 month before injury.

– Likelihood of injury recurrence
  • Are the same types of injuries occurring to the same people or people of similar anthropometry, suit/glove sizing, or EVA/training exposure makeup?
    – Consider injury recurrences by these group type.
Future Work (FY14)

- Assess LSAH EVA injury data
- Perform distribution and correlation analyses with current LSAH injury dataset in addition to:
  - Glove/Suit sizing Data for EVA and training runs
  - Hand/Arm Anthropometry Data
Acknowledgments

• Lifetime Surveillance of Astronaut Health (LSAH)
• Joe Dervay, M.D.
• Sam Strauss, D.O.
Any Questions?
Extra Slides
Generalized Injury Categories & Severities

• To allow general trends to be found in the data, the injuries were grouped into the following categories of increasing severity:
  – Thermal
  – Fatigue
  – Pain (without additional description)
  – I Dermatological
    • Abrasion/Rash/Erythema/Other)
  – II Dermatological
    • Bruise/Sores/Cuts/Edema/Paresthesia/Other)
  – III Trauma/Ecchymosis/Blanching
  – IV Delamination/Oncholysis/Subungual Hematoma
Injury Prevalence

Annual Training Incidence Rate By Number of Crew Incidents

Larger Circle Size = Higher Incidence Rate

Rate based on 100 NBL Runs (600hrs)
HUT Type and Size Distribution

Training Injured Distribution by HUT Type/Size

- Planar Medium: 38, 45%
- Planar Large: 40, 48%
- Planar UNK: 2, 2%
- Pivoted Large: 4, 5%

Planar vs. Pivoted

- Planar: 78, 95%
- Pivoted: 4, 5%

Medium vs. Large

- Medium: 42, 51%
- Large: 40, 49%

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EVA Injury Data
This chart is indicating how many training incidents occurred to crew when age and career hour increments are paired.
Age vs. Training Time 1 mo. Prior to Injury

Crew Training Incidents: Age vs Training Time 1 Month Prior to Injury (hrs)

<table>
<thead>
<tr>
<th>Age Range (Yrs)</th>
<th>0-4</th>
<th>5-10</th>
<th>11-20</th>
<th>21-30</th>
<th>UNK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trn Hrs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1-4</td>
<td>0</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>5-10</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11-20</td>
<td>4</td>
<td>1</td>
<td>7</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>21-30</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>UNK</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

There may be something here between 0 and 20hrs, but a majority seems to affect those in 40’s