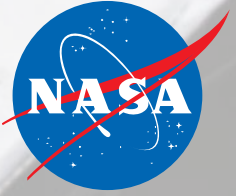


National Aeronautics and
Space Administration



NASA Space Medicine Operations Division



MSK, 400K Away

Rick Scheuring, DO, MS, RMSK, FAsMA

ISS, Program Medical Officer and Lead Physician Musculoskeletal and Rehabilitation Medicine
Colonel, United States Army

Danielle Anderson DPT, DSc, OCS, CSCS, FAAOMPT

Team Lead, Musculoskeletal and Rehabilitation Medicine
Major, United States Air Force



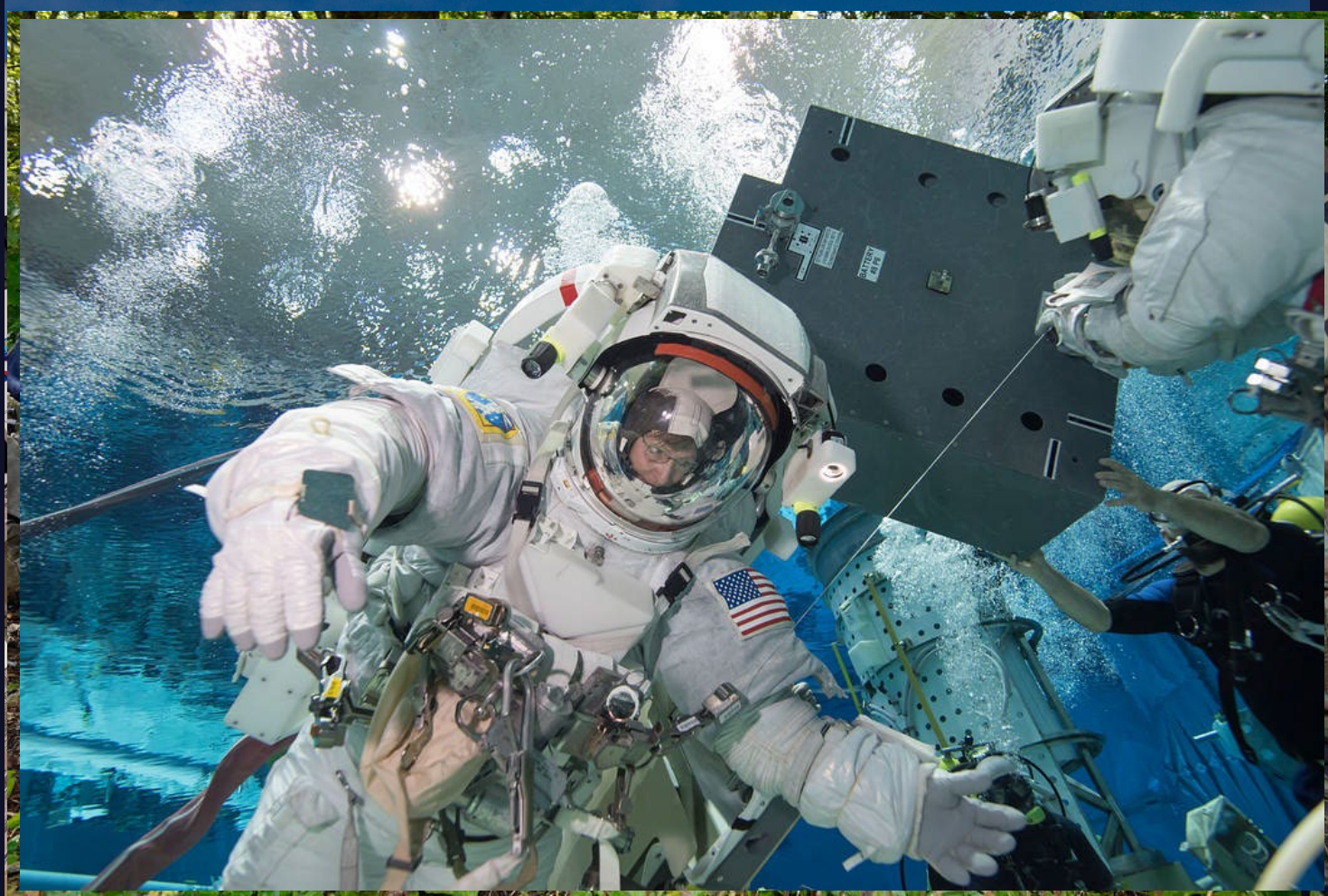
OBJECTIVES

- ① Background, Training, and Operational Demands
- ② Space Physiology and the MSK System
- ③ On Orbit Medical Capabilities and Cases
- ④ Post-flight Reconditioning Considerations
- ⑤ Exploration and MSK Considerations

How do we get to here?



Training Demands

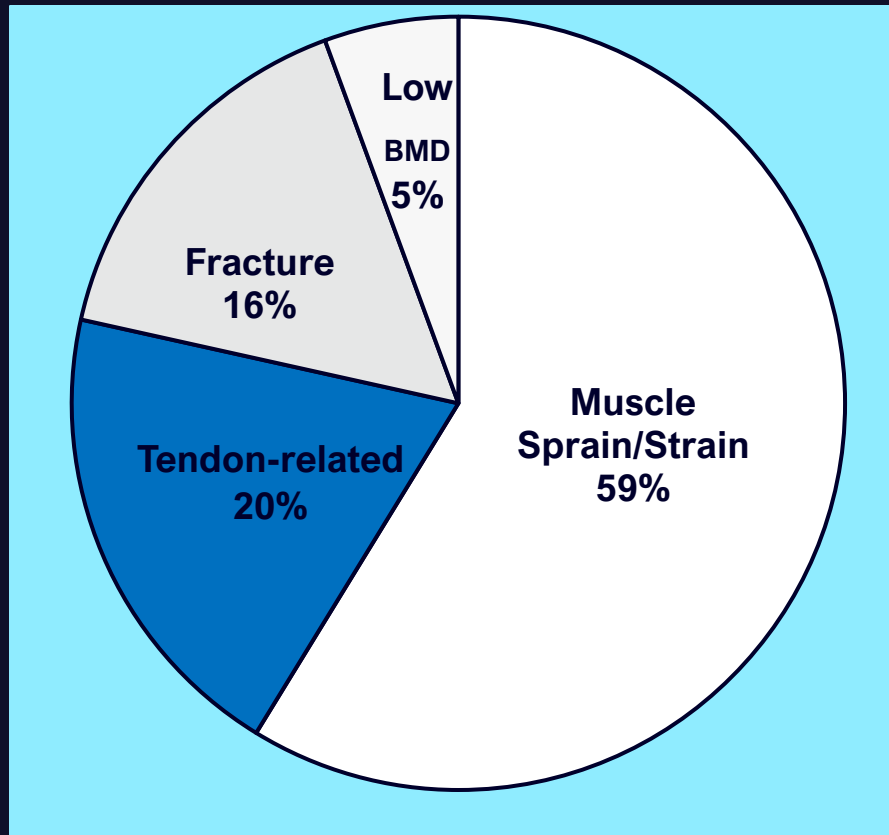


1 G MSK Issues, operationally consistent

- **Current as of 2022**
 - Total: 360 NASA Astronauts
 - Early Program male crew only (Mercury, Gemini, Apollo)
 - Of total, 17% female

Demographics	Male	Female
Astronauts (n, %)	299 (83.1%)	61 (16.9%)
Astronauts with ≥ 1 space flight (n, %)	270 (84.4%)	50 (15.6%)
Space Flight Missions (n, %)	955 (87.3%)	139 (12.7%)
	Mean $\pm$ SD	Mean $\pm$ SD
Age at selection (yr)	34.4 $\pm$ 3.7	32.5 $\pm$ 3.5
Age at first mission (yr)	40.7 $\pm$ 4.6	37.8 $\pm$ 4.2
Flight Duration (days)	25.7 $\pm$ 49.7	40.6 $\pm$ 68.7
Cumulative Duration in Space (days)	67.6 $\pm$ 94.8	102.4 $\pm$ 127.2

1G MSK Issues, operationally consistent



Demographics	Male	Female
Astronauts (n, %)	299 (83.1%)	61 (16.9%)
Astronauts with ≥ 1 space flight (n, %)	270 (84.4%)	50 (15.6%)
Space Flight Missions (n, %)	955 (87.3%)	139 (12.7%)
	Mean±SD	Mean±SD
Age at selection (yr)	34.4±3.7	32.5±3.5
Age at first mission (yr)	40.7±4.6	37.8±4.2
Flight Duration (days)	25.7±49.7	40.6±68.7
Cumulative Duration in Space (days)	67.6±94.8	102.4±127.2

1 G MSK Issues, operationally consistent

MSK medicine cases requiring surgery and RTD status

Data Time Frame: 1961-2019

Significant orthopedic cases in active crew

- THR
- Bilateral cubital and carpal tunnel syndrome
 - Successful unilateral UN transposition
- Trigger finger

TABLE 11-1 Musculoskeletal Injuries in U.S. Astronauts and Return to Duty (RTD) for T-38 Operations and Space Flight					
Region	Type of Injury	No. of Cases	Surgery?	RTD	AMB Waiver Required?
Shoulder	Rotator cuff tear—full thickness	4	Yes	T-38, NBL 6 mo, SF 1 yr	No
	Rotator cuff tear—partial thickness	3	No	T-38, NBL 6 wk, SF 3 mo	No
	SLAP lesion grade 2-4	3	Yes	T-38 3 mo, NBL 6 mo, SF 1 yr	No
	SLAP lesion grade 1	2	No	T-38, NBL, SF 3 mo	No
	Biceps tendon tear	2	Yes	T-38, NBL 3 mo, SF 6 mo	No
	Acromioclavicular joint	3	Yes	T-38, NBL 3 mo, SF 6 mo	No
Knee	Medial collateral ligament sprain	6	No	SF 6 wk	No
	Medial, lateral meniscus tear	6	Yes	T-38 3 wk, NBL 6 wk, SF	No
	Meniscus w/o repair	1	No	T-38, NBL, SF 6 wk	No
	Anterior cruciate ligament tear—complete	2	Yes	T-38, NBL 6 mo, SF 1 yr	No
	Anterior cruciate ligament tear—partial	1	No	T-38, NBL, SF 6 wk	No
	Osteoarthritis w/o replacement	3	Yes	T-38, NBL, SF 6 wk	No
	Osteoarthritis w/ replacement	2	Yes	T-38, NBL 6 mo, SDSF 1 yr	Yes
Hip	Femoral acetabular impingement	1	No	T-38, NBL, SF 3 wk	No
	Osteoarthritis w/ replacement	2	Yes	T-38, NBL 6 mo, SDSF 1 yr	Yes
	Fracture w/ ORIF	1	Yes	T-38, NBL 1 yr	Yes
Ankle	Fracture w/ ORIF	1	Yes	T-38, NBL 6 wk, SF 3 mo	Yes
	Osteoarthritis w/o replacement	1	Yes	T-38, NBL 3 wk, SF 3 mo	No
	Achilles tendon tear—complete	2	Yes	T-38, NBL 6 wk, SF 3 mo	No
Foot	Fracture w/ ORIF	1	Yes	T-38, NBL 6 wk, SF 3 mo	Yes
	Fracture w/o ORIF	2	No	T-38, NBL 3 wk, SF 6 wk	No
	Osteoarthritis w/o replacement	2	Yes	T-38, NBL 3 wk, SF 6 wk	No
Cervical spine	HNP w/ radiculopathy ACDF	4	Yes	T-38, NBL 6 mo, SF 1 yr	Yes
	HNP w/o radiculopathy	2	No	T-38, NBL 6 wk, SF 3 mo	No
	Degenerative disk disease	2	No	T-38, NBL 6 wk, SF 3 mo	No
Lumbar spine	HNP w/ radiculopathy	1	Yes	T-38, NBL, SF 3 mo	Yes
	HNP w/o radiculopathy	11	No	T-38, NBL 6 wk, SF 3 mo	No
	Degenerative disk disease	3	No	T-38, NBL 6 wk, SF 3 mo	No

ACDF, anterior cervical decompression and fusion; AMB, Aerospace Medicine Board; EVA, extravehicular activity; HNP, herniated nucleus pulposus; NBL, Neutral Buoyancy Laboratory; ORIF, Open Reduction and Internal Fixation; SDSF, short duration space flight; SF, space flight; SLAP, superior labrum anterior and posterior; W/, WITH; W/O, WITHOUT.

Reprinted from Lee SMC, Scheuring RA, Williams ME, et al. Physical performance, countermeasures, and post-flight reconditioning. In: Barratt MR, Baker F, Pool SL, eds. *Principles of Clinical Medicine for Space Flight*. 2nd ed. Springer Nature; 2019.

1 G MSK Issues, operationally consistent

MSK medicine cases requiring surgery and RTD status

Data Time Frame: 2019-2022

Significant orthopedic cases

- Carpal Tunnel x4
- ACL Tear
- Trigger Finger
- Shoulder Arthritis

<u>Region</u>	<u>Type of Injury</u>	<u>No. of Cases</u>	<u>RTD</u>	<u>AMB Waiver Required?</u>
Hand	Trigger Finger	3	T-38, NBL, SF, 8wks-8 mo	No
	Syndactyly	1	unknown	No
	Carpal Tunnel Release	4	T-38, NBL, SF, 5.5-9 weeks	No
Elbow	Cubital Tunnel Release	1	T-38, NBL, SF, 9 weeks	No
Shoulder	Degenerative Arthritis	1	T-38, NBL, SF, 11 mo	Yes
	Acromioclavicular joint	1	T-38, NBL, SF, 7 mo	No
Knee	Meniscus w/repair/debridement	2	T-38, NBL, SF, 12 wks	No
	Anterior cruciate ligament tear-complete	1	T-38, NBL, SF, 5 mo	No



SPACE PHYSIOLOGY

Human Response to Spaceflight

Astronauts experience a spectrum of adaptations in flight and post flight

Exposures:

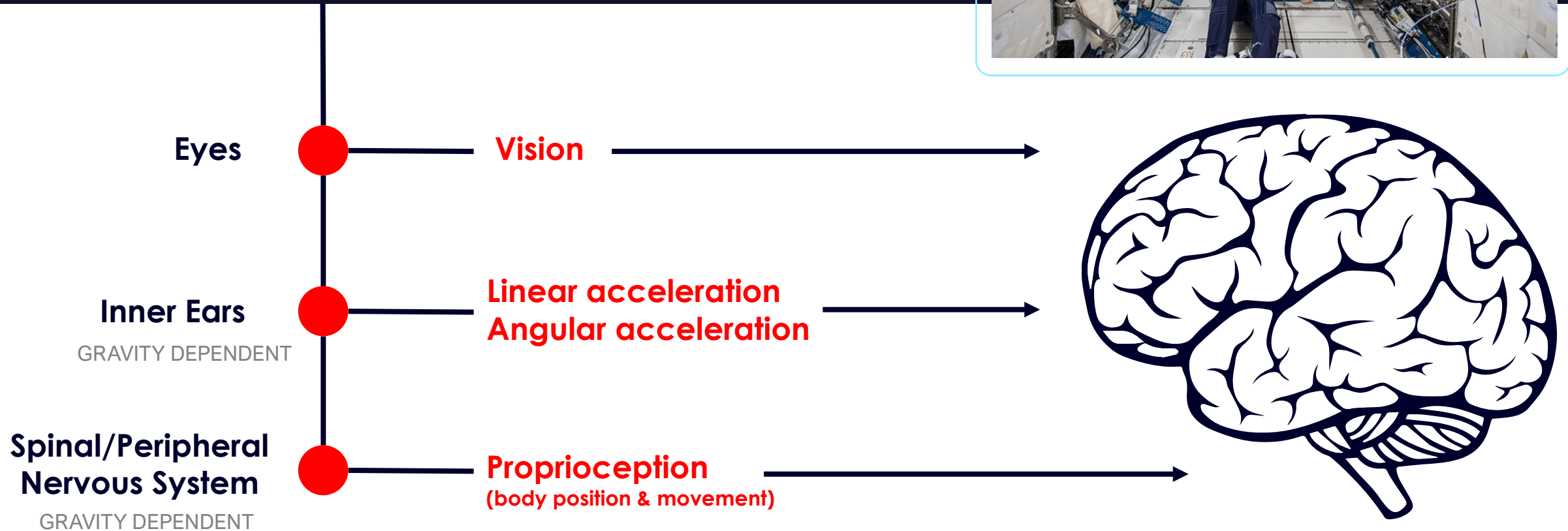
- Launch & Landing Loads
 - Microgravity
 - Closed Life Support System
 - Confined Habitat
 - Radiation Exposure
-
- Balance disorders
 - Cardiovascular deconditioning
 - Bone loss
 - Muscle atrophy
 - Decreased immune function
 - Vision changes



- Neurovestibular
- Cardiovascular
- Skeletal
- Muscular
- Immunological
- Nutritional
- Behavioral
- Occular

Neuro-vestibular Effects

- Sense of orientation
- Balance/posture
- Pursuit tracking/
- Maintaining gaze
- Smooth movement



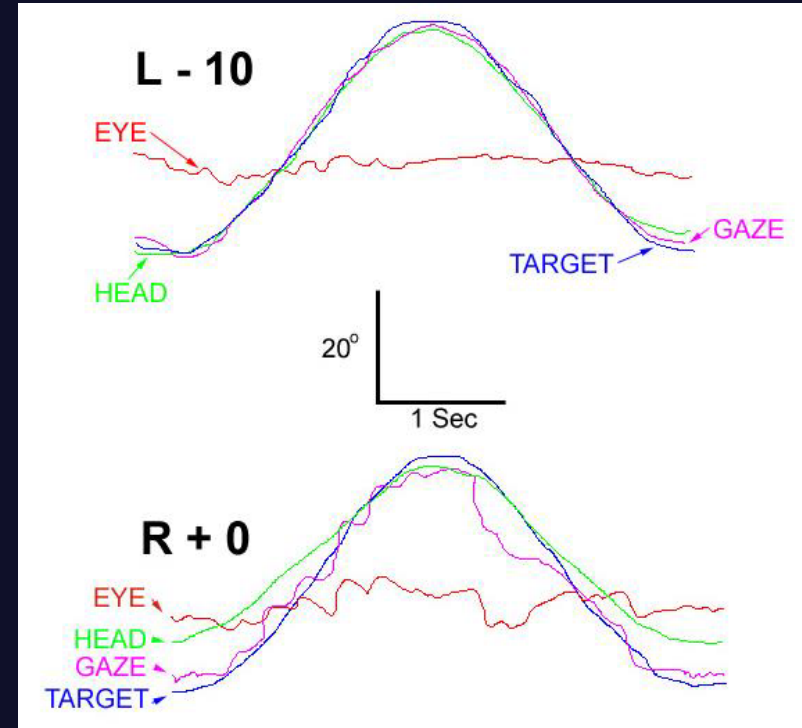
Space Motion Sickness

- **Predominate Theory: Sensory conflict**
 - Affects approximately 80% of crewmembers
- **Symptoms: Loss of appetite, nausea, vomiting**
 - Can occur within minutes of exposure to microgravity
 - Typically resolves within 1 week
- **Treatment:**
 - 1-G orientation
 - Medications
 - Inactivity/sleep
 - Preflight adaptation training



Neuro-vestibular Effects on Landing

- **Disequilibrium, vertigo** → nausea, vomiting
- **Balance/ posture (postflight)**
 - Instability upon standing
 - Swaying from side to side while walking
- **Pursuit tracking/ maintaining gaze**
 - Time required to clearly focus on an image increases by up to 1-1.5 sec relative to preflight



Fluid Shifts during Space Flight

In-flight

In space, the fluid tends to redistribute toward the chest and upper body. At this point, the body detects a “flood” in and around the heart.

In-flight

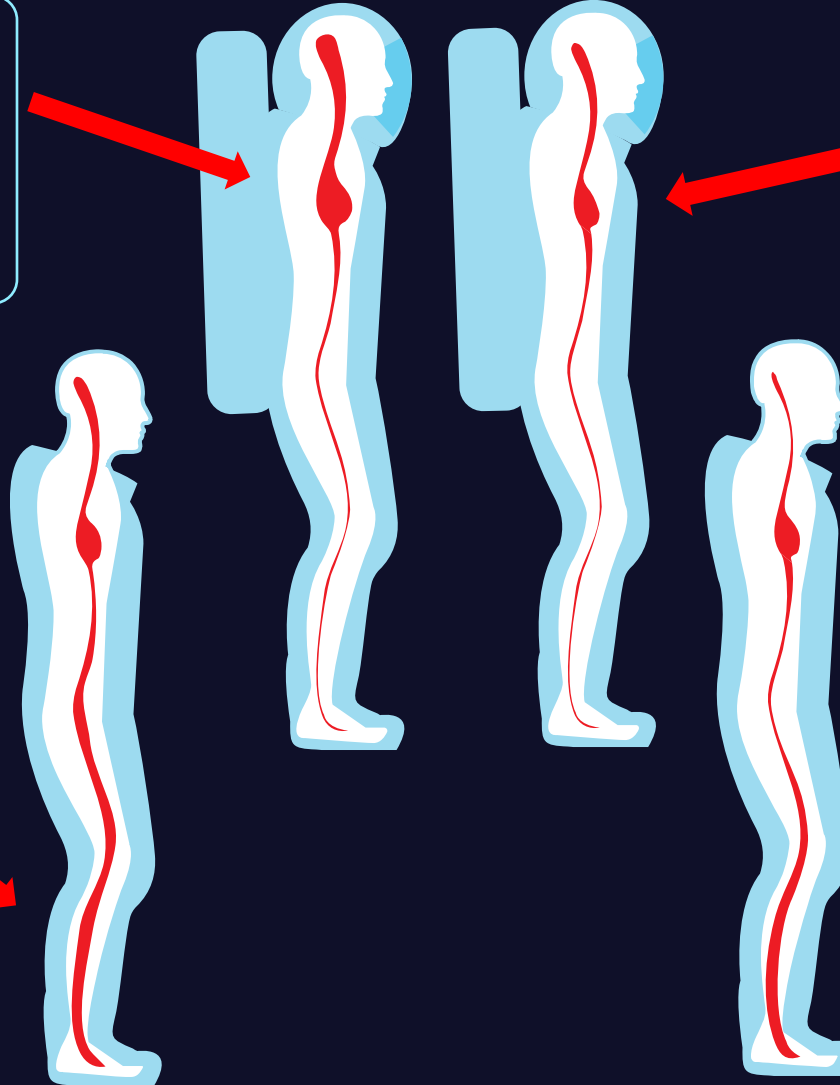
The body rids itself of this perceived “excess” fluid. The body functions with less fluid and the heart becomes smaller.

Pre-flight

On Earth, gravity exerts a downward force to keep fluids flowing to the lower body.

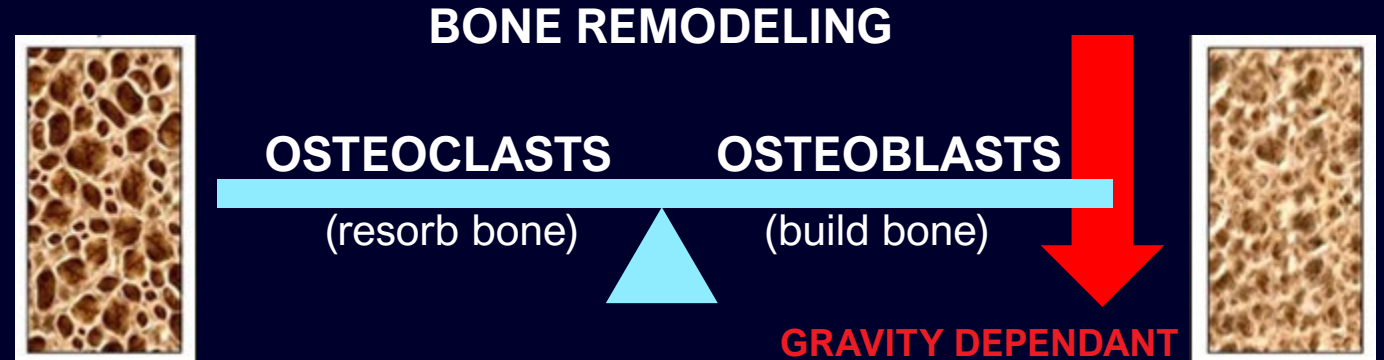
Post-flight

Upon return to Earth, gravity again pulls the fluid downward, but there is not enough fluid to function normally on Earth.

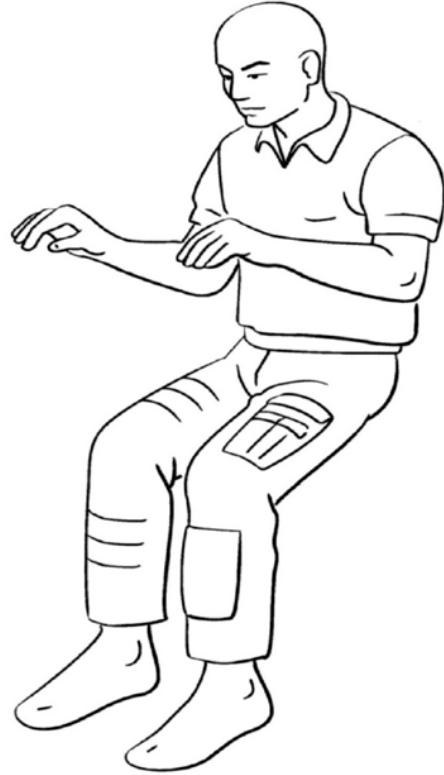
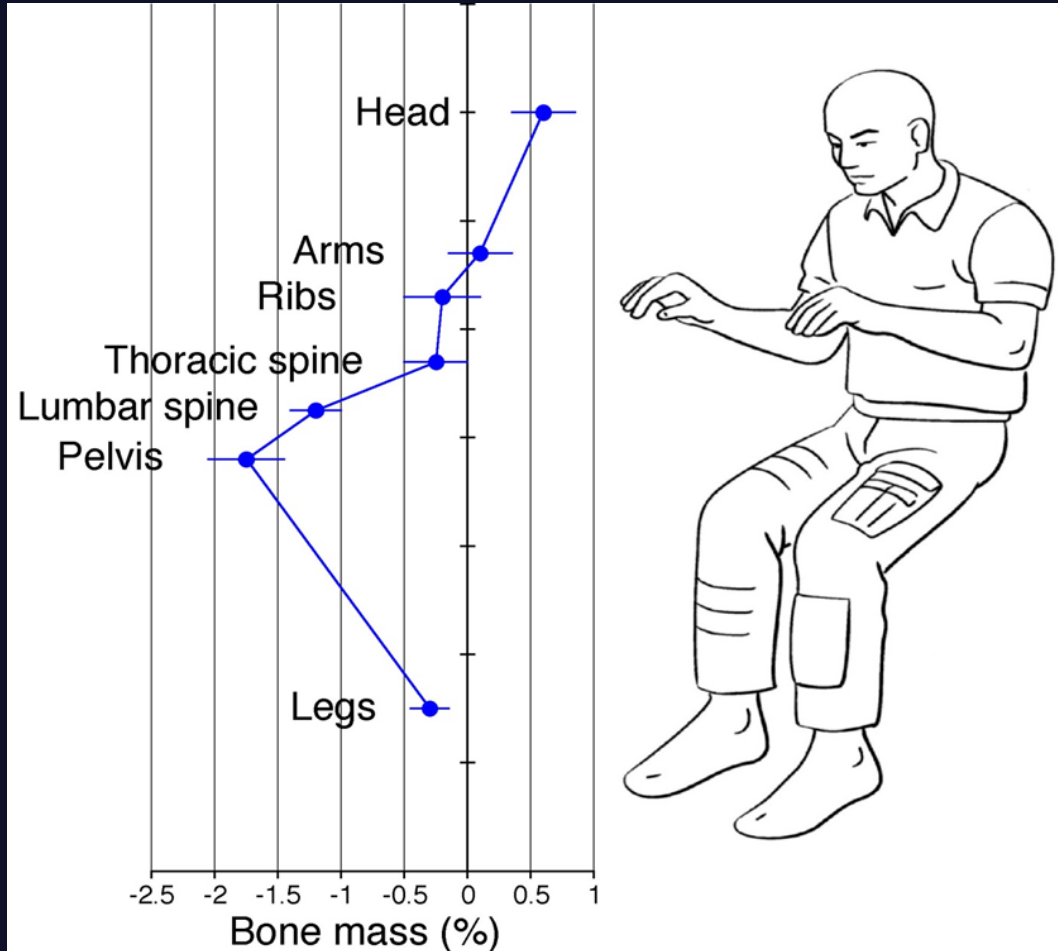


Musculoskeletal system

- When bones don't bear weight they lose density and strength
- Stabilizing muscles atrophy particularly in back, hips and legs

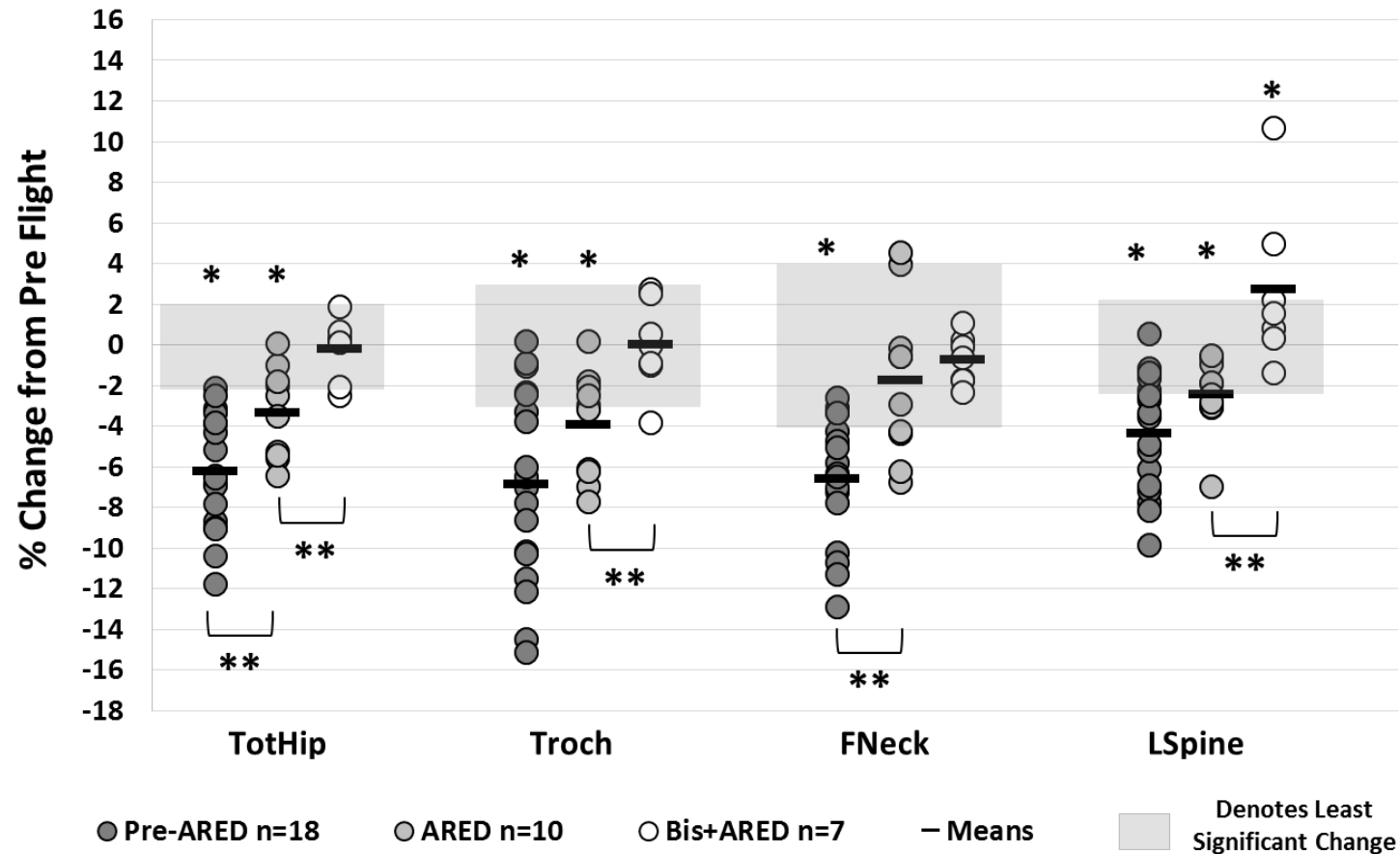


Bone loss during flight



Post-flight changes in bone density compared to pre-flight

Bone loss during flight



ISS Interim Resistive Exercise Device iRED

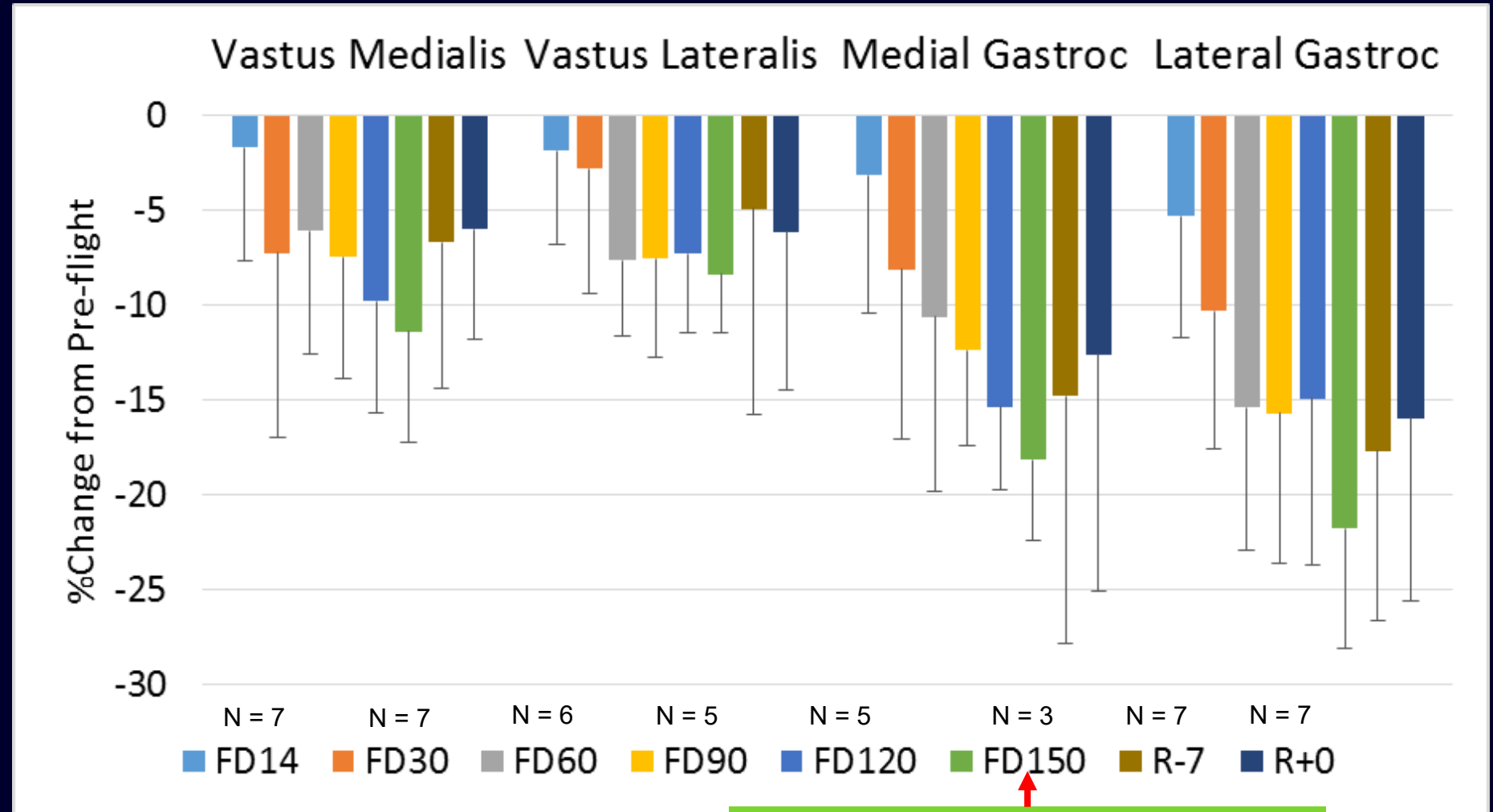


ISS Advanced Resistive Exercise Device- ARED

Muscle loss during flight

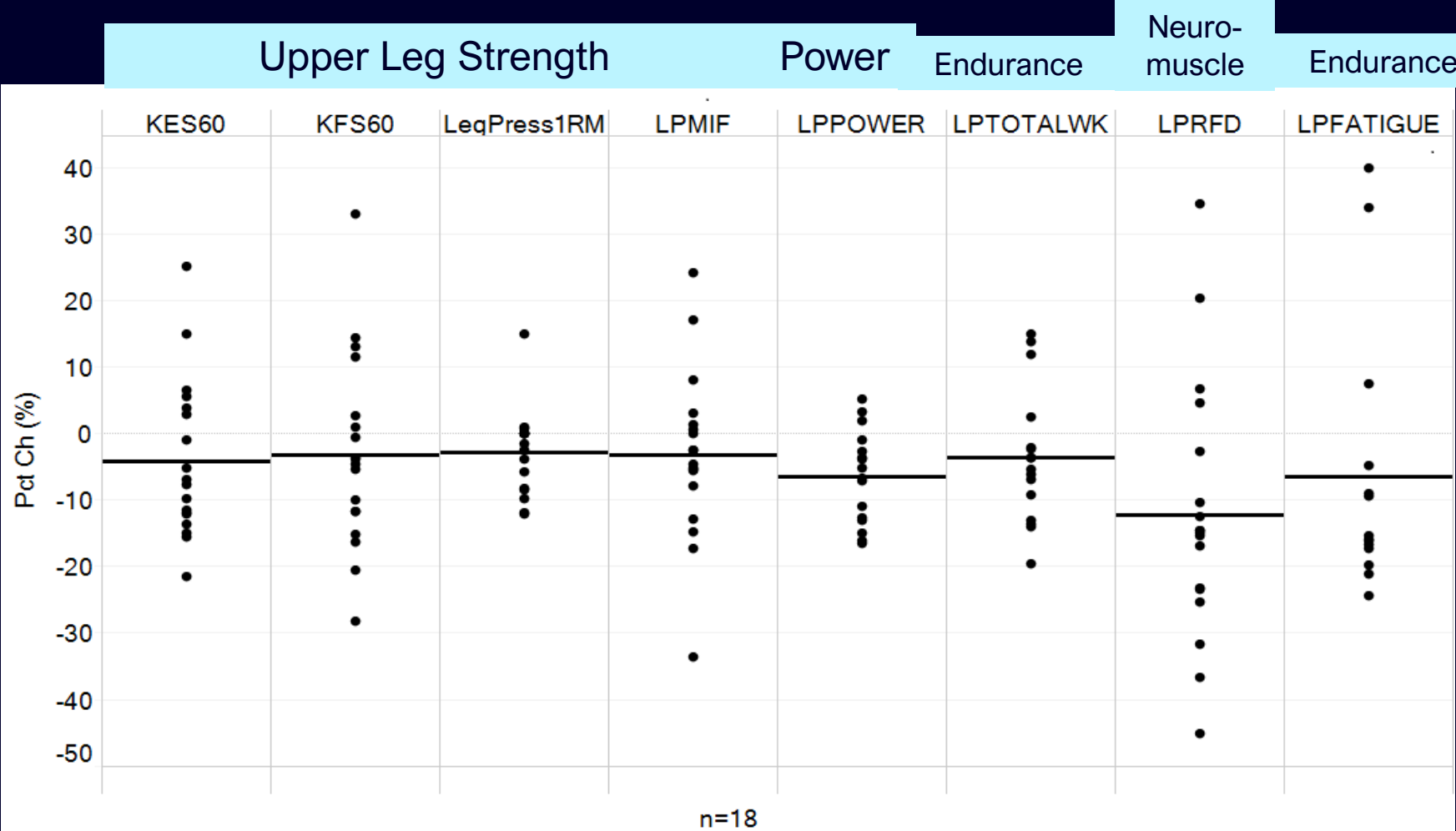
Measured using a novel ultrasound scanning device

Muscle size declines during space flight with larger loss in the lower



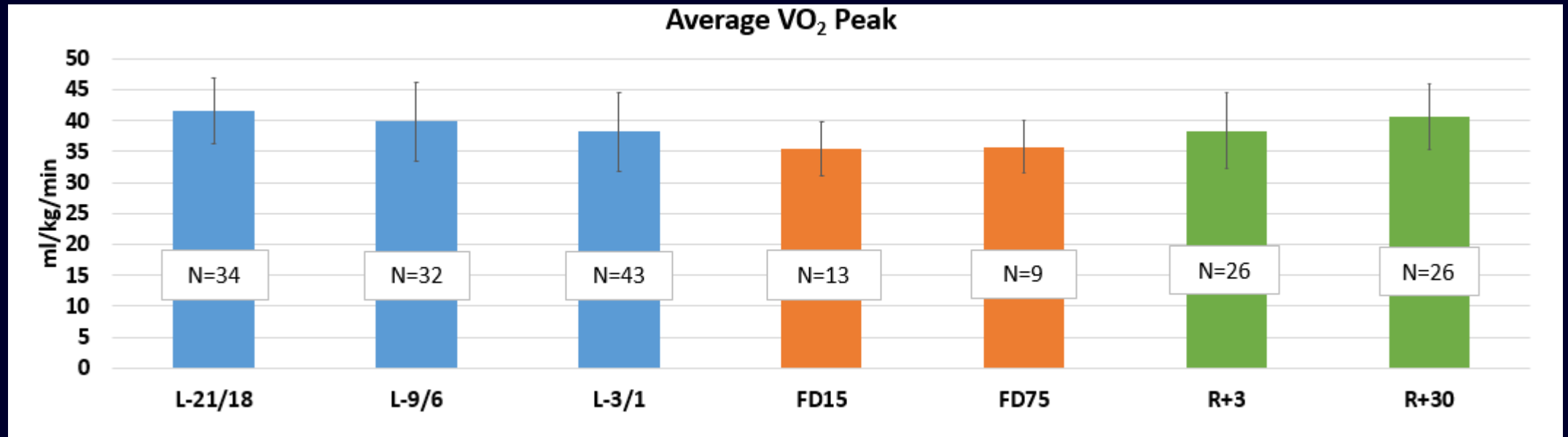
Note: N=3 on FD 150. Mean values are similar on FD 120 and R-7

Pre to Post flight Change in Muscle Strength, Power, and Endurance



There are many crewmembers with greater than 10% loss. For most parameters average crew return with less than 10% loss.

Aerobic Fitness



Mean decrease in VO_2 peak during and post-flight ranged from 8-10%.



In-Flight Exercise Countermeasures

2.5 hours of exercise scheduled daily

T2
(Treadmill 2)



CEVIS
(Cycle Ergometer with
Vibration Isolation & Stabilization)



ARED
(Advanced Resistive
Exercise Device)



Neurovestibular

✓

Cardiovascular

✓

Musculoskeletal

✓

✓

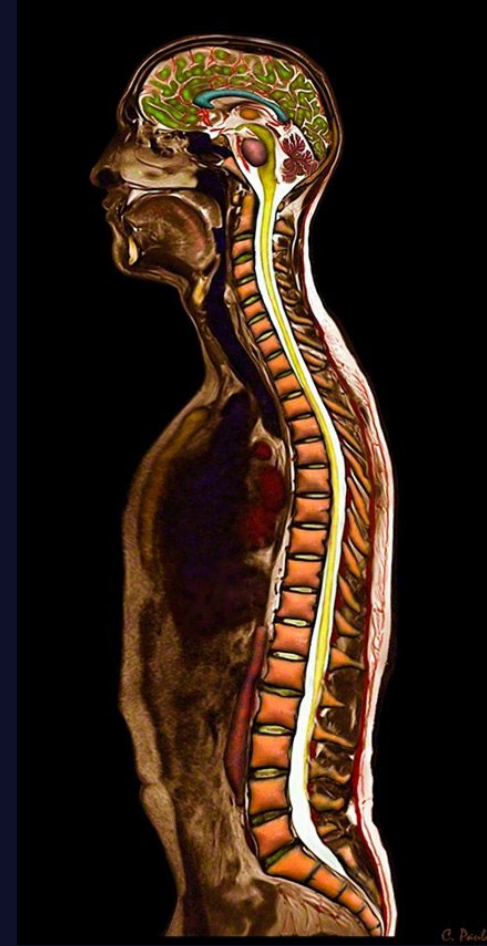
✓

✓

Spinal Related Changes

2021 NASA Human Research Program: Biomechanics of the lumbar spine following spaceflight and incidence of post-flight disc herniation

- N=12 subjects (10 males, 2 females)
- Evaluation:
 - **3T MRI** for facet arthropathy, endplate irregularities, HIZ, disc herniation, degeneration, water content and multifidus CSA, mCSA, m%
 - **Spine segment kinematics** max flexion-extension/lateral flexion/translation ROM per segment
 - Time points: pre-flight, R+2-7 (after 6 mos) and R+30-60

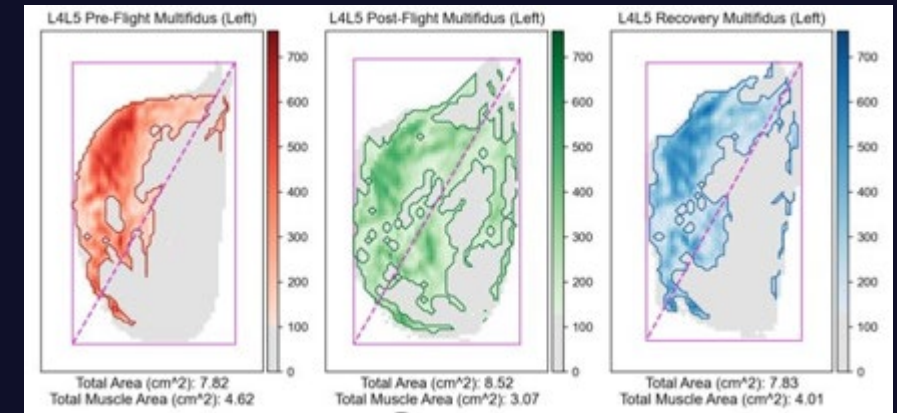


Spinal Related Changes

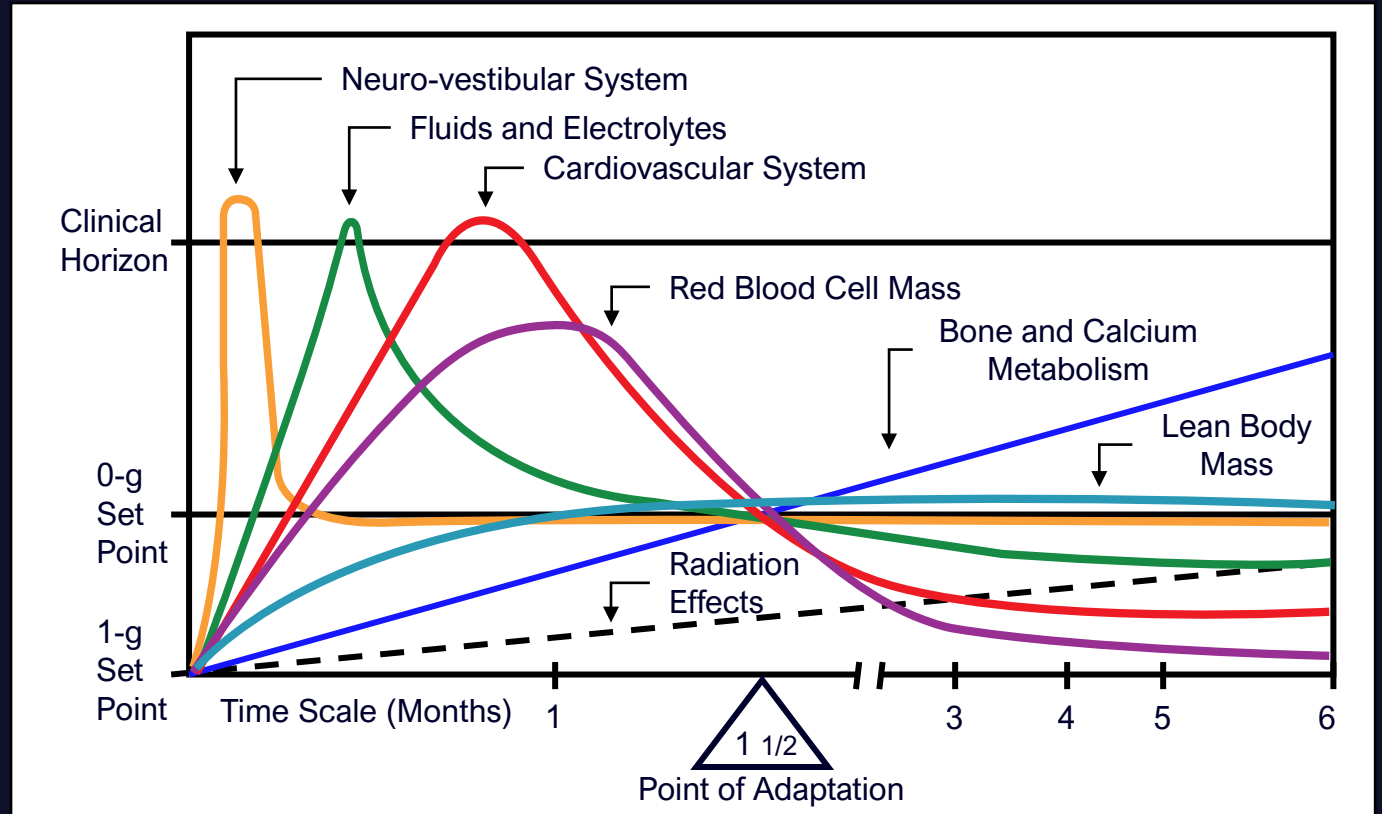
2021 NASA Human Research Program: Biomechanics of the lumbar spine following spaceflight and incidence of post-flight disc herniation

- **Results:**

- 50% (6 out of 12) of crew members returned from space with a symptomatic disc protrusion/herniation
- Decreased ROM → upper lumbar spine
 - **Associated with endplate irregularities**
- Lower pre-flight average multifidus % and higher asymmetry
- Decreased average multifidus % and increased asymmetry → lower lumbar spine
- Water content, muscle CSA, other spinal pathology did not associate



Time Course of Physiological Changes During Weightlessness



ON-ORBIT MEDICAL CAPABILITIES and CASES

Ground Medical Support

- Orbit 2 console (7a-4p M-F), on-call 24/7
- Video conferences weekly and more as needed
- Periodic health and fitness evaluations
- Weekly cardiovascular and strength training program updates
- On-orbit medical testing
- Pre-flight history



*ROI obtained through crew member and NASA LSAH

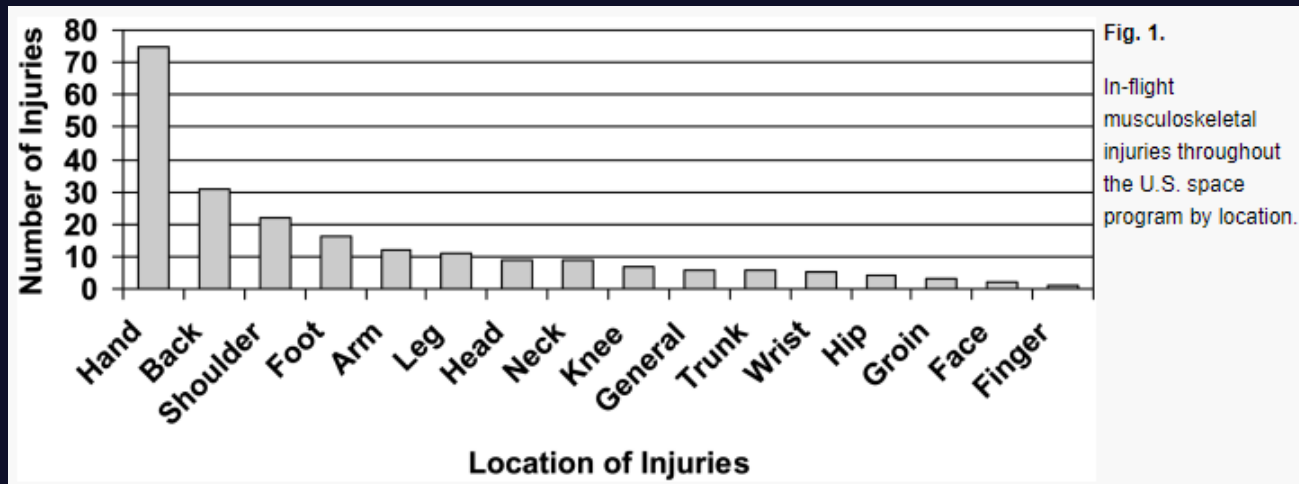
ISS medical capabilities

- **Ultrasound**
- **Medical Kits**
- **Supplemental oxygen, ventilator**
- **IV Fluids, injectable medications**
- **ECG**
- **Basic splinting, wound management**
- **Vision surveillance hardware:**
 - fundoscopy
 - optical coherence tomography (OCT)
 - ultrasound
 - visual acuity
 - tonometry



Select crew members trained as medical officers
Surgeon is available 24-7 via video or audio

On-orbit MSK Cases



- Require skilled clinical decision making, on-orbit ultrasound and innovative conservative management
- Full scope human performance team to maintain fitness/manage conditions



ISS Musculoskeletal Cases

Space Adaptation Back Pain

53% of Crew Members Experience, 90% resolve by Flight Day 12

85% mild pain, non-duty limiting

Precise mechanisms unknown, currently no accepted preventative measures

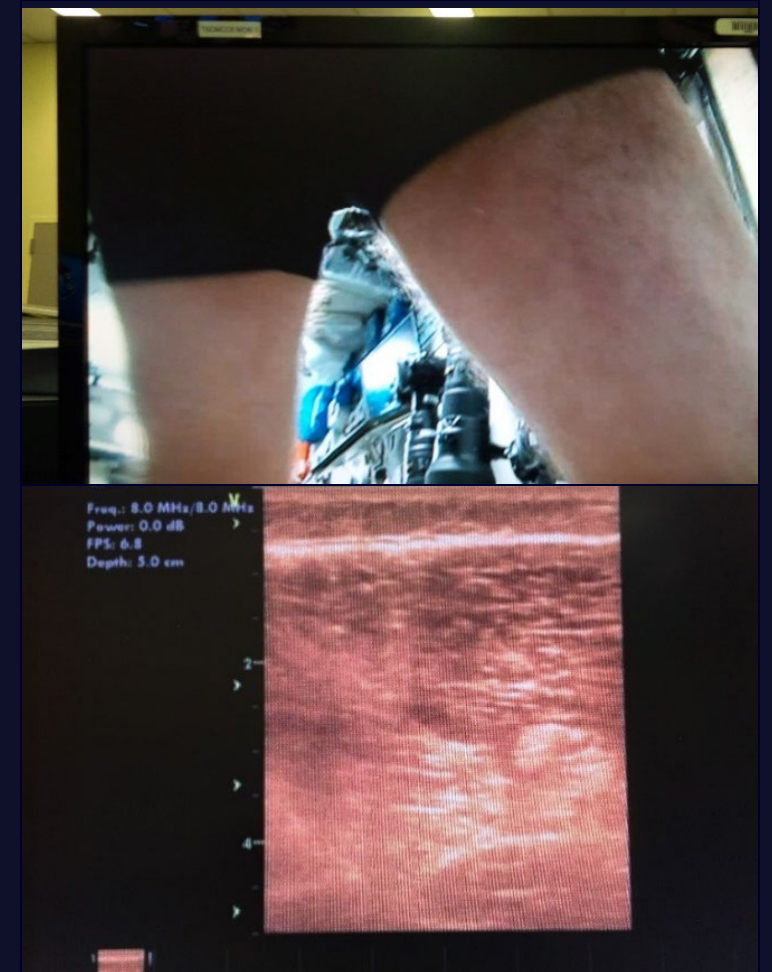
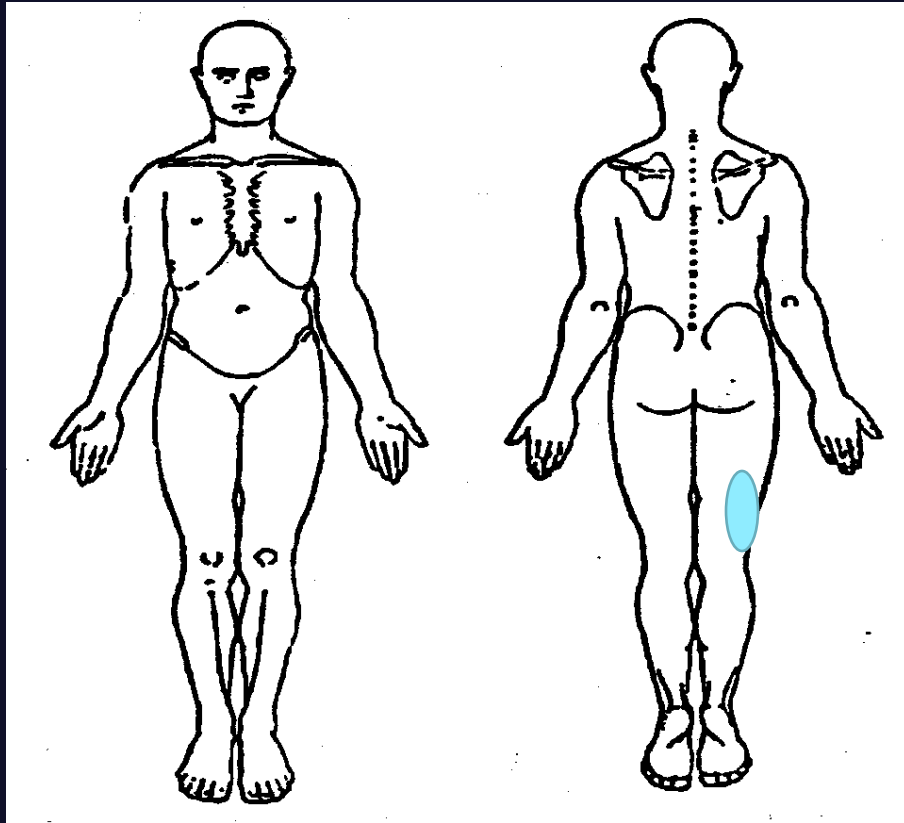
***Potential* mission impacted related to uncontrolled pain, sleep disturbance, or the adverse side effects of anti-inflammatory medications**



ISS Musculoskeletal Cases

42 y/o male w/right posterior leg pain, ecchymosis, swelling

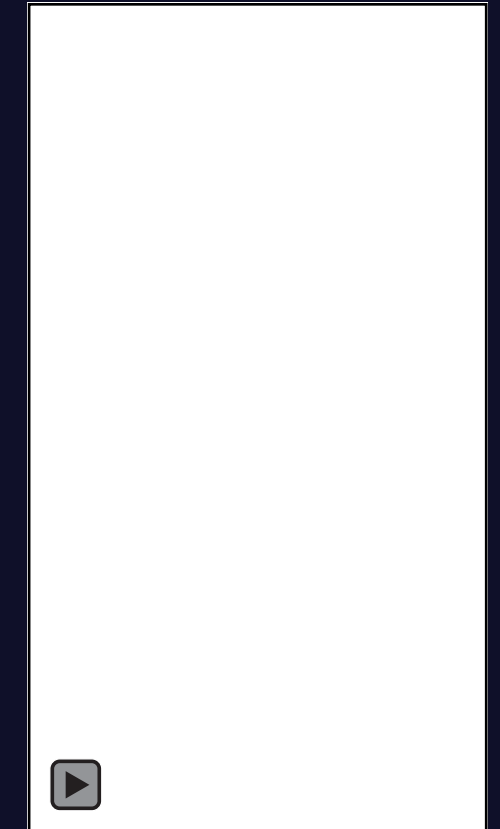
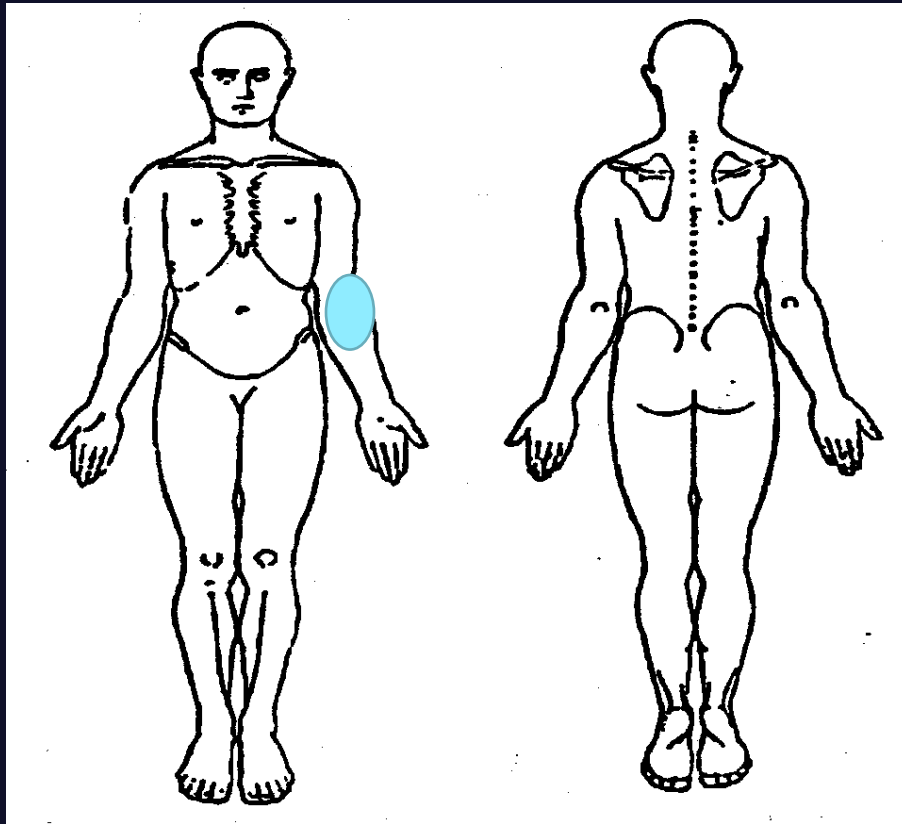
*For privacy the age and parts of the case description are made up but related to incidents that have occurred on the ISS



ISS Musculoskeletal Cases

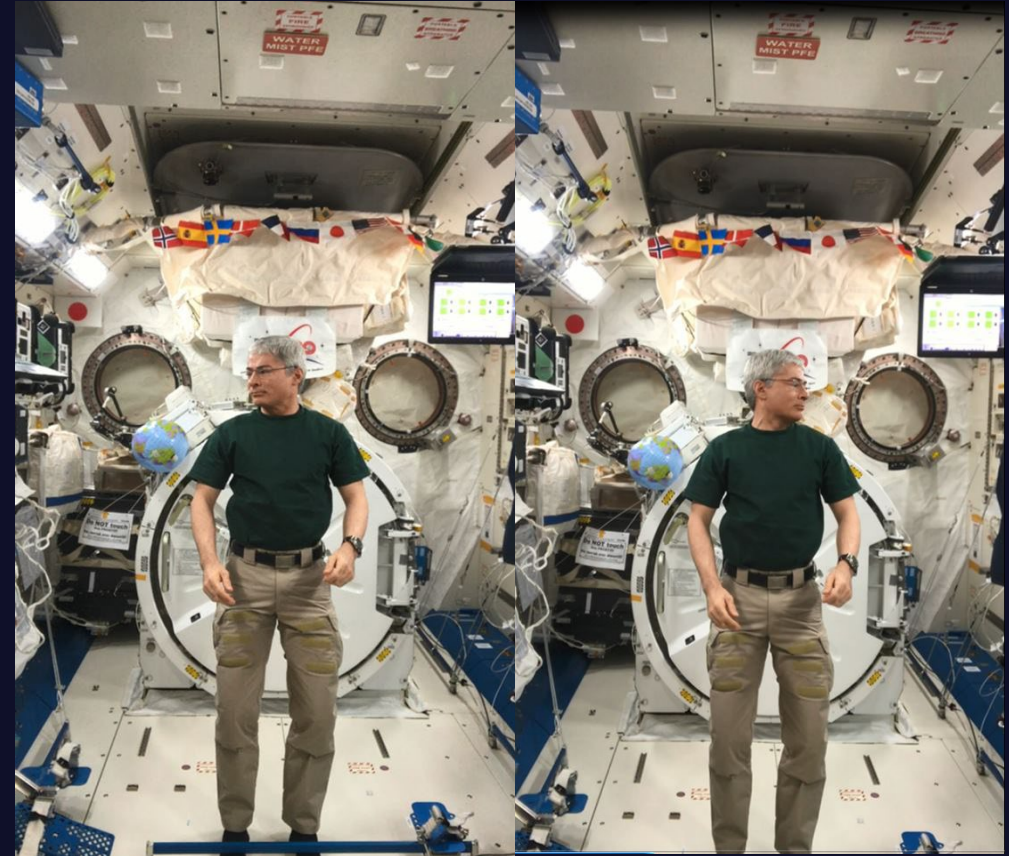
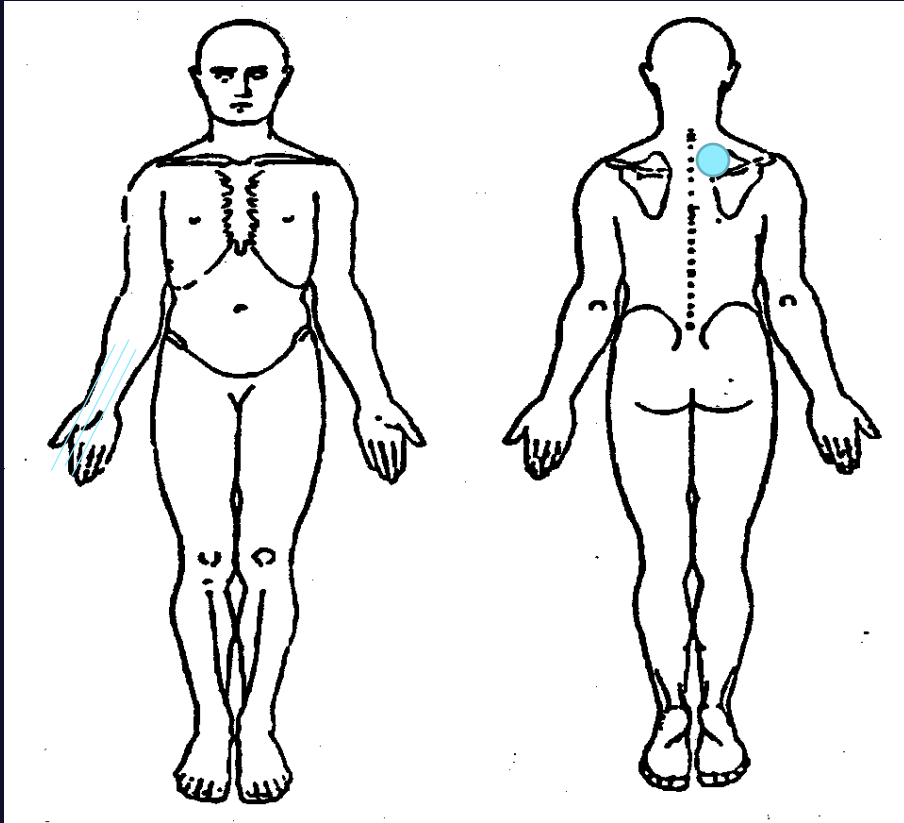
58 y/o male w/achy, intermittent pain over the left lateral epicondyle

*For privacy the age and parts of the case description are made up but related to incidents that have occurred on the ISS



ISS Musculoskeletal Cases

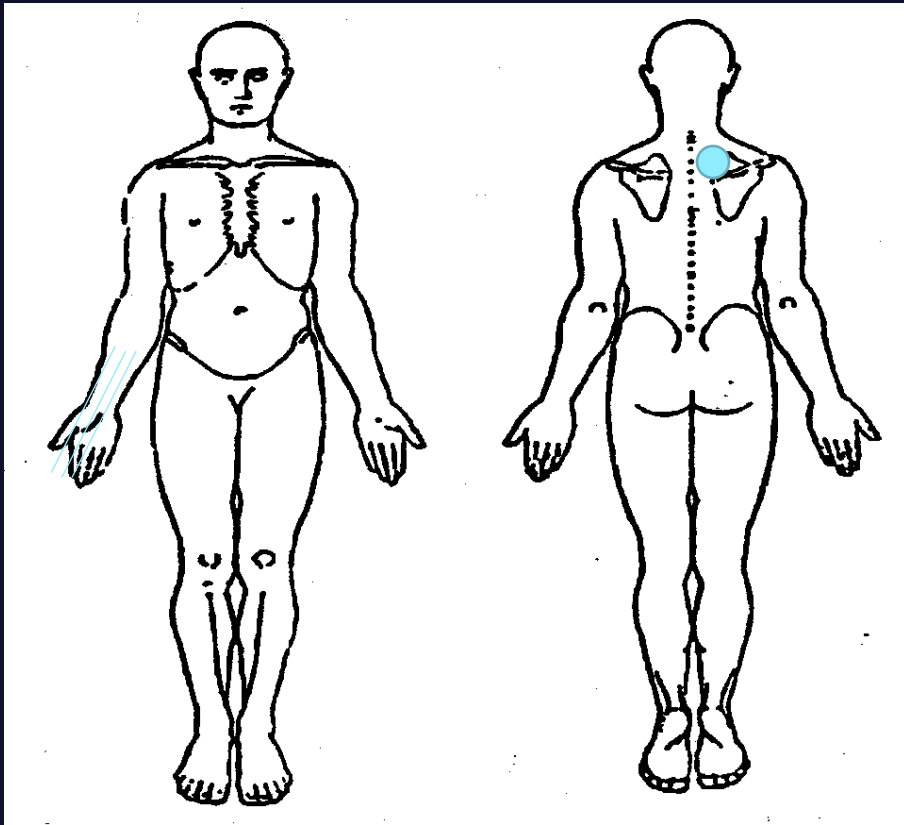
55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3rd digits



*ROI obtained through crew member and NASA LSAH

ISS Musculoskeletal Cases

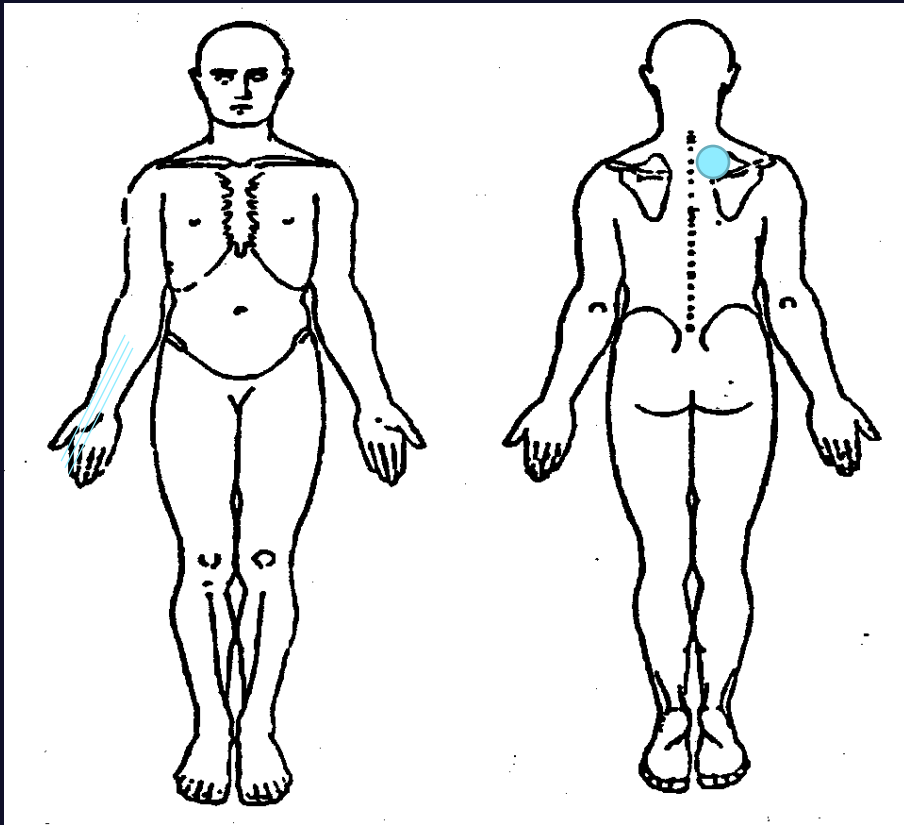
55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3rd digits



*ROI obtained through crew member and NASA LSAH

ISS Musculoskeletal Cases

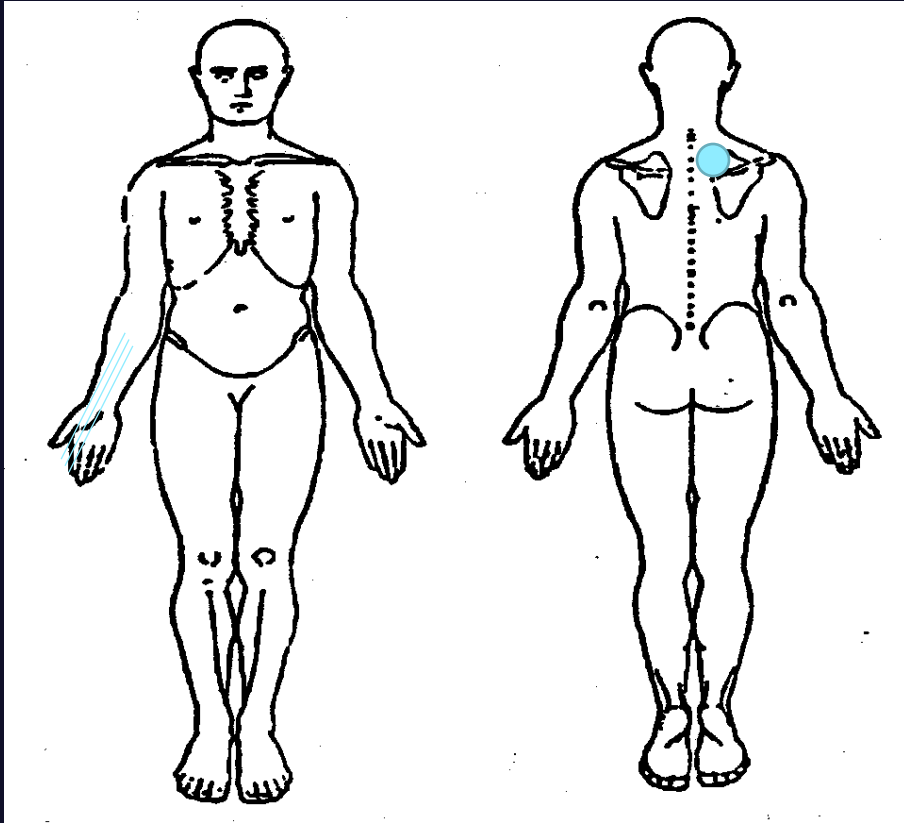
55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3rd digits



*ROI obtained through crew member and NASA LSAH

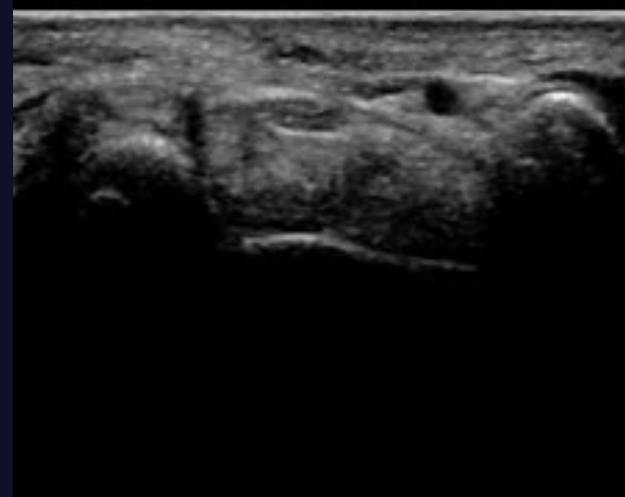
ISS Musculoskeletal Cases

55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3rd digits



Ultrasound utilized to rule out competing diagnoses:

- Vascular etiology (distended carotid)
- Peripheral nerve involvement (median and radial)



Internet stock photo of carpal tunnel

ISS Musculoskeletal Cases

55 y/o male w/sharp scapular pain and numbness/tingling in to the 1-3rd digits



*ROI obtained through crew member and NASA LSAH

Young IA, Phys Ther, 2010

POST-FLIGHT RECONDITIONING CONSIDERATIONS

Risk of
symptomatic
IVD ~2-21X

mCSA
decrease in
spine and lower
leg musculature

Peak Aerobic
Capacity and
power
reduced ~8-
10%

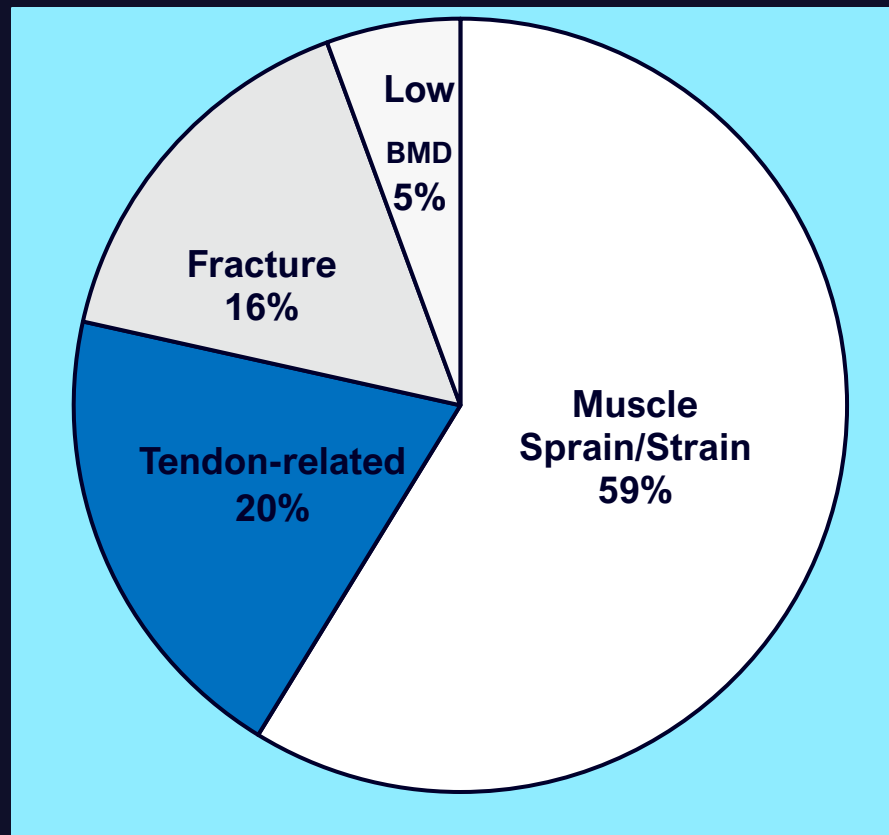
Decreased
sensorimotor
capability and
altered gaze
stability

BMD Loss
~5%

Lower
extremity
strength/
endurance
reduce >10%



Post-Flight MSK Cases



Demographics	Male	Female
Astronauts (n, %)	299 (83.1%)	61 (16.9%)
Astronauts with ≥ 1 space flight (n, %)	270 (84.4%)	50 (15.6%)
Space Flight Missions (n, %)	955 (87.3%)	139 (12.7%)
	Mean±SD	Mean±SD
Age at selection (yr)	34.4±3.7	32.5±3.5
Age at first mission (yr)	40.7±4.6	37.8±4.2
Flight Duration (days)	25.7±49.7	40.6±68.7
Cumulative Duration in Space (days)	67.6±94.8	102.4±127.2

Post-Flight MSK Cases

Postflight injuries most common (92%)

Large proportion of injuries (49.6%) occurred within 1 year of landing

7.3% within 1 month

8.1% between 1-3 months

9.2% between 3-6 months

25% between 6-12 months

Fewer injuries reported in females, but higher prevalence

F: 39 injuries in 20 astronauts

1.95 injuries per female

20% of female injuries occurred in flight

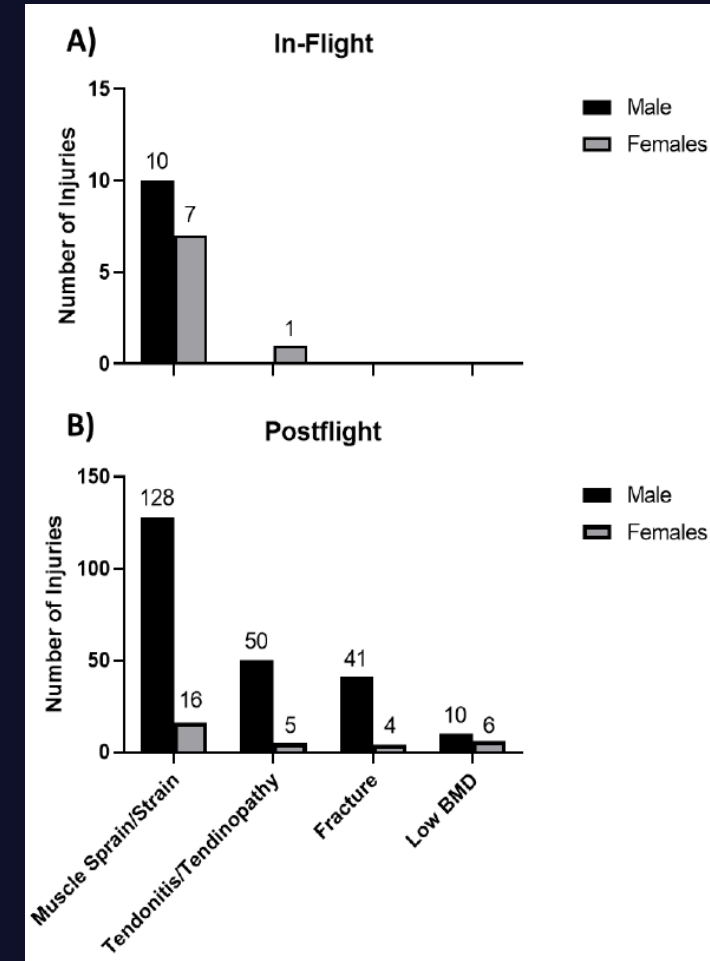
Low BMD diagnoses in 15% of females

M: 244 injuries in 131 astronauts

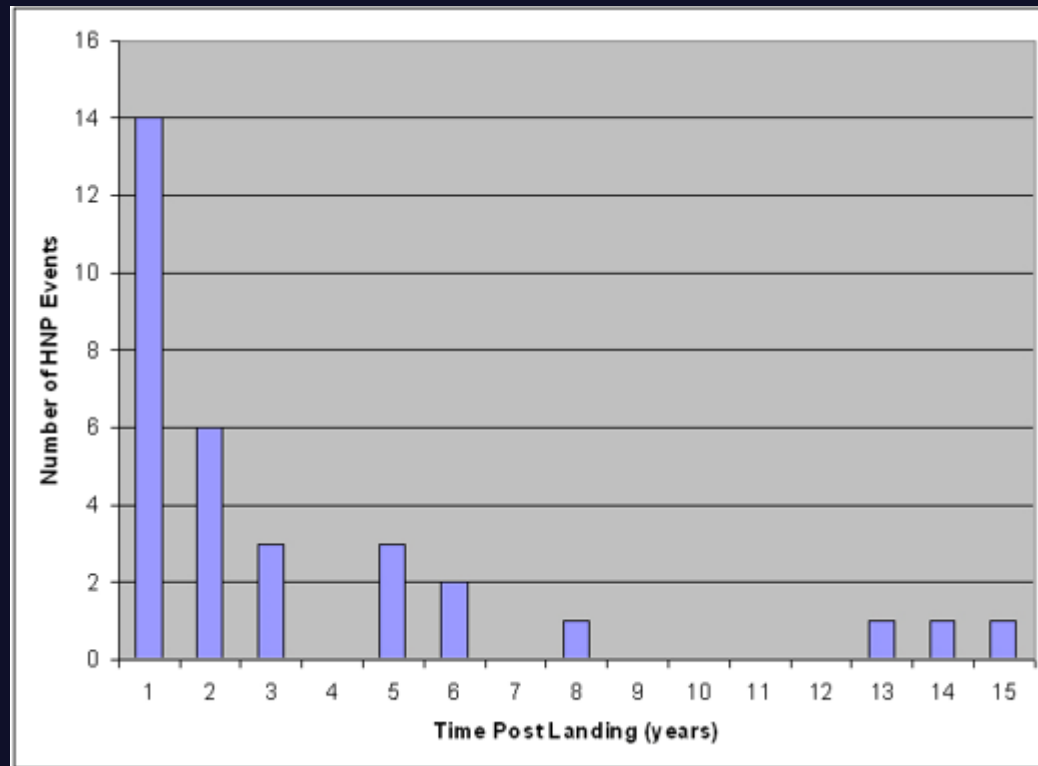
1.86 injuries per male

4% of injuries occurred in-flight

Low BMD diagnosed in 4% male astronauts



Post-Flight MSK Cases



Occurrence of symptomatic HNP greatest in first 2 weeks post flight

RESEARCH ARTICLE

Risk of Herniated Nucleus Pulposus Among U.S. Astronauts

SMITH L. JOHNSTON, MARK R. CAMPBELL, RICK SCHEURING,
AND ALAN H. FEIVISON

JOHNSTON SL, CAMPBELL MR, SCHEURING R, FEIVISON AH. Risk of herniated nucleus pulposus among U.S. astronauts. *Aviat Space Environ Med* 2010; 81:566-74.

Introduction: Astronauts have complained of back pain occurring during spaceflight, presumably due to the elongation of the spine from the lack of gravity. Herniated nucleus pulposus (HNP) is known to occur in aviators exposed to high G_x and has been diagnosed in several astronauts in the immediate post-spaceflight period. It is unknown whether astronauts exposed to microgravity are at added risk for developing HNP in the post-spaceflight period due to possible in-flight intervertebral disc changes. **Methods:** For a preset study period, incidence rates of HNP were compared between the U.S. astronaut population and a matched control population not involved in spaceflight using the Longitudinal Study of Astronaut Health database. Using a Weibull survival model, time trends of the risk of HNP prior to and after spaceflight were compared within the astronaut group. HNP incidences in other populations that have previously been reported in the literature were also compared with results in this study. **Results:** The incidence of HNP was 4.3 times higher in the U.S. astronaut population (N = 321) compared to matched controls (N = 983) not involved in spaceflight. For astronauts, there was relatively more HNP in the cervical region of the spine (18 of 44) than for controls (3 of 35); however, there was no clear increase of HNP incidence in those astronauts who were high performance jet aircraft pilots. There was evidence suggesting that the risk is increased immediately after spaceflight. **Conclusions:** Astronauts are at higher risk of incurring HNP, especially immediately following spaceflight. **Keywords:** spaceflight, back pain, back injury, cervical injury, lumbar injury, disc disease, microgravity, weightlessness.

HERNIATED NUCLEUS PULPOSUS (HNP) is usually secondary to degenerative disc disease, although that term is probably a misnomer as hereditary factors also have been found to be important. The peak patient age incidence is between 35 and 55 yr old. Herniation of the nucleus pulposus is due to the failure of the annulus fibrosus to retain nuclear material. This may result from a tear in the annulus or a disruption of the annular attachment to the vertebral body. Herniations in the cervical and lumbar spine that result in symptomatic radicular pain are typically due to extrusion of disc material in a posterolateral direction, causing compression or irritation of a nerve root. The presence of the posterior longitudinal ligament in both the cervical and lumbar regions makes the occurrence of direct central extrusion of disc material into the spinal canal less likely. When this does occur, direct compression of the spinal cord or cauda equina can occur.

The intervertebral disc is formed by the central nucleus pulposus, the outer annulus fibrosus, and the cartilaginous vertebral end plates. Each of the structures consists primarily of collagen, proteoglycans, and water.

Fluid shifts occur readily, with the disc expanding during bed rest and contracting during axial loading. The annulus fibrosus is the site of primary pathologic change due to repetitive stress during axial loading and flexion, which is the etiology for herniation (8). The nucleus pulposus usually herniates at the posterolateral corner, resulting in pressure on the spinal cord or nerve root, which causes pain or neurological deficits.

Several studies have suggested that aviators exposed to a repetitive high G_x environment in high performance aircraft or to the vibratory stress of helicopters have a higher incidence of cervical injuries (11,29,37) and HNP (12,26). Although higher rates of HNP are suspected in high G_x environments, definite statistical proof is still lacking. High G_x maneuvers place considerable stress on the cervical vertebrae, especially when combined with tilting and turning of the neck (37). An increase in degenerative cervical changes has been found on magnetic resonance imaging (MRI) of high G_x fighter pilots (32,33) and one study has shown that 3 out of 10 active fighter pilots demonstrate MRI cervical changes (22). However, MRI abnormalities are seen in asymptomatic patients and are not necessarily indicative of a higher risk of HNP.

Back pain and injury has been known to occur in astronauts during their ground activities (19) and in flight (21,34,35). Generalized back pain during spaceflight has been reported in 53–68% of astronauts responding to a questionnaire, with 28% describing the pain as severe to moderate (38). Back pain is usually most severe at the beginning of flight and gradually subsides as the flight progresses. The etiology of spaceflight back pain has been proposed as a lengthening of the vertebral column due to disc expansion secondary to unloading and loss of the thoracic and lordotic curvatures (16,20). Obviously, back pain is subjective and very difficult to accurately study. Although statistics on HNP are felt to be more objective, reliable, and reproducible, regional var-

From the NASA Johnson Space Center, Houston, TX, and General Surgery, Paris, TX.

This manuscript was received for review in September 2008. It was accepted for publication in February 2010.

Address correspondence and reprint requests to: Mark R. Campbell, M.D., 420 DeShong, #200, Paris, TX 75460; mcamp@tstarnet.com.

Reprint & Copyright © by the Aerospace Medical Association, Alexandria, VA.

DOI: 10.3357/ASEM.2427.2010

Post-Flight Reconditioning Considerations

Post-Flight Reconditioning Progression Model



Post-Flight Reconditioning Considerations

[illegible]

LUNAR OPERATIONS/FUTURE
CONSIDERATIONS F/MMMO OR
FS/HP TEAMS



EXPLORE MOON_{to}MARS

MOON LIGHTS THE WAY



Exploration



“We will go the Moon in the next decade in a way we have never gone before. We will go with innovative new technologies and systems to explore more locations across the surface than was ever thought possible. This time, when we go to the Moon, we will stay. And then we will use what we learn on the Moon to take the next giant leap - sending astronauts to Mars.”

—NASA Administrator Jim Bridenstine

Exploration



NASA is going forward to the Moon to stay, and on to Mars

Going forward to the Moon is part of a larger, sustainable exploration campaign with international and commercial partners

NASA's next big rocket, the Space Launch System, along with the Orion spacecraft and the mobile, lunar command module, Gateway, will be our backbone for deep space exploration.

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 photo courtesy of NASA

Scheuring RA, Davis, JR, et. al. The Apollo Medical Operations Project: Recommendations to Improve Crew Health and Performance for Future Exploration Missions and Lunar Surface Operations. [Acta Astronautica](#), 63 (2008); 980 – 987.

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



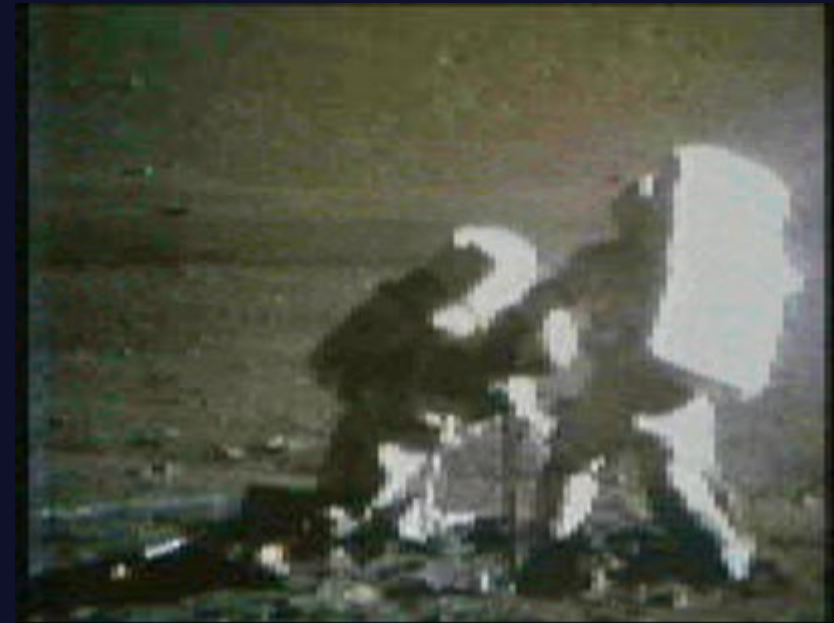
H. Schmitt, Apollo 17 photo courtesy of NASA

Scheuring RA, Davis, JR, et. al. The Apollo Medical Operations Project: Recommendations to Improve Crew Health and Performance for Future Exploration Missions and Lunar Surface Operations. *Acta Astronautica*, 63 (2008); 980 – 987.

Lunar MSK Conditions

- **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

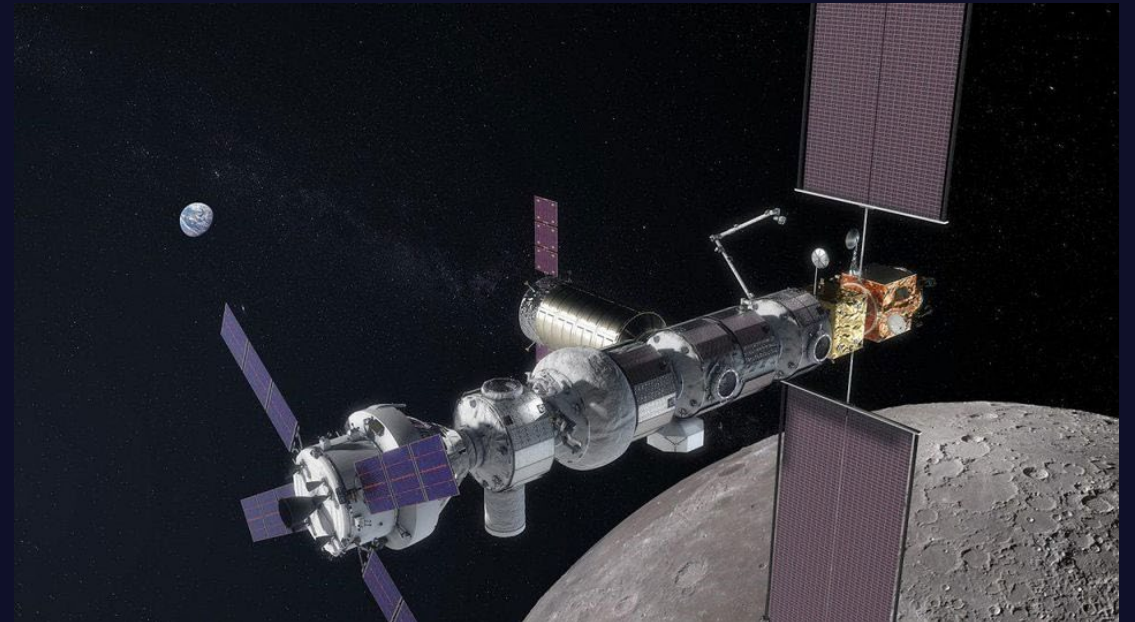


G. Cernan, H. Schmitt, Apollo 17 photo courtesy of NASA
Scheuring RA, Davis, JR, et. al. The Apollo Medical Operations Project:
Recommendations to Improve Crew Health and Performance for Future Exploration
Missions and Lunar Surface Operations. *Acta Astronautica*, 63 (2008); 980 – 987.

Exploration

New medical challenges will arise:

- Increased distance from Earth = delays in communication
- Less frequent opportunities for re-supply
- Evacuation of sick or injured astronauts may become impossible
- Requires innovative Countermeasures due to changes in vehicles and physical demands of longer missions



Exploration

What will we need?

- The right components of a Human Performance Team
- A posture of physical readiness
- Adequate pre-flight screening, monitoring, and fitness
- Appropriate diagnostic Capability with trained crew (Ultrasound)
- Innovative assessments of performance (biomarkers, fatigue monitoring, etc) and approaches to maximize fitness to protect the MSK system
- Evidenced based strategies to manage common MSK conditions
- Appropriate screening and progression for reconditioning post-flight





Conclusion

Thank You

danielle.n.anderson@nasa.gov

