Musculoskeletal Injuries in US Astronauts

Injury prevention strategies, including pre-flight EVA fitness training, return to flight following injuries, and post-flight reconditioning

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Bethesda, MD
MSK Medicine and Rehabilitation Program

• Background
• Terrestrial experience
  – Initial investigation into MSK injuries
  – MSK Medicine Program
  – Training injuries
  – NBL EMU Work Hardening Program
  – Return to duty
  – Post-flight reconditioning program
• Inflight musculoskeletal conditions
• Lunar Surface Operations
• Post-flight injuries

Colliding galaxies, Hubble Space Telescope, March, 2016
Terrestrial experience

- First study to look at terrestrial-based musculoskeletal injuries in US astronauts
- Genesis of the Astronaut Strength, Conditioning and Rehabilitation (ASCR) specialists

Musculoskeletal Injury Review in the U.S. Space Program

Richard T. Jennings, M.D., M.S., and James P. Bagian, M.D.

In the past, terrestrial-based musculoskeletal injuries in US astronauts have been a major concern for both astronauts and researchers. The first study to look at terrestrial-based musculoskeletal injuries in US astronauts was conducted in the early 1990s. The Genesis of the Astronaut Strength, Conditioning and Rehabilitation (ASCR) specialists is a significant milestone in the study of musculoskeletal injuries in space. This study was presented at UCSD Ortho Grand Rounds on September 9, 2018.
## Fractures and physical activities associated with fractures

<table>
<thead>
<tr>
<th>Fractures</th>
<th>Physical Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ribs 5</td>
<td>Running 7</td>
</tr>
<tr>
<td>Tibia 4</td>
<td>Snow Skiing 4</td>
</tr>
<tr>
<td>Fingers 3</td>
<td>Basketball 2</td>
</tr>
<tr>
<td>Toes 3</td>
<td>MVA 2 (1 motorcycle)</td>
</tr>
<tr>
<td>Metatarsal 2</td>
<td>Household 2</td>
</tr>
<tr>
<td>Radius 2</td>
<td>Softball 1</td>
</tr>
<tr>
<td>Medial Malleolus 1</td>
<td>Water Skiing 1</td>
</tr>
<tr>
<td>Talus 1</td>
<td>Horse 1</td>
</tr>
<tr>
<td>Fibula 1</td>
<td>Soccer 1</td>
</tr>
<tr>
<td>Metacarpal 1</td>
<td>Training 1</td>
</tr>
<tr>
<td>Os calcis 1</td>
<td>Other than Athletic 4</td>
</tr>
<tr>
<td>Humerus 1</td>
<td></td>
</tr>
<tr>
<td>Face 1</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fractures</th>
<th>Physical Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee 19</td>
<td></td>
</tr>
<tr>
<td>Neck and low back 8</td>
<td></td>
</tr>
<tr>
<td>Shoulder 2</td>
<td></td>
</tr>
<tr>
<td>Ankle 1</td>
<td></td>
</tr>
<tr>
<td>Foot 1</td>
<td></td>
</tr>
</tbody>
</table>

### Orthopedic surgeries in US astronauts

1\textsuperscript{J} Jennings RT, Bagian JP. *Aviation, Space, and Environmental Medicine*; Vol 67, No. 8 9 August 1996
CONCLUSION

“NASA astronauts are generally competitive and desire fitness. Athletic activities that result in fitness are associated with a certain risk of injury due to accident, overuse, or training injury. Dependence on self-regulated training, running, and competitive sports for conditioning has resulted in a relatively high level of injury and subsequent orthopedic surgery in this very small group. Even though the outcome of these injuries has generally been favorable, with minimal permanent physical deficits, it is probably time to move beyond documentation of injuries and treatment to providing a program that strives to prevent or mitigate training related injury. Several changes could assure a better outcome. Among these are the employment of fulltime training staff for preflight, inflight, and post-flight conditioning/rehabilitation, cross training, and less reliance on running. The addition of a lap pool for swimming would be helpful for providing a more rational method to insure preflight total fitness as well as post-flight variably weighted rehabilitation.”

Richard Jennings, MD Jim Bagian, MD, August, 1996.
MSK Medicine and Rehabilitation Program

• Objectives
MSK Medicine and Rehabilitation Program

• Space Act Agreement
  – Orthopedic Surgery and Primary Care Sports Medicine Program at Methodist Hospital
  – Weekly orthopedic clinic at JSC
• Revise and update the astronaut selection standards
• Certification in Musculoskeletal Ultrasound
Center of Excellence

ATHLETIC TRAINING BEYOND THE ATMOSPHERE
A condition seen for physical demands at the “Final Frontier”
BY JANIE McQUE

9-Sep-18
UCSD Ortho Grand Rounds
MSK Medicine and Rehabilitation Program

**Benefits**
- Identify risk factors for injury
- Diagnosis and treatment kept “in-house”
- Improved injury reporting and tracking
- **Limit off-site time** in orthopedic consults unless deemed necessary for surgery
- Provide cutting edge orthopedic care

**And…**
Orthopedic Consults at NASA since 2012

- Total orthopedic consults seen in the Wednesday clinic from 2012-current (March, 2016)
  - 246 total visits*
    - 180 “new” pts
    - 66 follow up visits
  - Astronaut time (estimated)
    - BTW 832-1,248 hrs
  - Cost (if NASA were billed)
    - Total cost (savings) to NASA:
      > $140,000

*estimated
Musculoskeletal Ultrasound (MSK US)

• Incorporation of musculoskeletal ultrasound in diagnosis and treatment
• Collaborations
  – Detroit Medical Center
  – Mayo Clinic
  – Andrews Institute
Astronaut Training Injuries

- Activities
  - Neutral Buoyancy Lab
  - T-38 flight operations
  - Parabolic flight a.k.a. Vomit Comet
  - Analog environments
  - Physical fitness training
Extravehicular activity Mobility Unit (EMU) Training Injuries

- **Shoulder**
  - rotator cuff tendonitis, SASD bursitis, LHBT tenosynovitis, SLAP lesion, impingement syndrome, anterior impingement (subscapularis), AC joint pain, GH joint pain
- **Elbow**
  - lateral epicondylitis, radial/cubital tunnel syndromes
- **Forearm/wrist**
  - Dequervan’s tenosynovitis, Extensor Pollicis Longus (EPL) tendonitis, carpal tunnel syndrome
- **Fingers**
  - onycholysis
- **Spine**
  - cervical, thoracic strain, lumbar spasm
Upper extremity conditions related to EMU NBL training

Normal right EPL in SAX, and abnormal left EPL.
Normal right CET in LAX, and abnormal left CET.

- 3rd dorsal (extensor) compartment (EPL)
- Common extensor tendon (CET) tendinosis
Number of Reported Shoulder Injuries & Surgeries by Year

Data courtesy of Mitzi Laughlin, PhD. LSAH epidemiology group.

MSK Injury Prevention Program initiated

Shuttle Program Ends
• Shoulder experts (Orthopedic surgeons, PM&R specialists, Biomechanists) provided several recommendations for mitigating NBL EVA training shoulder injuries

NASA Shoulder Injury TIM Recommendations

03-Dec-2012
Neutral Buoyancy Lab (NBL)
Sonny Carter Training Facility
Houston, TX

A Shoulder Injury Technical Interchange Meeting (TIM) was convened on December 3, 2012 to identify problems associated with the current Extravehicular Activity (EVA) Mobility Unit (EMU) suit and discuss measures for improving the screening methods and treatment for shoulder injuries. The panel agreed with the shoulder injury mitigation steps that have already been implemented by NASA, including:

a) Prioritizing training in the pivoted hard upper torso (HUT) for astronauts at risk,
b) Consider performing EVA “Super Fit Checks” for incoming ASCANs before shoulder injuries occur,
c) Removing EVA suit upper arm during NBL EVA donning/doffing,
d) Further reductions in inverted body position time in the NBL,
e) Maintaining the interval between NBL EVA training runs to no sooner than one week
f) Improve compliance with the NBL post-run icing for shoulders and elbows.

The following list of recommendations was compiled by the panel for potential mitigation of injuries while training in the EMU suit and categorized as operational (O), research (R), or selection standard (S) recommendations.

1. Non-contrast MRI screening of shoulder should be performed during final astronaut selection. Full thickness rotator cuff tears are disqualifying. Other shoulder conditions should be addressed on a case-by-case basis with a board-certified orthopedic surgeon. (S)

2. Formal range of motion and strength assessment should be conducted by the musculoskeletal/sports medicine team lead physician in conjunction with a board-certified orthopedic surgeon for final astronaut selection. (S)

   a. Investigate the use of isokinetic testing to objectify strength and endurance capabilities
NBL EMU Shoulder Injury Prevention Program

• 17 mitigation strategies
NBL EMU Shoulder Injury Prevention Program

- Remove lower arm assembly to prevent doff/don injuries
- Feedback has generally been favorable for decreasing shoulder/elbow stresses
- Not performed on -orbit
Conclusions

• Since 2010, when the MSK Injury Prevention Program was initiated
  – Reported shoulder injuries have increased but that means more injuries are getting evaluated and ultimately treated.
  – On average, shoulder surgeries have decreased slightly but this was non-significant.
What does an astronaut need to be able to do, physically, in the EMU during an NBL run, to perform the function?

- In terms of:
  - Endurance/stamina
  - Strength (force/time)
  - Range of motion
  - Position of the body relative to the task

“The best training for performing EVA in the NBL is actually doing EVA in the NBL.”

Astronaut Suni Williams, CAPT, USN
• Match physical fitness training with NBL tasks to improve EVA performance (from ASCRs)
  • **Grip tasks** - kettlebell swings, dumbbell crawl
  • **Shoulder tasks** - handstand push-ups, push press, Farmer’s walk
  • **Core/Back** - RDL’s, axle-wheel row, back extensions
  • **Articulating portable foot restraint (APFR) ingress** - Squats, lunges, box jumps
  • **Inverted operations** - Windmills, battle ropes, overhead bag toss

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**NASA EVA Functional Capacity Evaluation (FCE) and Work Hardening Program Development Effort Summary**

16 Sept 2013

In attendance:

CR: Sarina Amin, Dan Borback, Tracy Caldwell-Dyson, Amy Ellis, Pat Forsythe, Nicole Stotz, Peg Whitson, Suvi Williams

DG: Jordan Lindsey, Paul Dunn

SD: Jamie Chastain, Joe Devay, David Heisler, Smith Johnston, Eric Kersten, Jim Locke, Bruce Nesmith, Rick Scharrer, Bill Taver

SK: Lori PHOTO-SYNK, Jamie Guinnel

X: Jessica Mclanahan

I. Definitions

a. **Functional Capacity Evaluation (FCE):**
   i. A comprehensive functional test designed to measure the maximum safe functional abilities of an employee across a broad range of physical capabilities.

b. **Work Hardening (WH):**
   i. A program designed to improve the employee’s strength, flexibility, and aerobic condition/condition through exercises and activities that simulate or include the actual job functions.

II. Background

a. **Recommendations from NASA EMU Shoulder Injury TIM, Dec. 2012:**
   i. Develop an NBL functional capacity evaluation (FCE) for selection and operational evaluation by the ASCRs.
   ii. Develop a supervised mandatory rotate cuff and angular stabilizer training program to be conducted within 6 months of initial NBL run, with a pre-run fitness check.
   iii. Develop a “work hardening” program, to be performed on land before NBL training and following rehabilitation for injury or surgery.

b. **Crew input regarding EVA Fitness Program**
   i. General comments: the EVA fitness program should include activities that improve suited performance in the NBL along with activities that prevent injury.
   ii. The current exercise program prepares astronauts well for most NBL activities. Note that the best physical training program for NBL activities is actually being in the EMU in the pool.
   iii. Shoulder flexibility for suited operations is very important, especially external and internal rotation.
   iv. Need to be able to push oneself physically in the pool. Therefore exercise programs should include activities that demand stamina training as well as strength.

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**UCSD Ortho Grand Rounds**
<table>
<thead>
<tr>
<th>MONDAY</th>
<th>TUESDAY</th>
<th>WEDNESDAY</th>
<th>THURSDAY</th>
<th>FRIDAY</th>
</tr>
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<tbody>
<tr>
<td><strong>WARM UP EXERCISE</strong></td>
<td><strong>WARM UP EXERCISE</strong></td>
<td><strong>WARM UP EXERCISE</strong></td>
<td><strong>WARM UP EXERCISE</strong></td>
<td><strong>HIGH VOLUME ENDURANCE</strong></td>
</tr>
<tr>
<td>20-15-10</td>
<td>3 Rounds</td>
<td>4 Rounds</td>
<td>3 Rounds</td>
<td><strong>Grind</strong></td>
</tr>
<tr>
<td>Pull Ups</td>
<td>15 Thrusters</td>
<td>25 Air Squats</td>
<td>10 Push Press</td>
<td>Every 30 secs</td>
</tr>
<tr>
<td>Dips</td>
<td>15 Push ups</td>
<td>15 Pushups</td>
<td>5 Knee to Elbow</td>
<td>2 burpees + 5 Dips for 10 rounds</td>
</tr>
<tr>
<td>Walking Lunges (on 15+1)</td>
<td></td>
<td></td>
<td></td>
<td>Then</td>
</tr>
<tr>
<td><strong>STRENGTH &amp; SKILL</strong></td>
<td><strong>ENERGY SYSTEM DEVELOPMENT</strong></td>
<td><strong>STRENGTH &amp; SKILL</strong></td>
<td><strong>ENERGY SYSTEM DEVELOPMENT</strong></td>
<td></td>
</tr>
<tr>
<td>Then Super Set: Deadlifts (Heavy) &amp; Hammer Row: 3 x 12, 4th set AMAP Presses</td>
<td>Aerobic System</td>
<td>Then Super Set: Dumbbell Bench Press &amp; Shrugs 3 x 12, 4th set AMAP</td>
<td>ATP-CP (Phosphagen System)</td>
<td></td>
</tr>
<tr>
<td>Treadmill- 5’ @30-50% Max HR, 4’ 80%, 3’ 30-50%, 4’ 80%, 3’ 30-50%, 4’ 80%, 3’ 30-50%, 4’ 80%, 5 min 30%.</td>
<td></td>
<td>Then 10 Rounds of Jacobs Ladder with weighted vest (1 min fast climb, 20 secs rest)</td>
<td>10 Pushups</td>
<td></td>
</tr>
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<td><strong>FINISHER WORKOUT</strong></td>
<td><strong>FINISHER WORKOUT</strong></td>
<td><strong>FINISHER WORKOUT</strong></td>
<td><strong>FINISHER WORKOUT</strong></td>
<td><strong>FINISHER WORKOUT</strong></td>
</tr>
<tr>
<td>As Many Rounds as Possible in 20 Minutes of:</td>
<td>Row 800</td>
<td>Row 800</td>
<td>Row 800</td>
<td>1 Lap Framers Walk</td>
</tr>
<tr>
<td>10 Push Ups</td>
<td>21 Renegade Man Makers</td>
<td>15 Renegade Man Makers</td>
<td>Band Pull Apart Stayin’ Alive</td>
<td>Then</td>
</tr>
<tr>
<td>10 Front Squats</td>
<td><strong>SHOULDER MAINTENANCE</strong></td>
<td>10 rounds</td>
<td><strong>SHOULDER MAINTENANCE</strong></td>
<td>10 rounds</td>
</tr>
<tr>
<td>10 Weight Sit Ups</td>
<td><strong>CORE DEVELOPMENT</strong></td>
<td><strong>CORE DEVELOPMENT</strong></td>
<td><strong>CORE DEVELOPMENT</strong></td>
<td><strong>CORE DEVELOPMENT</strong></td>
</tr>
<tr>
<td>2x10: 3 Way Scarecrow (palms up, palms in and palms out) 5 lbs DB max</td>
<td>2x10: Kneeling &quot;Bottoms Up&quot; Kettlebell Press (10 each arm)</td>
<td>9 Renegade Man Makers</td>
<td>3 x 30-45 sec holds Reverse Plank</td>
<td></td>
</tr>
<tr>
<td>2x10: Shoulder Slides w/ towel, 2x10: Plank Shoulder Taps (1 tap each side = 1)</td>
<td></td>
<td>Renegade Man Makers are DB burpees (with no jump) to a Push-</td>
<td>2x10 Wood Chopper/Hay Baler w/ med ball</td>
<td></td>
</tr>
<tr>
<td>2x10: Front Plank hip dips (1 tap each side = 1)</td>
<td></td>
<td></td>
<td>4 x Plank Walks 3 steps forward, 3 steps backwards</td>
<td></td>
</tr>
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<td></td>
<td></td>
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</tr>
<tr>
<td><strong>10 MINUTES OF STRETCHING / FOAM ROLLER</strong></td>
<td><strong>10 MINUTES OF STRETCHING / FOAM ROLLER</strong></td>
<td><strong>10 MINUTES OF STRETCHING / FOAM ROLLER</strong></td>
<td><strong>10 MINUTES OF STRETCHING / FOAM ROLLER</strong></td>
<td><strong>10 MINUTES OF STRETCHING / FOAM ROLLER</strong></td>
</tr>
</tbody>
</table>
NBL EMU Work Hardening Program

Stack translation

Dumbbell “astronaut” crawl

Axle-wheel row
NBL EMU Work Hardening Program

Windmills
Musculoskeletal Injuries in US Astronauts and Return to Duty

- Aerospace Medical Board (AMB)
  - Standards for astronaut selection, retention and approval for long duration spaceflight
<table>
<thead>
<tr>
<th>REGION</th>
<th>TYPE OF INJURY</th>
<th># OF CASES</th>
<th>SURGERY?</th>
<th>RTD</th>
<th>AMB WAIVER REQUIRED?</th>
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</thead>
<tbody>
<tr>
<td>Shoulder</td>
<td>Rotator cuff tear-full thickness</td>
<td>4</td>
<td>Yes</td>
<td>T-38, NBL six months, SF one year</td>
<td>No</td>
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<tr>
<td></td>
<td>Rotator cuff tear-partial thickness</td>
<td>3</td>
<td>No</td>
<td>T-38, NBL six weeks, SF three months</td>
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<tr>
<td></td>
<td>SLAP lesion Grade 2-4</td>
<td>3</td>
<td>Yes</td>
<td>T-38 three months, NBL six months, SF one year</td>
<td>No</td>
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<tr>
<td></td>
<td>SLAP lesion Grade 1</td>
<td>2</td>
<td>No</td>
<td>T-38, NBL, SF three months</td>
<td>No</td>
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<tr>
<td></td>
<td>Biceps tendon tear</td>
<td>2</td>
<td>Yes</td>
<td>T-38, NBL three months, SF six months</td>
<td>No</td>
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<tr>
<td></td>
<td>Acromioclavicular joint</td>
<td>3</td>
<td>Yes</td>
<td>T-38, NBL three months, SF six months</td>
<td>No</td>
</tr>
<tr>
<td>Knee</td>
<td>Medial Collateral Ligament Sprain</td>
<td>6</td>
<td>No</td>
<td>SF six weeks</td>
<td>No</td>
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<tr>
<td></td>
<td>Medial, Lateral Meniscus tear</td>
<td>6</td>
<td>Yes</td>
<td>T-38 three weeks, NBL six weeks, SF*</td>
<td>No</td>
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<tr>
<td></td>
<td>Meniscus w/o repair</td>
<td>1</td>
<td>No</td>
<td>T-38, NBL, SF six weeks</td>
<td>No</td>
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<tr>
<td></td>
<td>Anterior Cruciate Ligament tear- complete</td>
<td>2</td>
<td>Yes</td>
<td>T-38, NBL six months, SF one year</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Anterior Cruciate Ligament tear- partial</td>
<td>1</td>
<td>No</td>
<td>T-38, NBL, SF six weeks</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Osteoarthritis w/o replacement</td>
<td>3</td>
<td>Yes</td>
<td>T-38, NBL six months, SF six weeks</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Osteoarthritis w/ replacement</td>
<td>2</td>
<td>Yes</td>
<td>T-38, NBL six months, SDSF one year</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Unpublished data, courtesy Rick Scheuring, DO, MS, 2013

UCSD Ortho Grand Rounds
In-flight MSK Conditions

**Known**
- From STS-1 and STS-89 there was a greater *in-flight* injury rate among crewmembers than their age and sex-matched cohorts

**Unknown**
- The incidence, type and mechanism of in-flight injuries for US astronauts across all mission programs (Mercury to 2010)

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**Musculoskeletal Injuries and Minor Trauma in Space: Incidence and Injury Mechanisms in U.S. Astronauts**

Richard A. Schembri, Charles H. Mathews, Jeannie A. Monse, and Mary L. Wolf

**RESEARCH ARTICLE**

In-flight MSK Conditions

**UCSD Ortho Grand Rounds**

9-Sep-18
In-flight MSK US

- Used to diagnose musculoskeletal injuries and guide treatment plans and predict return to duty timeframe
  - Recurrent knee pain
  - Hamstring strains
  - Finger dislocations
  - Foot trauma related to CEVIS
  - EMU doffing injury
  - Low back pain/injury
  - Cervical spine pain
Results

Location of Injuries

Number of Injuries

Hand
Back
Shoulder
Foot
Arm
Leg
Head
Neck
Knee
General
Trunk
Hip
Wrist
Groin
Face
Finger

9-Sep-18
UCSD Ortho Grand Rounds
Results

- EVA accounted for an incidence rate of 0.26 injuries per EVA.
  - EVA injuries occurred primarily in the hands and feet
  - These injuries may represent an exacerbation of pre-flight injury during training in the Neutral Buoyancy Laboratory
  - Shoulder SLAP lesion occurred during suit doffing after second EVA
In-flight MSK Conditions cont’d…

• Definition of SABP
  - Symptoms are not precipitated by an injury or related to prolonged recumbent sitting on the launch pad
  - Symptoms develop within the first 5 days of space flight
  - Multiple days of in-flight back pain were considered as one case
SABP Characteristics

- Symptoms are usually mild to moderate
- Symptoms are usually localized to the lumbar region
- Symptoms are described as an ache or stiffness
- Symptoms typically occur during the sleep period
- Neurological symptoms (radicular pain, numbness, tingling) are absent
- Symptoms tend to improve or resolve with the use of bending the knees to the chest, stretching of the lumbar spine, or anti-inflammatory medication
SABP is present in the early phase of spaceflight, with a peak prevalence on FD 2 and none reported after FD12.
SABP Intensity

Pain Intensity

- Mild pain: 86%
- Moderate pain: 11%
- Severe pain: 3%

9-Sep-18
UCSD Ortho Grand Rounds
SABP Location

Back Pain Location

- Lumbar: 86%
- Thoracic: 12%
- Cervical: 2%

9-Sep-18
UCSD Ortho Grand Rounds
Conclusions

• The incidence of SABP has been determined to be 53% among astronauts in the U.S. space program

• Most cases of SABP are mild, self-limited, or respond to available treatments

• There are no currently accepted preventive measures for SABP

• It is difficult to predict who will develop SABP

• The precise mechanism and spinal structures responsible for SABP are uncertain

• There was no documented evidence of direct operational mission impact related to SABP

• There is potential mission impact related to uncontrolled pain, sleep disturbance, or the adverse side effects of anti-inflammatory medications
Post-flight reconditioning

- Dynamic stretching and warm-up: R+0d
- **Mobialanception**: R+0d
- Medicine ball: R+0d
- Ladder and cone drills: R+7d
- Jumping drills: R+21d
- Core exercises: R+1d
- Static stretching: R+0d
Physiological Issues in Partial Gravity*

- Apollo lunar crews adapted quickly to the 1/6g environment
  - Initial unsteady gait related to EVA suit CG issues *not* neurovestibular dysfunction
  - Forearm and upper extremity fatigue attributed to glove design
  - Inadequate sleep, dietary caloric intake experienced by most crewmembers
  - Other physiologic function (cardiovascular, bone) unknown

Lunar MSK Conditions

• Apollo Lunar Surface Musculoskeletal Events or Minor Trauma
  – 9 Events were reported on the lunar surface related to EVA
    • 5 events located in the hand
    • 2 events occurred in the wrist
    • 1 event resulted in shoulder strain after EVA 2/3
    • 1 event described as general muscle fatigue while covering large distances by foot on the lunar surface

H. Schmitt, Apollo 17 Video courtesy of NASA
• Apollo Lunar Surface
Musculoskeletal Events or
Minor Trauma

– MCP, distal phalanx pain, swelling and abrasions after
lunar 3/3 EVA
  • “Completing a subsequent EVA would have been
very difficult on account of how sore and swollen
my hands were”

– 2 events occurred in the wrist
  • Wrist laceration due to suit wrist ring cutting into skin
  • Wrist soreness where suit sleeve repetitively rubbed
on surface

– 1 event resulted in shoulder strain after EVA 2/3
  • Crewmember injured shoulder during surface drilling
activity
    – Required large doses of aspirin to relieve pain
Post-flight MSK Conditions

- Herniated nucleus pulposus (HNP)
- Lumbar back pain
- Soyuz landing injuries
Post-flight MSK Conditions

Risk of Herniated Nucleus Pulposus Among U.S. Astronauts

Herniated Nucleus Pulposus (HNP) is usually secondary to degenerative disc disease, although some factors are probably idiopathic. The peak incidence is between 35 and 55 years old. Herniation of the nucleus pulposus due to disc material is a postero-lateral direction, causing compression of the nerve root. The presence of the posterior longitudinal ligament in both the cervical and lumbar region makes the occurrence of direct central extension of disc material into the spinal canal less likely. When disc herniation occurs, compression of the spinal cord or cauda equina can occur. The intervertebral disc is formed by the annular nucleus pulposus, the outer annulus fibrosus, and the cartilaginous vertebral end plates. Each of the structures consists primarily of collagen, proteoglycans, and water.

RESEARCH ARTICLE

Fluid shifts occur readily, with the disc expanding during bed rest and contracting during normal loading. The annulus fibrosus is the main primary pathologic change due to destructive stress during axial loading and flexion, which is the strategy for herniation. The nucleus pulposus usually herniates at the posterosentral corner, resulting in pressure on the spinal cord or nerve root, which can cause pain or neurological deficits.

Several studies have suggested that an increase in HNP is associated with high G environments in high performance aircraft or in the vertical axis of helicopters. In high G environments, degenerative changes can be seen in the vertebrae, which can lead to changes in the nucleus pulposus. These changes can result in changes in the nucleus pulposus due to high performance or aircrafts.

Although fewer cases of HNP are suspected in high G environments, degenerative changes are still seen in the vertebrae, which can result in changes in the nucleus pulposus due to high performance or aircrafts. However, MRI abnormalities are seen in asymptomatic patients and are not necessarily indicative of a higher risk of HNP.

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Smith L. Johnston, Mark R. Campbell, Rich Schrueer, and Alan H. Tucker

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Results

- HNP incidence is not related to in-flight back pain (SABP)
- More multiple events in astronauts
- No correlation with BMI or Age or Time Period
- Slightly less incidence with women (both astronauts and controls), same statistical results
Intraoperative Observation

• Mechanism of nucleosis pulposus herniation
Conclusions

- Astronauts have a greatly increased incidence of HNP (4.3 X)
- Risk is greatest immediately following space flight (35.9 X during the first year post-mission)
- The risk of cervical HNP is especially high (21.4 X), not related to previous High Gz experience
- Pre-mission astronauts have an increased incidence of HNP due to previous High Gz environment experience
Recommendations of the NASA IVD Summit (May 2009)

- Minimize axial loading first 48 hrs post-landing
- Minimal and protected ambulation first week post-landing
- Pre-flight neck muscle strengthening is of only speculative benefit
- In-flight countermeasures would likely not be effective with our current capability (need sustained axial loading)
USOS Soyuz Injuries (continued)

The following injuries were reported in the Electronic Medical Records and/or in the Space Medicine Operational Team tags.

Note: Some crew have experienced more than one injury. 9 of 24 crew have experienced at least one injury.

- **4 cases of nerve trauma requiring follow-up**
  - Mild left radial nerve distribution pattern reduction without evidence of acute or chronic denervation
  - Muscle fasciculation ("shivering" of lower extremities) lasting for approximately 2 hours
  - Meralgia paresthetica, i.e. Lateral femoral cutaneous nerve (LFCN) entrapment*

- **1 case of retinal ischemia** – requiring medical follow-up – no treatment
  - Retinal ischemia, right eye – vision not affected
Soyuz Injuries – Summary Chart

**Injuries due to Soyuz Landings - Expeditions 6 – 30,**
US Crews Only – 24 Individuals

All Injuries resolved within 3 months post landing.

- Minor bruising
- Muscle skeletal injuries
- Nerve trauma
- Miscellaneous

No Follow-up treatment

Follow-up Physical Therapy

Medical Follow-up

Note: Some crew members had multiple injuries. 9 of 24 experienced an injury.
Meralgia Paresthetica


Future Considerations
Injuries to Crewmembers during Nominal Operation of Soyuz Landing Systems Bibliography Травмы членов экипажа во время спуска на КК Союз


Seoul, South Korea. Первый Ю. Корейский астронавт госпитализирован в больнице с болями в спине. Сеул, Южная Корея.


