Musculoskeletal Injuries in US Astronauts

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

Rick Scheuring, DO, MS, RMSK, FAsMA
Team Lead, Musculoskeletal, Sports Medicine and Rehabilitation
Flight Surgeon
NASA-Johnson Space Center

Associate Professor
Uniformed Services University of the Health Sciences
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. BAGIANI, M.D.

NASA ASTRONAUTS are informally expected to maintain a certain degree of fitness to perform their critical duties. As with all physical training programs, some risk is associated with exercise, even where appropriately supervised (6, 9–11, 13, 17, 21). NASA’s fitness program has generally been voluntary and self-directed with minimal coordination of total individual assessment, equipment safety training, or identification of job-related personal fitness targets. Post-flight acclimation science data collection has actually been associated with causing some injuries. There has been no postflight rehabilitation program during the shuttle era until the advent of the long duration flights in the MIR space station.

The lack of a coordinated fitness and rehabilitation program has resulted in reliance on self-motivation and formally competitive athletics, unsupervised gym activity, and running the preflight aerobic and strength conditioning and postflight rehabilitation. This approach may not be totally casual, but has been associated with a concerning number of orthopaedic injuries, surgical procedures, and lost work and training time. This article reviews the NASA astronaut orthopaedic injury statistics from 1987–95, examines the U.S. and Russian approaches to crew fitness, and suggests potential improvements to the astronaut training and rehabilitation program.

METHODS

All NASA astronauts receive their health care through the Flight Medicine Clinic (FMC) at the Johnson Space Center. During the period between January 1992 and March 1995, all reported injuries seen at the FMC were recorded in a database as to the injury, cause, and subsequent treatment. The number of active astronauts during the 36-month study period varied from 45–99, with a mean corps size of 94. The number of female astronauts ranged from 12–19, except for March 1995 when there were 22. The women’s mean age during the study was 45. All injuries, including those requiring surgical interventions, were supervised by the flight surgeons at the FMC, although specialist referrals were provided when appropriate. Astronauts who were assigned to flights during the period were prohibited from participating in some activities such as lifting, softball, or contact sports. About one-half of the active astronauts are assigned to flights at any one time. Injuries resulting from two aircraft accidents that caused two astronauts to be not included in the study.

RESULTS

There were 26 events that resulted in fractures. The location and number of separate occurrences are listed below:

<table>
<thead>
<tr>
<th>Location</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rib</td>
<td>8</td>
</tr>
<tr>
<td>Tibia</td>
<td>4</td>
</tr>
<tr>
<td>Finger</td>
<td>3</td>
</tr>
</tbody>
</table>

From the University of Texas Medical Branch, Galveston, TX. This manuscript was received for review in July 1995, revised and accepted for publication in December 1995. Address reprint requests to: Richard T. Jennings, M.D., Astronaut Office, Space Station Freedom, Astronaut Office, Glover Building, Unit 34, Code 215, Houston, TX 77058. Copyright © by Aerospace Medical Association, Arlington, VA.
Terrestrial MSK Injury in US Astronauts

Fractures and physical activities associated with fractures

<table>
<thead>
<tr>
<th>Fractures</th>
<th>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>

Knee 19
Neck and low back 8
Shoulder 2
Ankle 1
Foot 1

Orthopedic surgeries in US astronauts

1Jennings 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

9-Sep-18 UCSD Ortho Grand Rounds
Center of Excellence
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…

Photo courtesy of www.crossfitnewworld.typepad.com
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.
Shoulder experts (Orthopedic surgeons, PM&R specialists, Biomechanists) provided several recommendations for mitigating NBL EVA training shoulder injuries.

- Prioritizing training in the pivoted hard upper torso (HUT) for astronauts at risk.
- Consider performing EVA “Super Fit Checks” for incoming ASCANs before shoulder injuries occur.
- Removing EVA suit upper arm during NBL EVA donning/doffing.
- Further reductions in inverted body position time in the NBL.
- Maintaining the interval between NBL EVA training runs to no sooner than one week.
- 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.
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
<table>
<thead>
<tr>
<th>MONDAY</th>
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<tbody>
<tr>
<td>Up &amp; Back Dynamic Warm-Up Routine</td>
</tr>
<tr>
<td>WARM UP EXERCISE</td>
</tr>
<tr>
<td>20-15-10</td>
</tr>
<tr>
<td>3 Rounds</td>
</tr>
<tr>
<td>Pull Ups</td>
</tr>
<tr>
<td>15 Thrusters</td>
</tr>
<tr>
<td>Dips</td>
</tr>
<tr>
<td>15 Push ups</td>
</tr>
<tr>
<td>Walking Lunges (on 15+1)</td>
</tr>
<tr>
<td>STRENGTH &amp; SKILL</td>
</tr>
<tr>
<td>Energy System Development</td>
</tr>
<tr>
<td>Finishing Workout</td>
</tr>
<tr>
<td>As Many Rounds as Possible in 20 Minutes of:</td>
</tr>
<tr>
<td>10 Push Ups</td>
</tr>
<tr>
<td>10 Front Squats</td>
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<tr>
<td>10 Weight Sit Ups</td>
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<tr>
<td>Core Development</td>
</tr>
<tr>
<td>2x10: Shoulder Slides w/ towel</td>
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<tr>
<td>2x10: Front Plank hip dips (1 tap each side = 1)</td>
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<td>10 MINUTES OF STRETCHING / FOAM ROLLER</td>
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<td>4 Rounds</td>
</tr>
<tr>
<td>25 Air Squats</td>
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<tr>
<td>15 Pushups</td>
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<tr>
<td>10 Half Moons (5 each side)</td>
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<tr>
<td>STRENGTH &amp; SKILL</td>
</tr>
<tr>
<td>Energy System Development</td>
</tr>
<tr>
<td>Finishing Workout</td>
</tr>
<tr>
<td>800 Row</td>
</tr>
<tr>
<td>21 Renegade Man Makers</td>
</tr>
<tr>
<td>2x10: Kneeling &quot;Bottoms Up&quot; Kettlebell Press (10 each arm)</td>
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<td>10 MINUTES OF STRETCHING / FOAM ROLLER</td>
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<td>WARM UP EXERCISE</td>
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<tr>
<td>3 Rounds</td>
</tr>
<tr>
<td>10 Push Press</td>
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<tr>
<td>5 Knee to Elbow</td>
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<td>10 Half Moons (5 each side)</td>
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<tr>
<td>Row 800</td>
</tr>
<tr>
<td>15 Renegade Man Makers</td>
</tr>
<tr>
<td>200 Row</td>
</tr>
<tr>
<td>9 Renegade Man Makers</td>
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<tr>
<td>Hitchiker w/ DBs 5 lbs max</td>
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<tr>
<td>Grind</td>
</tr>
<tr>
<td>10 Pushups</td>
</tr>
<tr>
<td>12 Swings</td>
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<tr>
<td>1 Lap Framers Walk</td>
</tr>
<tr>
<td>STRENGTH &amp; SKILL</td>
</tr>
<tr>
<td>Energy System Development</td>
</tr>
<tr>
<td>Finishing Workout</td>
</tr>
<tr>
<td>800 Row</td>
</tr>
<tr>
<td>200 Row</td>
</tr>
<tr>
<td>10 rounds</td>
</tr>
<tr>
<td>Run or row 100M</td>
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<td>10 MINUTES OF STRETCHING / FOAM ROLLER</td>
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<tr>
<td>Grind</td>
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<tr>
<td>10 Pushups</td>
</tr>
<tr>
<td>12 Swings</td>
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<tr>
<td>1 Lap Framers Walk</td>
</tr>
<tr>
<td>STRENGTH &amp; SKILL</td>
</tr>
<tr>
<td>Energy System Development</td>
</tr>
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<td>Finishing Workout</td>
</tr>
<tr>
<td>800 Row</td>
</tr>
<tr>
<td>200 Row</td>
</tr>
<tr>
<td>10 rounds</td>
</tr>
<tr>
<td>Run or row 100M</td>
</tr>
<tr>
<td>10 MINUTES OF STRETCHING / FOAM ROLLER</td>
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</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</td>
<td>3</td>
<td>No</td>
<td>T-38, NBL six weeks, SF three months</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>thickness</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<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>
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<td>SLAP lesion Grade 1</td>
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<td>T-38, NBL, SF three months</td>
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<td>Biceps tendon tear</td>
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<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>
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<tr>
<td>Knee</td>
<td>Medial Collateral Ligament</td>
<td>6</td>
<td>No</td>
<td>SF six weeks</td>
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<tr>
<td></td>
<td>Sprain</td>
<td></td>
<td></td>
<td></td>
<td></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>
</tr>
<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>
</tr>
<tr>
<td></td>
<td>Anterior Cruciate Ligament</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>tear- complete</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Anterior Cruciate Ligament</td>
<td>1</td>
<td>No</td>
<td>T-38, NBL, SF six weeks</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>tear- partial</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Osteoarthritis w/o replacement</td>
<td>3</td>
<td>Yes</td>
<td>T-38, NBL six weeks</td>
<td>No</td>
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<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)
ISS Medical Capabilities Comparison

- Hospital
- Polar Ops
- Submarine
- Ambulance
- Everest Base Camp

Current Capabilities:
- Diagnostics
- Therapeutics
- Communication
- Evacuation
- Personnel
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

Results
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

Photo courtesy of Drs. Sam Strauss and Jeff Jones, NASA-JSC

Photo courtesy of Dr. Joseph Dervay, NASA-JSC

EVA 32, ISS EXP 35/36, July, 2013
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

Space Adaptation Back Pain: A Retrospective Study

ERIC L. KERSTMAN, RICHARD A. SCHRERING, MATT G. BARNES, TYPHOE A. BURTON, and ANN G. SAILL

RESEARCH ARTICLE

Space Adaptation Back Pain is frequently reported by astronauts in the early phase of spaceflight as they adapt to the microgravity environment (1-5). However, the etiology of space adaptation back pain (SABP) has not been well established. There have been few studies regarding SABP, and the studies that have been performed are of limited scope (14). The exact incidence of SABP among astronauts is unknown. The pathophysiology and operational impacts of SABP also are largely unknown.

In 1997, a retrospective review of the medical records of 54 Shuttle crewmembers was conducted by the Flight Medicine Clinic at NASA Johnson Space Center to determine the incidence of back pain during spaceflight (16). Of the crewmembers, 68% had reported in-flight back pain. To obtain additional information regarding the nature of the reported in-flight back pain, pain questionnaires were completed by 34 Shuttle payload specialists, a subset of the original 54 Shuttle crewmembers. Of the 10 payload specialists, 14 (74%) reported in-flight back pain.

In 1994, a prospective but not study was performed on eight subjects to compare back pain and spinal lengthening during simulated microgravity (6th head-down 10°) with the same parameters during actual microgravity (7). The researchers concluded that back pain in actual and simulated microgravity may result from stretching of the spinal and/or paraspinal tissues until a new spinal length is reached. In 2018, a retrospective study evaluated in-flight musculoskeletal injuries occurring throughout the U.S. space program (9). However, cases of in-flight back pain related to space adaptation were excluded from that study.

The main objective of this study was to determine the incidence of SABP among astronauts in the U.S. space program. A case definition of SABP was developed to facilitate the determination of this incidence. Additional objectives of this study were to delineate the nature and pattern of SABP’s treatment, and its operational impact. To accomplish these objectives, a comprehensive analysis of astronaut mission medical records was performed.

METHODS

All available mission records of astronauts in the U.S. space program from the NASA Johnson Space Center Flight Medicine Clinic were reviewed by the authors. These records included mission summaries, flight surgeon logs, postflight medical exams, postflight medical schemes, and postflight medical debriefs. All missions of the Mercury, Gemini, Apollo, Apollo-Sojourner Test Project (ASTP), and Mir progressed were included in the analysis. International Space Station (ISS) missions from Expedition 1 through Expedition 15 were included in the analysis. All Shuttle missions from STS-1 through STS-122 were reviewed, with the exception of STS-51L (Challenger) and STS-107 (Columbia). For more Shuttle missions, the postflight medical debriefs included a standardized back pain questionnaire. If available, Shuttle medical debriefs were reviewed via electronic data query. If electronic data were not available, paper
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 & Flight Days

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%

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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


G. Cernan, H. Schmitt, Apollo 17 Video courtesy of NASA
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

Introductions: Astronauts have complained of back pain occurring during spacewalks, presumably due to the elongation of the spine from the 10–12% of gravity present on Earth. Herniated nucleus pulposus (HNP) is commonly seen in astronauts exposed to high Gx, and has been diagnosed in several astronauts in the immediate post-spacewalk period. It is unclear whether astronauts are at increased risk of developing HNP in the postflight period compared to their non-flight counterparts. A study was therefore undertaken to evaluate the incidence of HNP in astronauts during the postflight period. Methods: A cohort of 16 non-crew members was evaluated post-flight for 15 years. Of these, 11 had HNP diagnosed. Results: The incidence of HNP was 4.3% higher in the U.S. astronaut population (N = 21, compared to matched controls (N = 23) in a broad sample for spaceflight. Conclusions: For astronauts, there was a difference in the incidence of HNP compared to non-astronauts who were exposed to the same environment. The difference was statistically significant.

Keywords: spaceflight, back pain, back injury, cervical injury, lumbar injury, disc disease, degenerative degeneration, weightlessness.

Herniated Nucleus Pulposus (HNP) is usually a result of degenerative disc disease, although it is thought to be a result of acute trauma. Increased intradiscal pressure due to abnormal disc material can result in degenerative changes and a decrease in the nucleus pulposus. This may result from a tear in the annulus fibrosis or a disruption of the annulus fibrosis or the posterior longitudinal ligament. Herniations in the central and peripheral regions result in symptoms such as radiculopathy, pain, and loss of function. The intervertebral disc is formed by the central nucleus pulposus, the outer annulus fibrosis, and the cartilaginous endplates. Each of these structures consists primarily of collagen, proteoglycans, and water.
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)
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

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

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

All Injuries resolved within 3 months post landing.

Injury Type

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

No Follow-up treatment
Follow-up Physical Therapy
Medical Follow-up

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Meralgia Paresthetica

LFCN

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


