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

Christopher Reid, Ph.D. – Lockheed Martin [1]
Elizabeth Benson, M.S. – MEI [1]
Scott England, M.S. – MEI [1]
Jacqueline Charvat, Ph.D. – Wyle [2]
Jason Norcross, M.S. – Wyle [3]
Shane McFarland, M.S. – MEI [4]
Sudhakar Rajulu, Ph.D. - NASA [1]

[1]Anthropometry & Biomechanics Facility (ABF), [2]Lifetime Surveillance of Astronaut Health (LSAH), [3]EVA Physiology, [4]Space Suit and Crew Survival Systems Branch

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

Glove	Description	Years in Service	First Flight
A7L Gloves	*Original Apollo gloves*	1960's	Apollo 7 (1968)
A7LB Gloves	*Modified for A7LB*	1960's	Apollo 15 (1971)
1000 Series	*EMU Baseline Glove*	1981-1984	STS-6 (1983)
2000 Series	*EMU Modified Baseline Glove*	N/A	Never Flew
3000 Series	*Evolution of 2000 series*	1985-late 90's	STS-61B (1985)
4000 Series	*Evolution of 3000 series*	1986-2001+	1986
5000 Series	*Flight version of the Phase IV High Pressure Glove*	1991	STS-37 (1991)
4750 Series	*4000 Series w/ 5000 series TMG*	1992+	STS-49 (1992)
Phase VI	*Current EVA Glove Iteration*	1998+	(STS-88) 1998

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

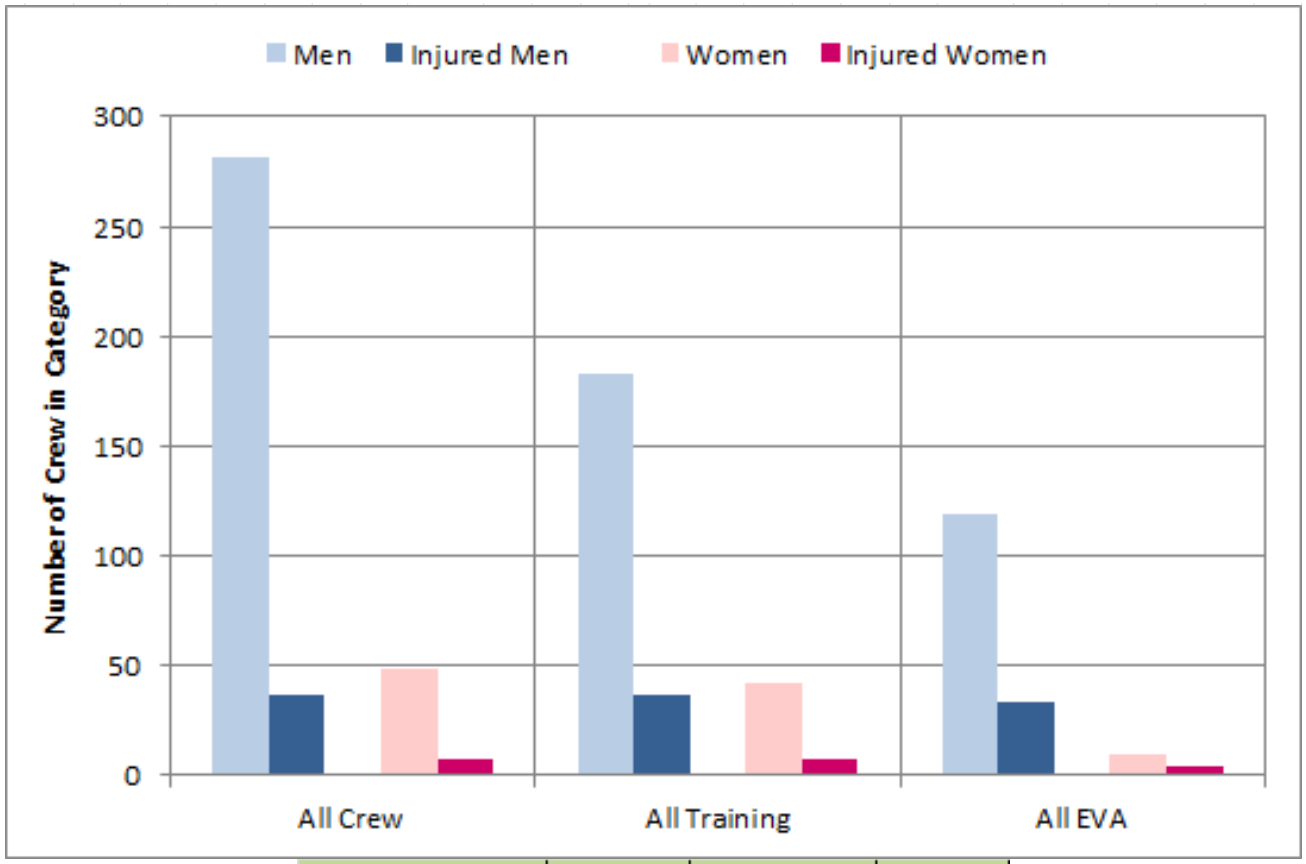
Initial Assessment of LSAH Injury Data

Training Data

	Data Type	Number of Injury Incidents
Overall	Total Training Incidents Listed	89
	Non-Applicable Training Incidents	2
	Total Applicable Incidents	**87**
Training Location	NBL Training Incidents	80
	WETF Training Incidents	1
	Unknown Training Location Incidents	6
Gender	Women	19
	Men	68

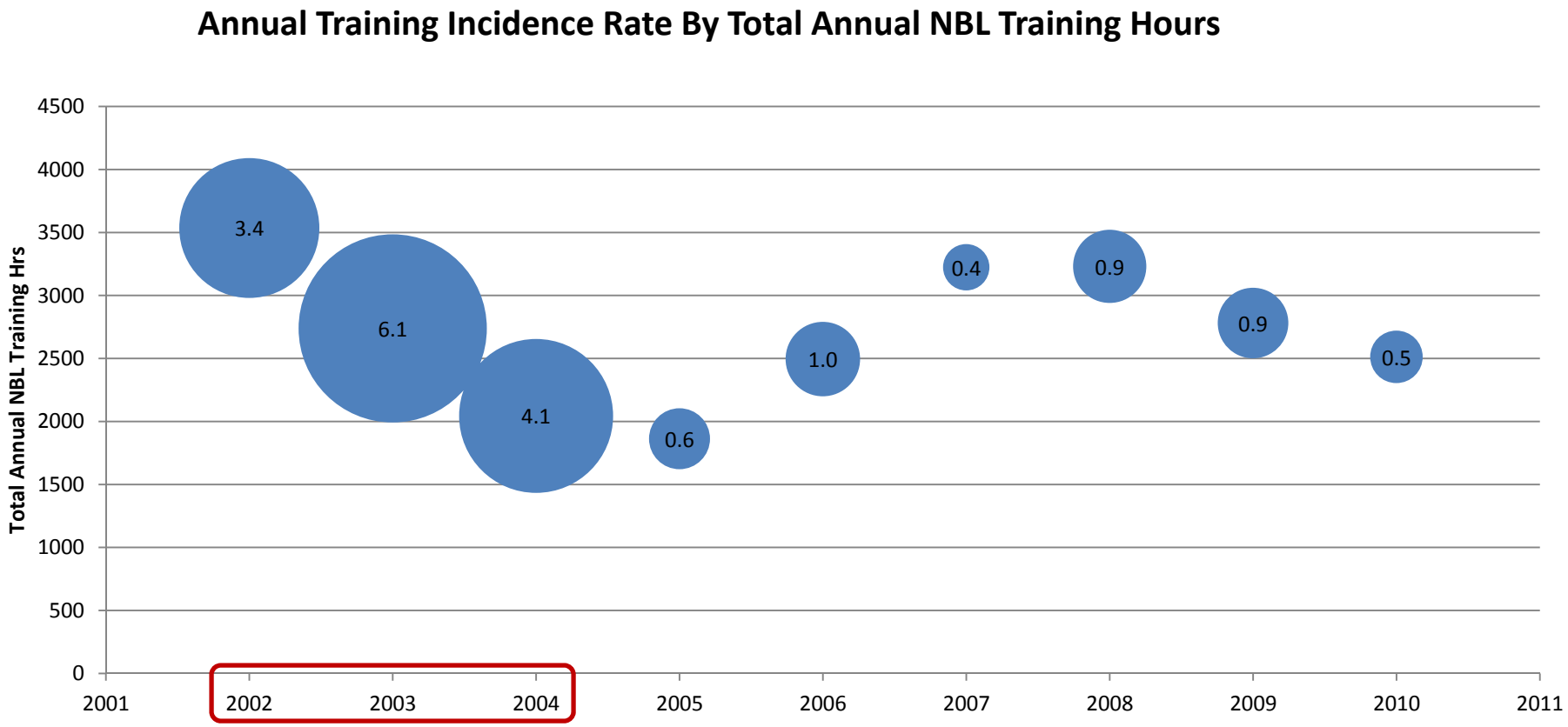
Multiple injuries may have occurred to the same crew member over several training run incidents or within the same training run incident. The data above only looks at the number of injury incidents, not the number of crew affected or injury counts.

Crew Injury Distributions By Gender



Crew Category	All Crew	All Training	All EVA
Men	282	183	119
Injured Men	37	37	33
% Injured	13%	20%	28%
Women	48	42	10
Injured Women	7	7	4
% Injured	15%	17%	40%

NBL Injury Prevalence

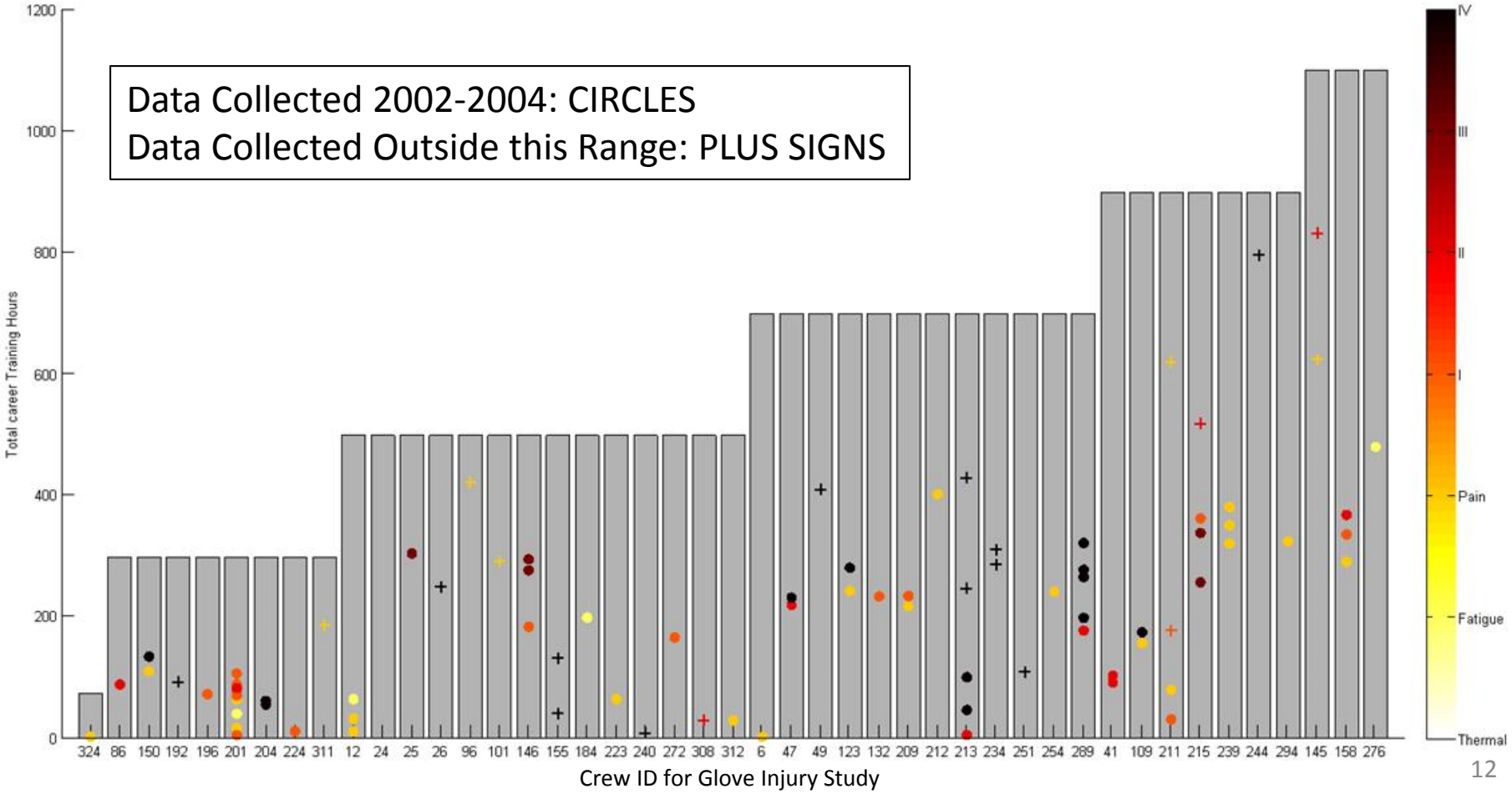


Larger Size = Higher Incidence Rate

Rate based on 100 NBL Runs (600hrs)

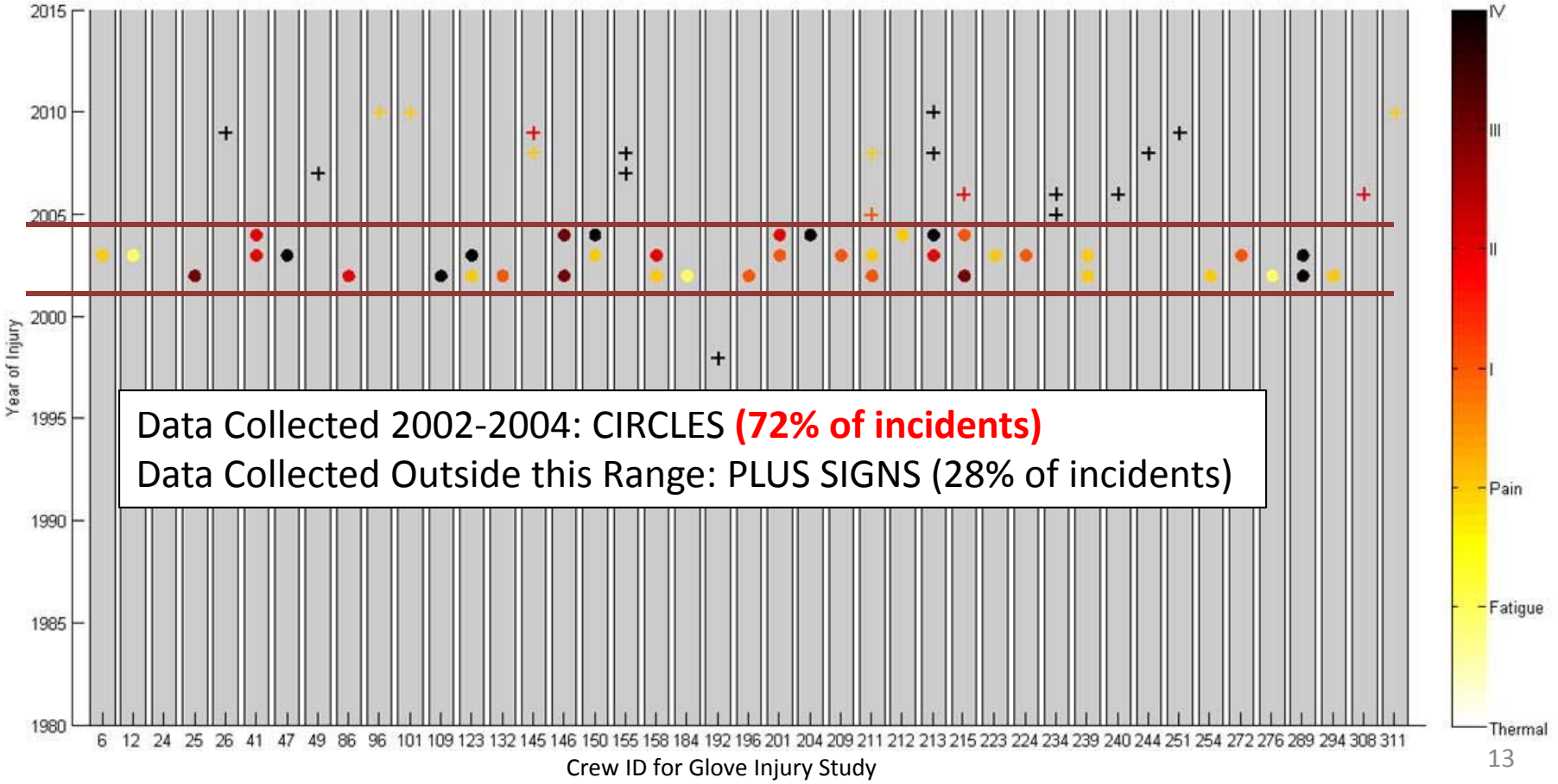
Career Training Hours of Injured

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



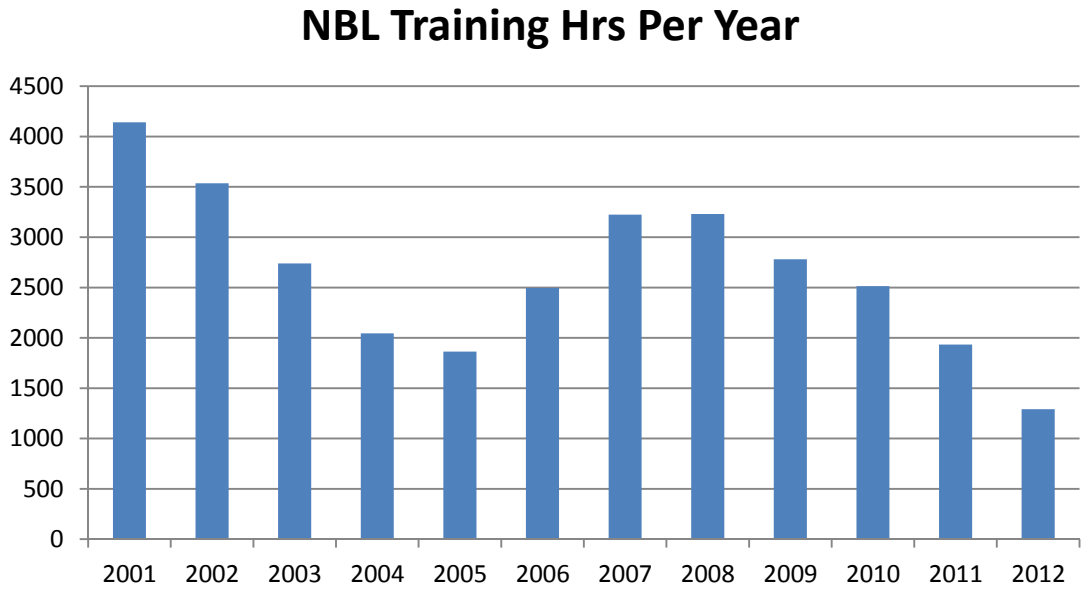
Training Injuries by Year

- 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)



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)
  - The EMU Tiger Team Investigation on shoulder related injuries (Williams and Johnson, NASA/TM—2003–212058, 2003)
- 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)



Training Injury Types

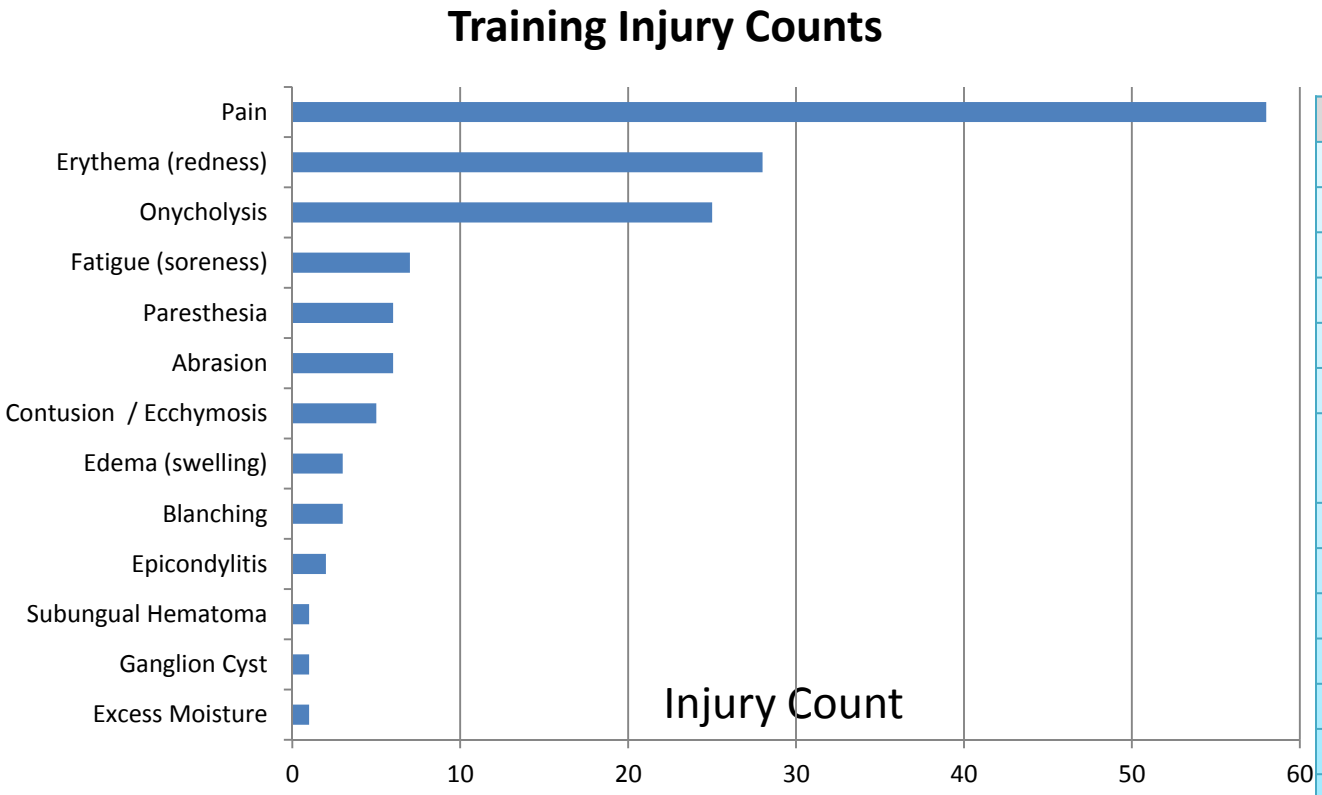
Training Injury Types

- 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

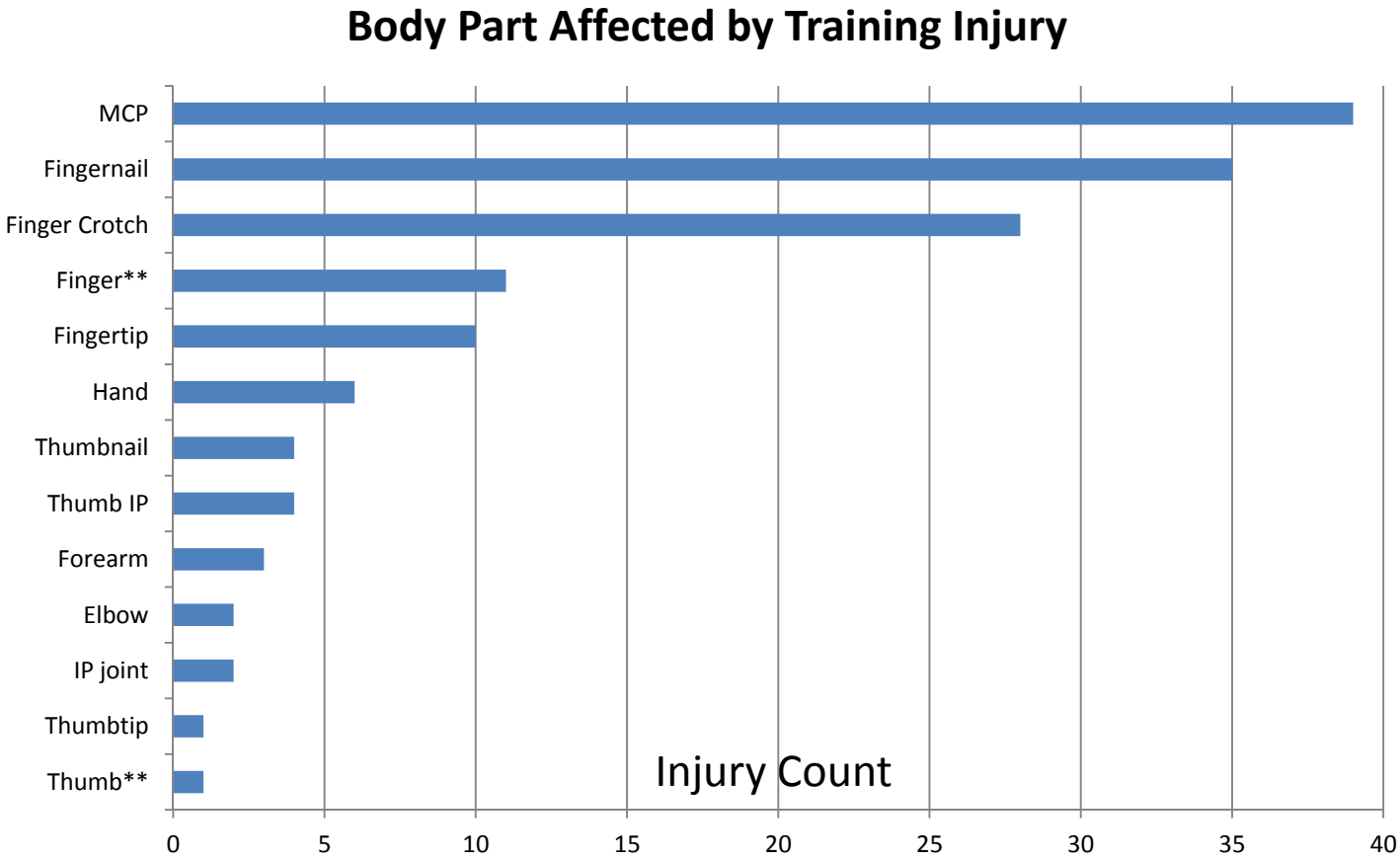
** These variables may be considered as possible precursors to injury or were accompanied with injury and are included in the analysis

Training Injury Types



Injury Type	Count
Pain	58
Erythema (redness)	29
Onycholysis	25
Fatigue (soreness)	7
Abrasion	6
Paresthesia	6
Contusion / Ecchymosis	5
Blanching	3
Edema (swelling)	3
Epicondylitis	2
Excess Moisture	1
Ganglion Cyst	1
Subungual Hematoma	1
Total Injury Count	**147**

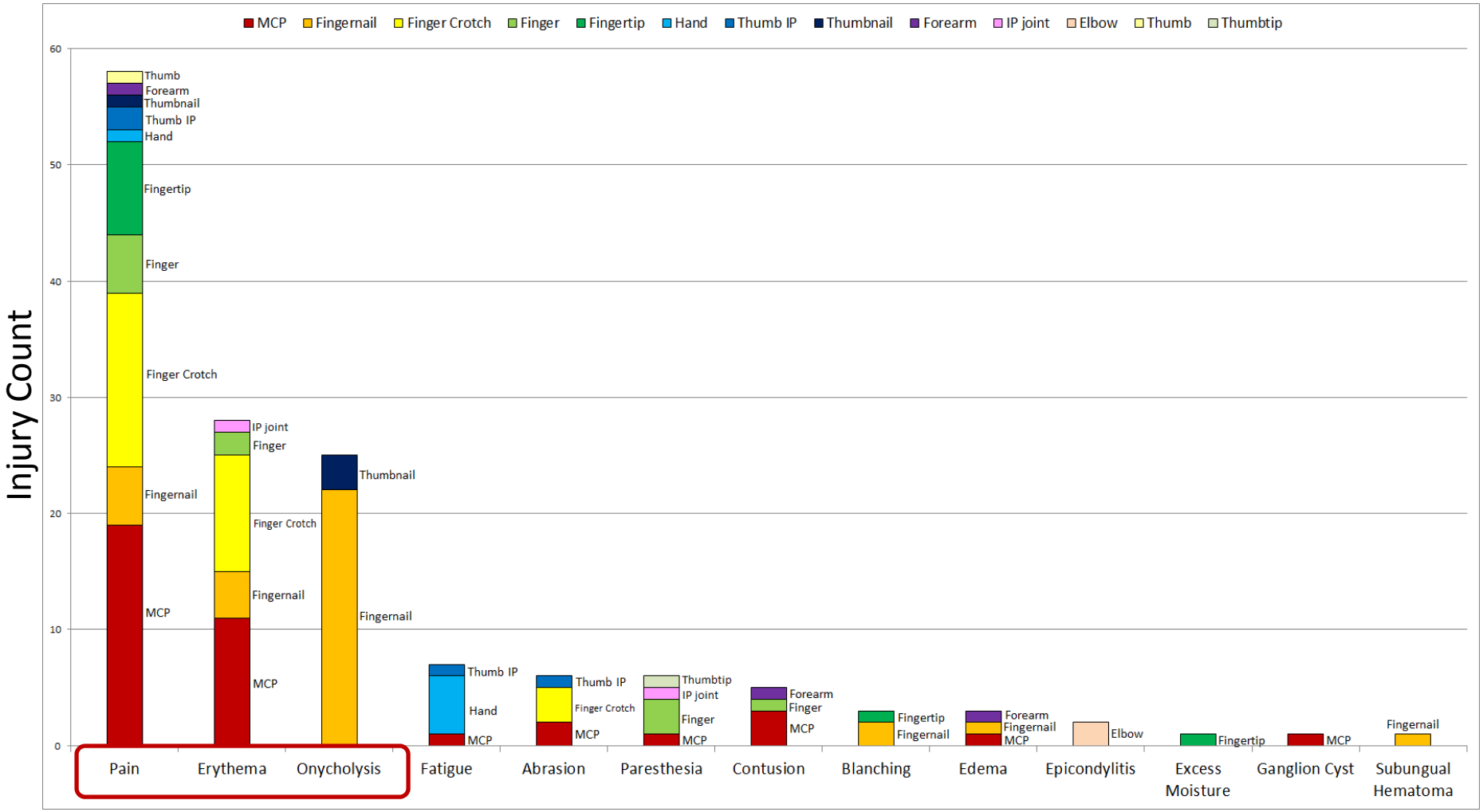
Training Injury Types



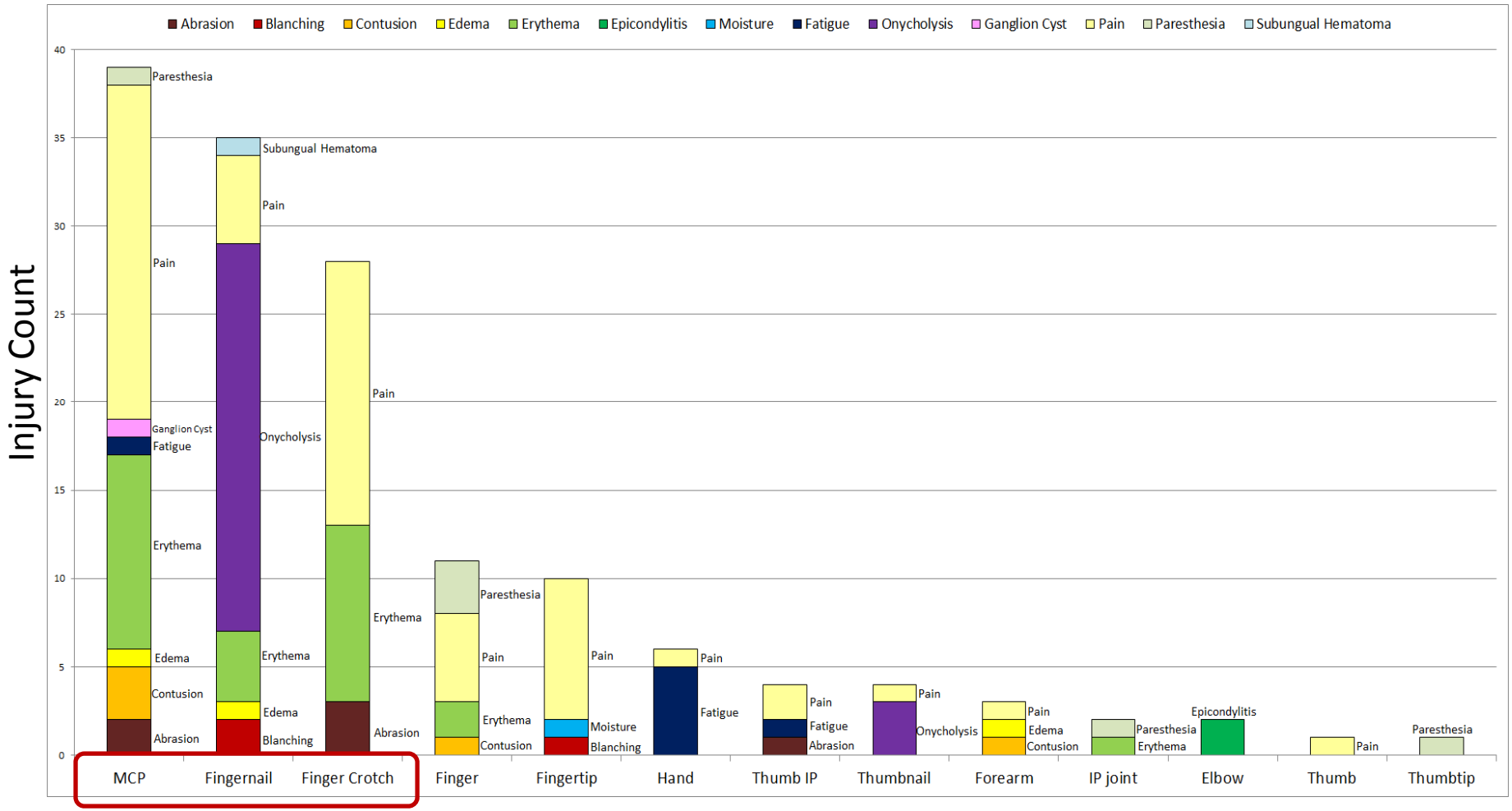
Body Part Affected	Count
MCP	39
Fingernail	35
Finger Crotch	28
**Finger	11
Fingertip	10
Hand	6
Thumb IP	4
Thumbnail	4
Forearm	3
IP joint	2
Elbow	2
**Thumb	1
Thumbtip	1
Total Injury Count	**146**

**Thumb and finger categories do not include more detailed categories such as fingertip, thumbnail, or interphalangeal joint (IP)

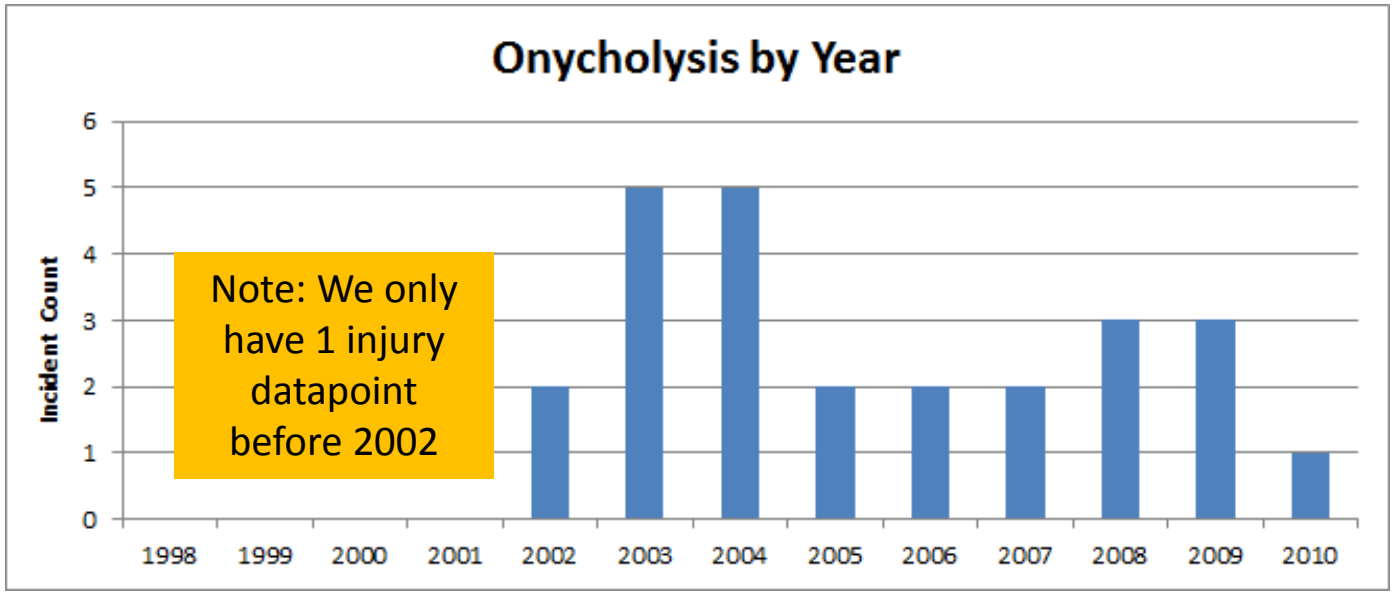
Training Injury Type vs. Body Part

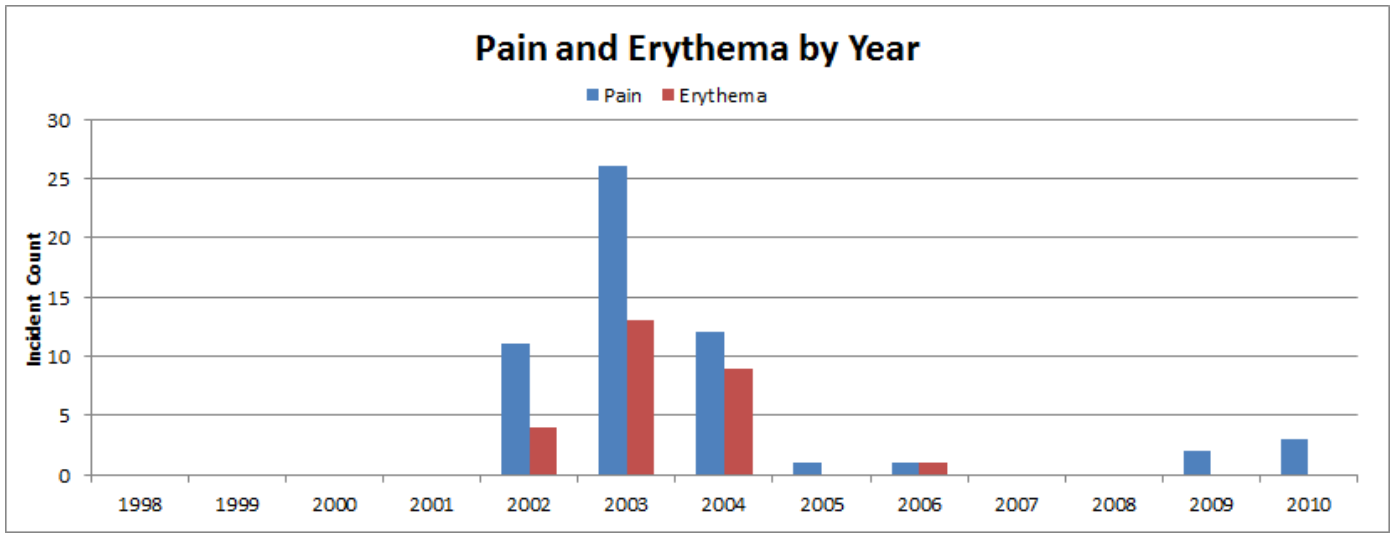


Body Part vs. Training Injury Type



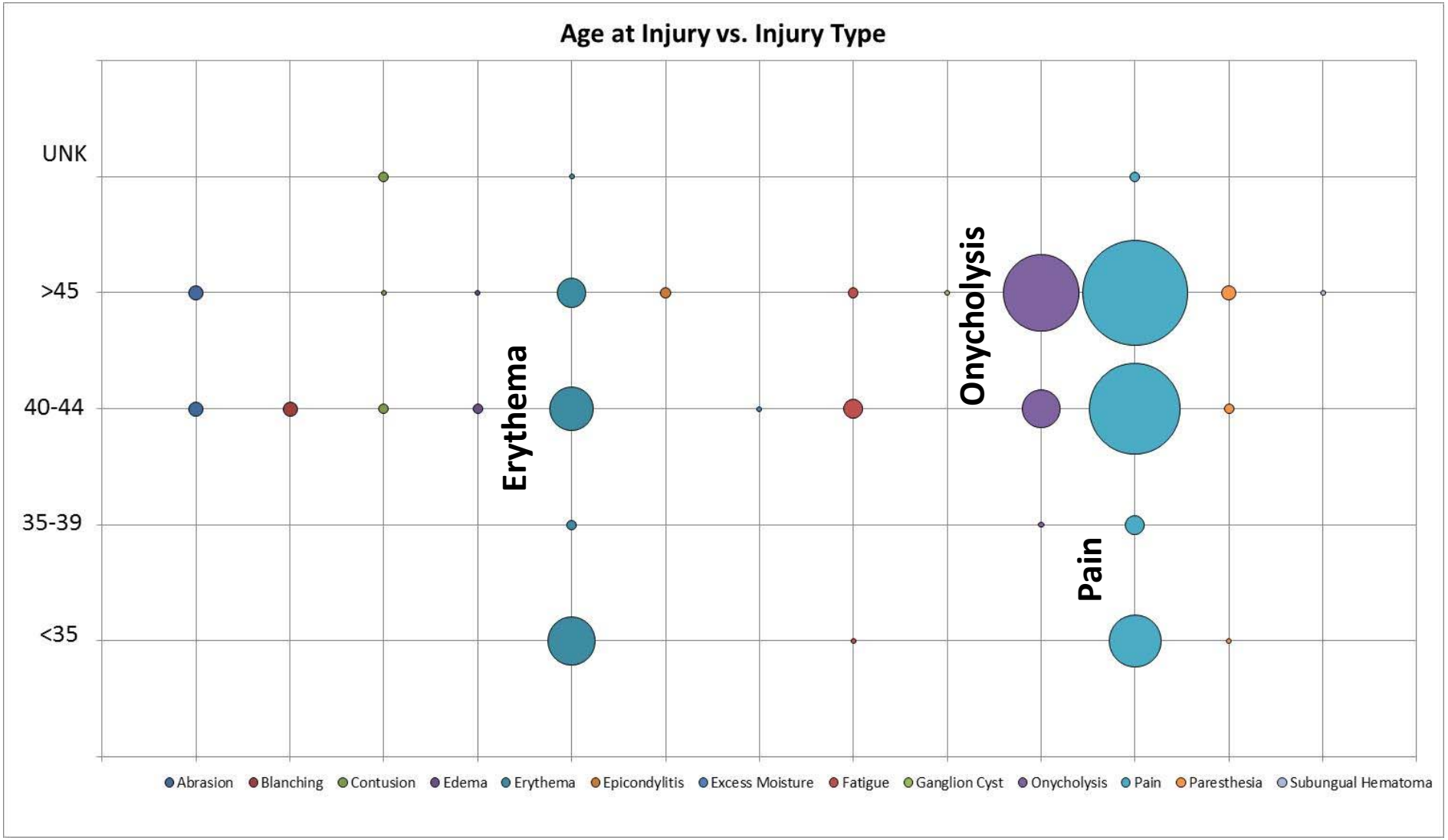
Top 3 Injuries over Time



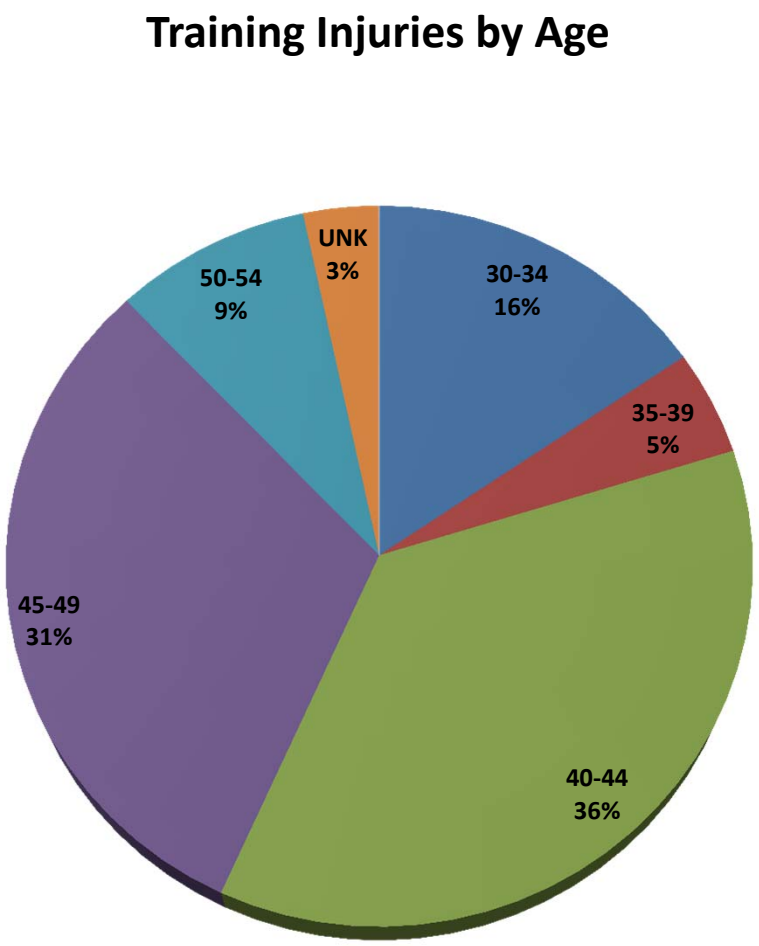


Injuries by Age

Age vs. Injury Type

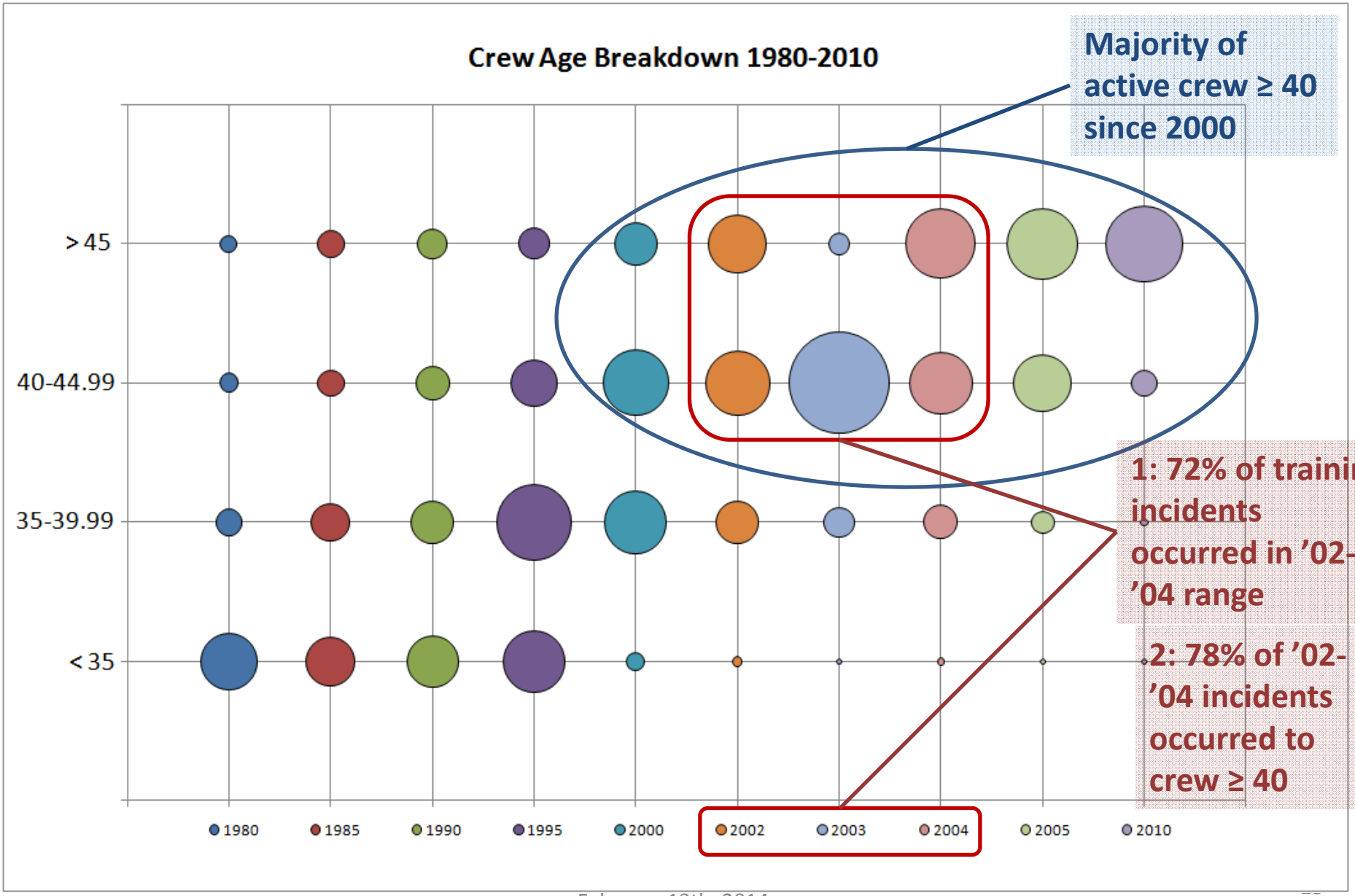


Injury Distribution by Age



- 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?

Why are 40-Somethings More Affected?



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.**

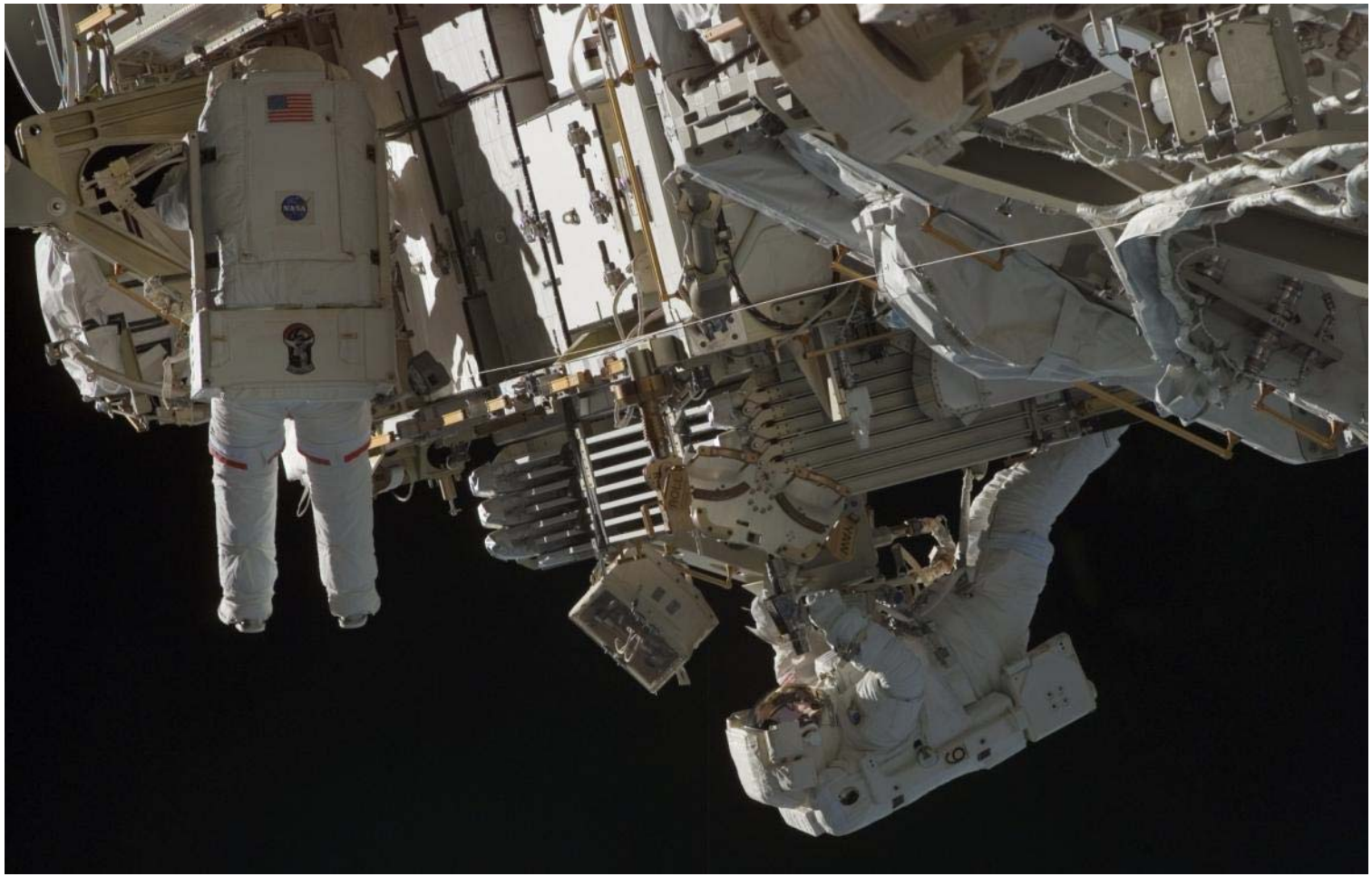
Future Work (FY14)

- 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?

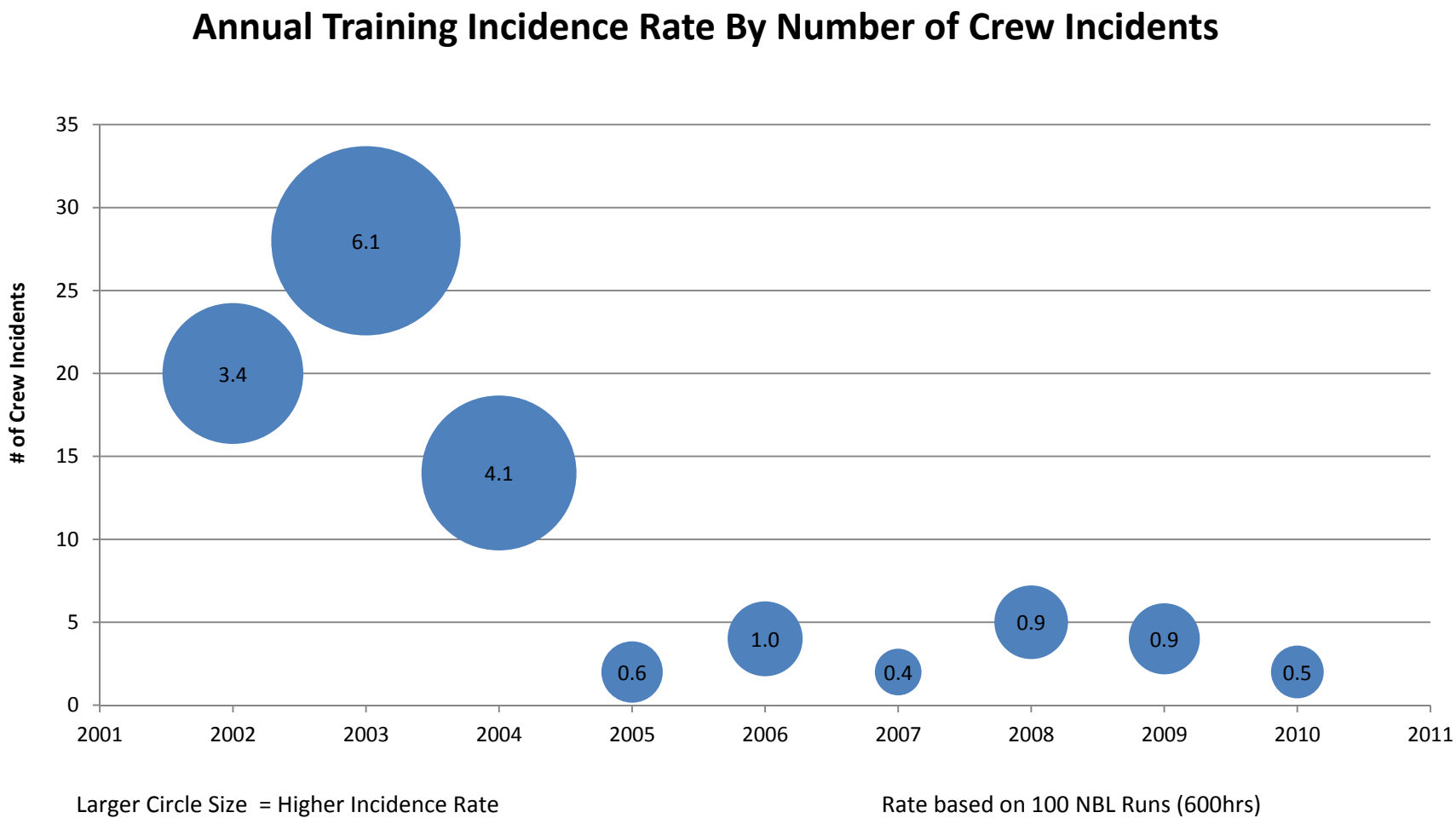


Extra Slides

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

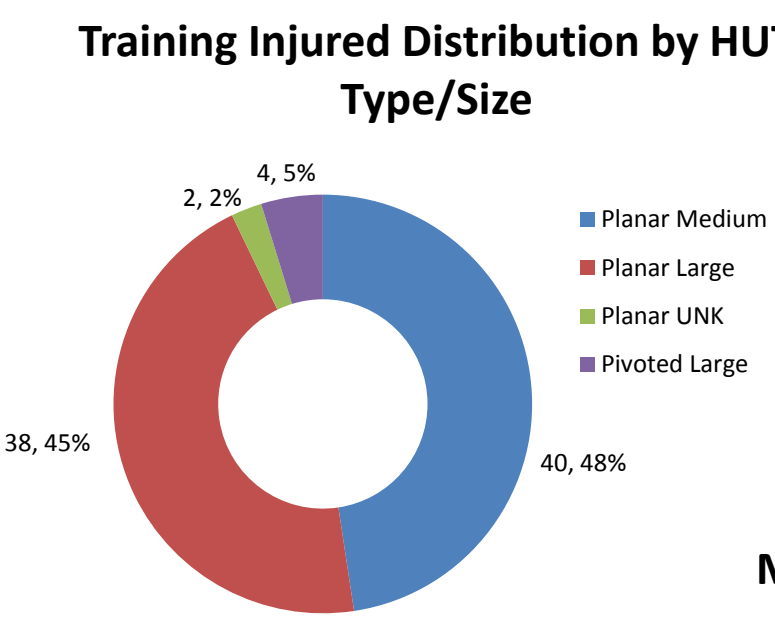
Injury Prevalence

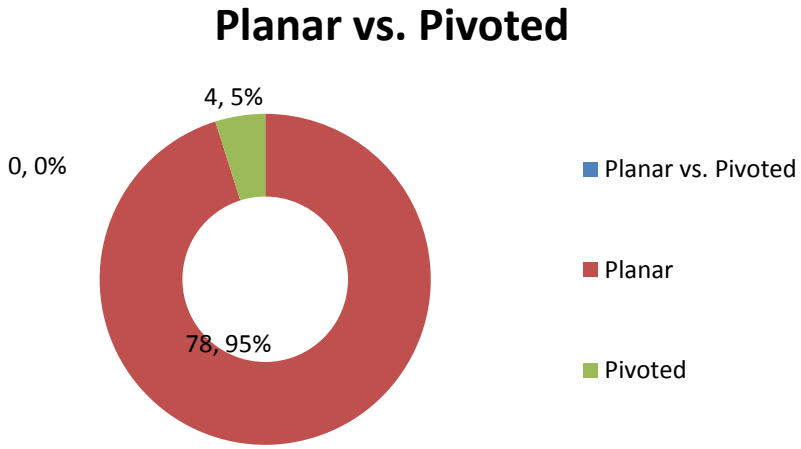


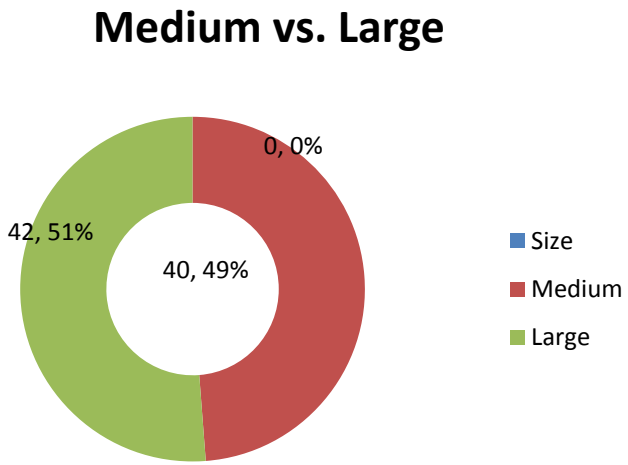
Larger Circle Size = Higher Incidence Rate

Rate based on 100 NBL Runs (600hrs)

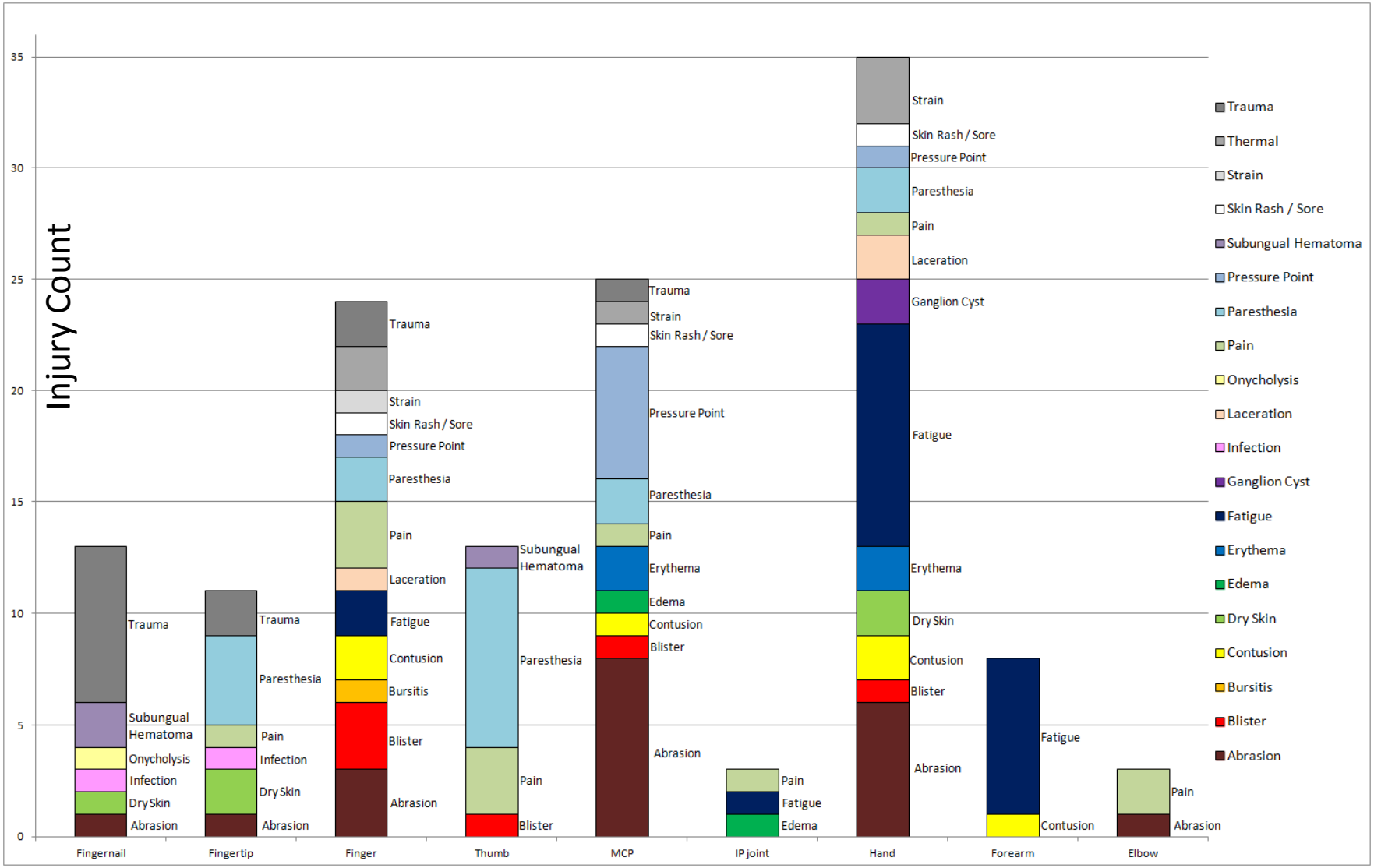
HUT Type and Size Distribution



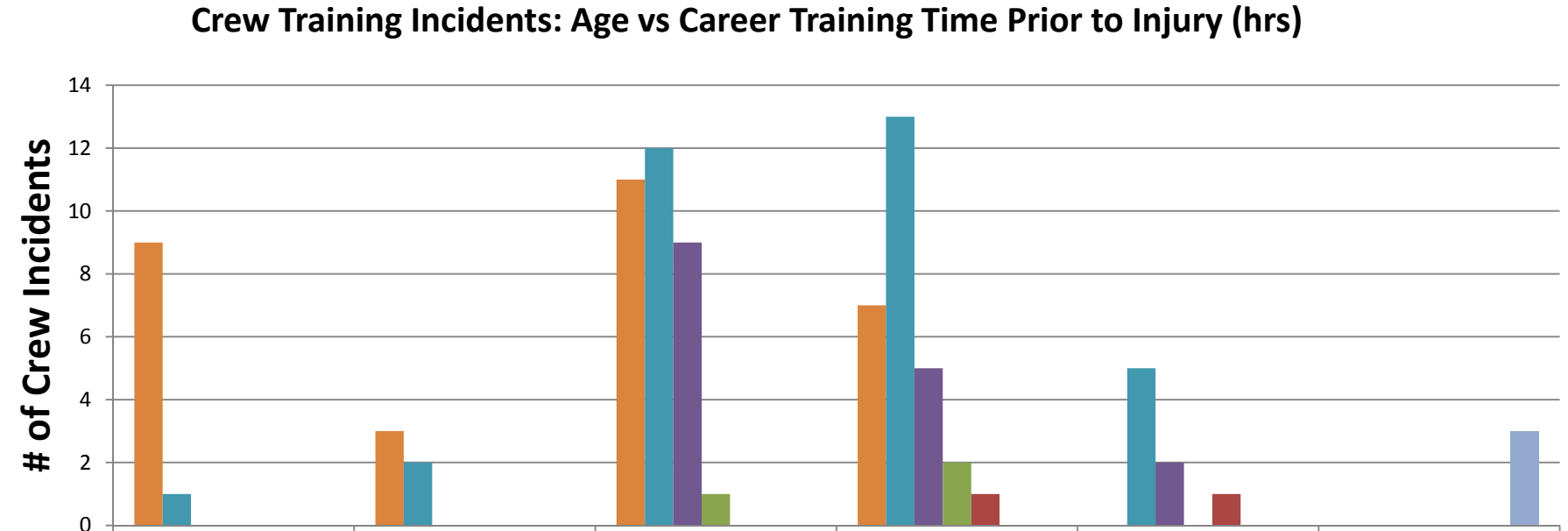




EVA Injury Data



Age vs. Career Training Time Prior to Injury

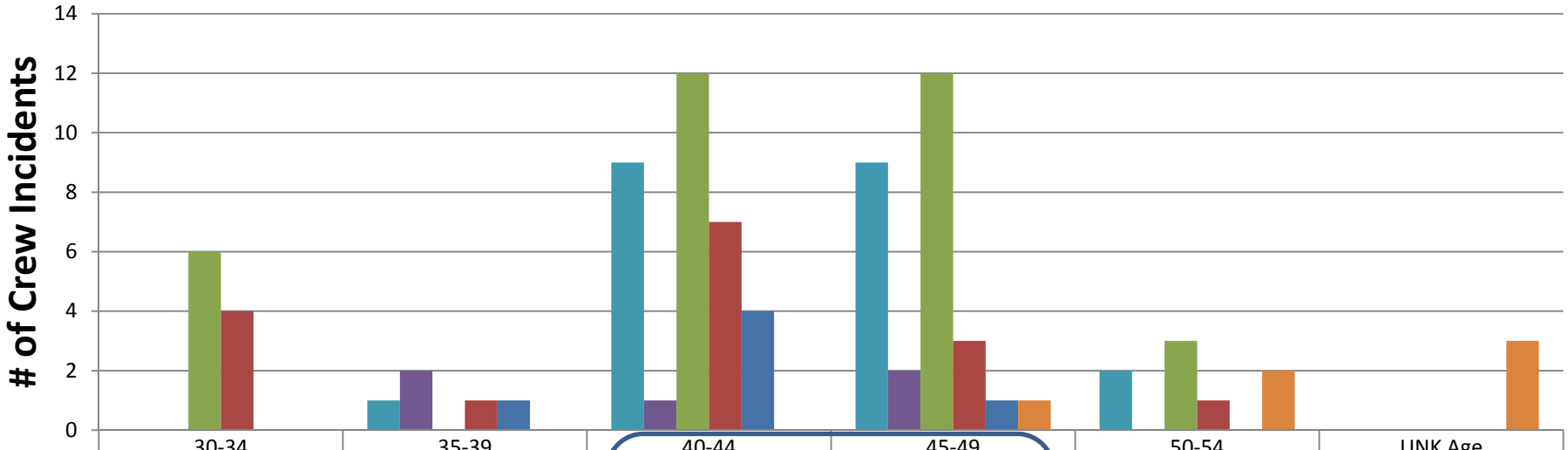


Career Hrs	30-34	35-39	40-44	45-49	50-54	UNK Age
<100	9	3	11	7	0	
100-299	1	2	12	13	5	
300-499	0	0	9	5	2	
500-699	0	0	1	2	0	
700-899	0	0	0	1	1	
900+	0	0	0	0	0	
UNK	0	0	0	0	0	3

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)



Trn Hrs	30-34	35-39	40-44	45-49	50-54	UNK Age
0	0	1	9	9	2	
1-4	0	2	1	2	0	
5-10	6	0	12	12	3	
11-20	4	1	7	3	1	
21-30	0	1	4	1	0	
UNK	0	0	0	1	2	3

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