Factors contributing to biomechanical changes in the lumbar spine following spaceflight and incidence for post-spaceflight intervertebral disc herniation

1Jeannie F. Bailey, PhD; 1Priya Nyayapati; 1Gabriel Johnson; 1Lucas Dziesinski; 2Aaron Scheffler, PhD; 3Rebecca Crawford, PhD; 4Richard Scheuring, DO; 1Conor W. O’Neill, MD; 5Douglas G. Chang, MD, PhD; 5Alan R. Hargens, PhD; 1Jeffrey C. Lotz, PhD

1Department of Orthopaedic Surgery, University of California, San Francisco, USA; 2Department of Epidemiology and Biostatistics, University of California, San Francisco, USA; 3Body Urbanist, Rotterdam, South Holland, The Netherlands; 4NASA Johnson Space Center, Houston, Texas, USA; 5Department of Orthopaedic Surgery, University of California, San Diego, USA
No relevant disclosures.
1) Spaceflight leads to a heightened incidence for LBP and disc herniation → Why?

2) Prolonged unloading in space disrupts diurnal loading (experienced on Earth) on the spinal tissues and biomechanical function

- IVD hydration
- Load bearing
- Controlled motion between trunk and lower extremities
- Muscle size/composition
- Effect on existing pathology

**Hypothesis:** Pre-existing spinal pathology and paraspinal muscle atrophy following spaceflight is associated with risk for post-flight low back pain and disc herniation
Spinal pathology:
- facet arthropathy
- endplate irregularities
- HIZ
- disc herniation

Disc:
- Degeneration (Pfirrmann)
- Water content (T2-map)

Multifidus:
- CSA, mCSA, m%

SUBJECTS
n=12
10 males, 2 female
51.3 ± 5.6 years

DATA COLLECTION TIMEPOINTS
- Pre-flight
- R + 2-7
- R + 30-60

6-months spaceflight

3T MRI

Spine segment kinematics

Maximum flexion-extension ROM (per segment)
Maximum lateral bending ROM (per segment)
Maximum translation during motion (per segment)
Results: disc herniation

50% (6 out of 12) of crew members returned from space with a symptomatic disc protrusion/herniation.
Results: multifidus muscle quality

Total CSA → L4L5 (-7.67%) → Recovered

Muscle CSA → L4L5 (-11.0%) and L5S1 (-9.9%) → Recovered

Muscle % → L3L4 (-3.8%) and L5S1 (-4.6%) → Recovered
Results: multifidus muscle quality

In those that experienced post-flight disc herniation (n=6):

Average Muscle %:

→ L4L5: -6.2%, L5S1: -7.0%

→ Recovered

Muscle Asymmetry

→ L4L5: 8.9%

→ Recovered
Results: lumbar segment kinematics

Max Flexion-Extension ROM

-17.2% at L2L3 and -20.5% at L3L4

-20.2% ROM following spaceflight

No Δ for levels w/out endplate irregularities

Endplate irregularities most prevalent in upper lumbar spine

Existing endplate irregularities (37% of levels)
Results: factors associated with disc herniation

1. Decreased ROM → upper lumbar spine
   *associated with endplate irregularities

2. Lower pre-flight average multifidus % and higher asymmetry

3. Decreased average multifidus % and increased asymmetry → lower lumbar spine

4. Water content, muscle CSA, other spinal pathology did not associate.
Increased stiffness with existing endplate irregularities

Decreased muscle quality

Increased asymmetry

Zone for disc herniations

Possible mechanism for spaceflight-related disc herniation

Preflight risk factors → spinal pathology and muscle quality
Can countermeasure exercises protect crew from disc herniation?