Effects of a proposed microgravity countermeasure, the MK VI SkinSuit, upon markers of lumbar geometry and kinematics following unloading

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Background

Daily living on Earth involves a cycle of intermittent axial loading absent in space

Stature increases up to 7cm reported in microgravity

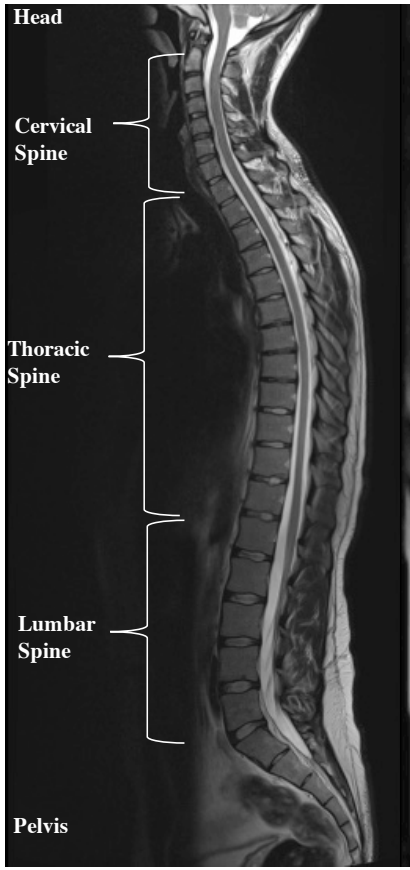
Severe back pain also reported in orbit

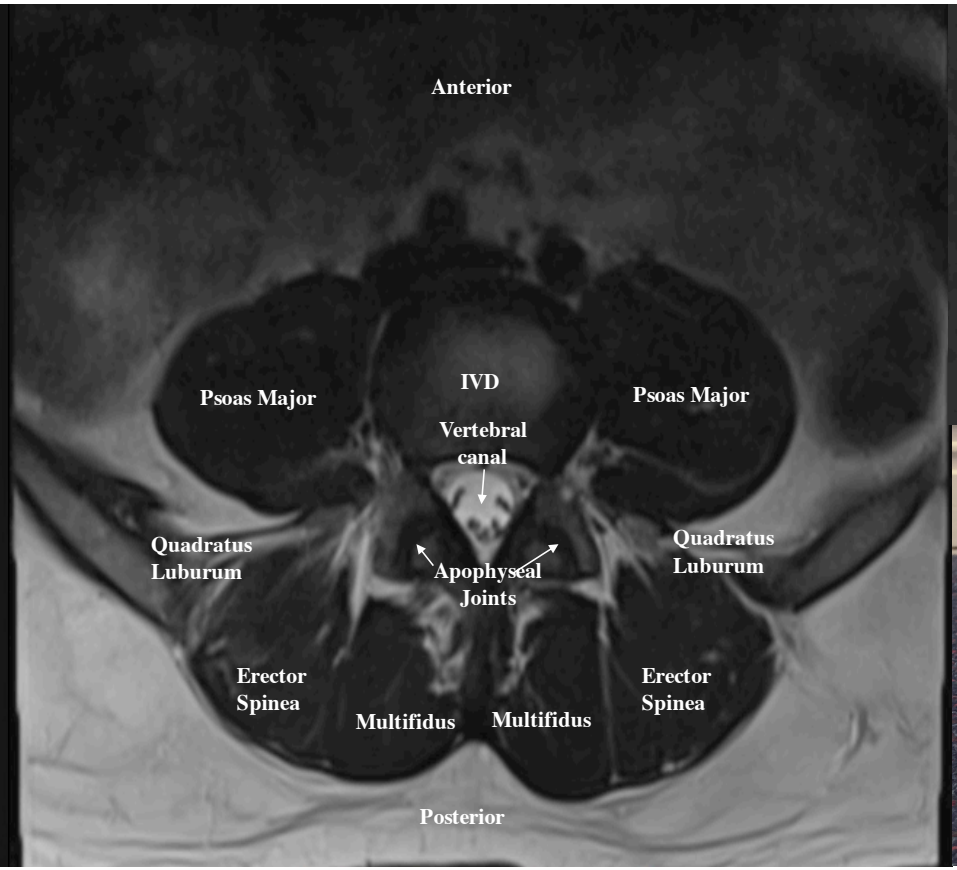
On return a 4-fold increased risk of **intervertebral disc (IVD)** herniation has been reported, particularly in the lumbar spine

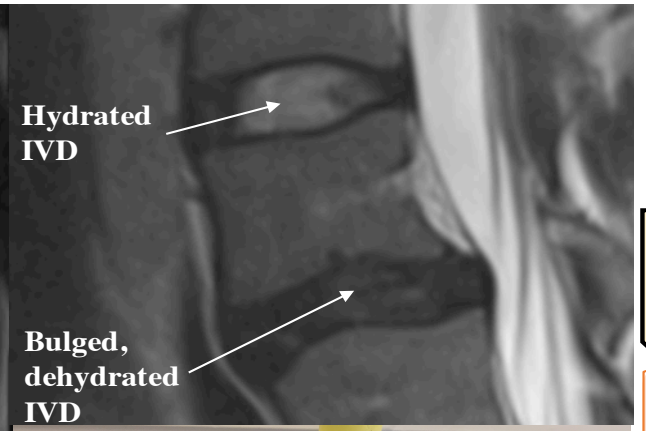
Post-mission no observable lumbar IVD swelling detected, however, a decreased range of motion and paraspinal muscle volume observed

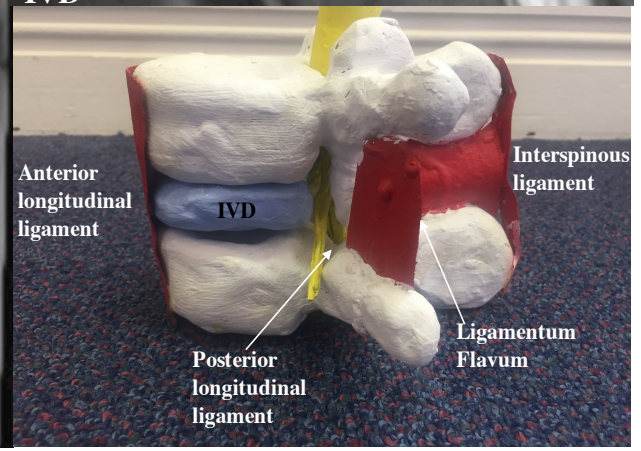
Spinal Countermeasures are needed to re-introduce axial loading in space

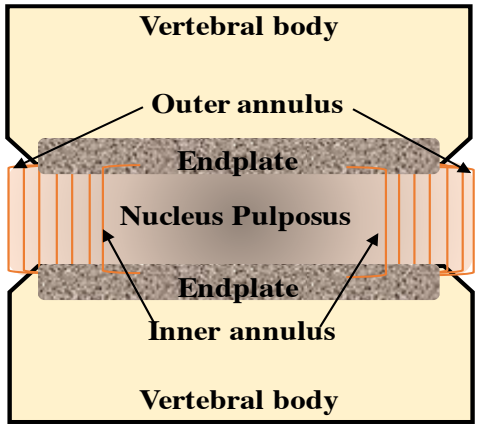
Background – The Spine and IVD











Countermeasures

Exercise forms a critical part of this program providing musculoskeletal and cardiovascular support

Exercise modalities can impart high axial loading on the spine >100% bodyweight (BW) for acute periods of time

However, the IVD's response are to acute loading **and** ' loading over time

Countermeasures which can be utilised for longer periods might offer greater spinal protection

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Countermeasures: SkinSuit

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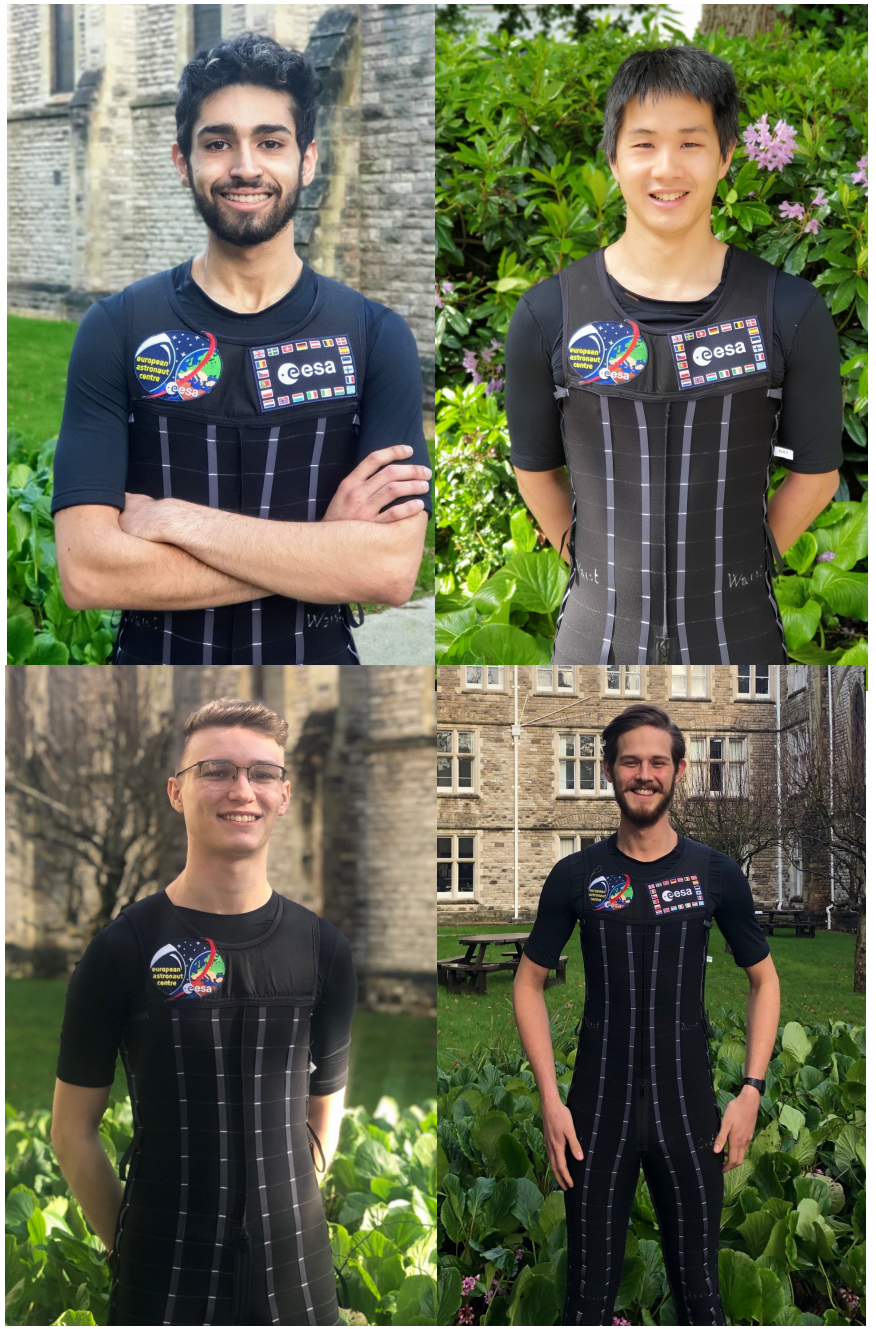
- Bi-directional elastic weaves impart low resistive tension circumferentially and high resistive tension axially
- Design modifications over time have been incorporated to facilitate long duration wear (>8h)
- Mk VI Skinsuit provides tolerable ~20% bodyweight loading (axially) at the feet

Aims

Investigate the effect of 4-hour axial reloading upon markers of disc swelling in the lumbar spine, induced by the Mk VI SkinSuit

Determine if reloading acts to increase intervertebral motion, by comparing parameters of intervertebral restraint between conditions (with and without SkinSuit loading)



Method - Participants

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22 male participants (26±4y; 1.77±0.07m; 76±11.1kg)

Reviewed by UK NHS Ethics Board

Each participant measured for a custom Mk VI Skinsuit, that provided on average 0.19±0.03Gz axial loading at the foot

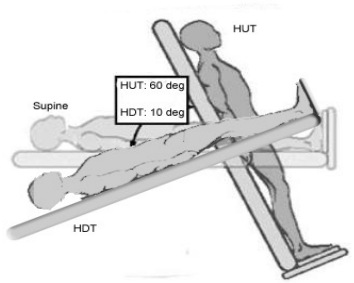
Each participant was screened for suitability by radiographer

Two participants withdrew, not in analysis

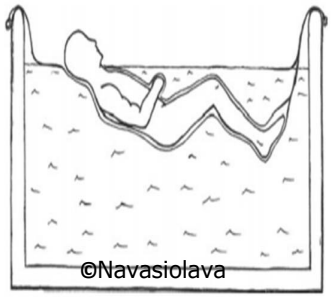
Method – Simulating microgravity

An **analogue** was required to evaluate countermeasures and investigate this effect of unloading that is representative of spaceflight – Hyper Buoyancy Flotation

6º Head down tilt (HDT)

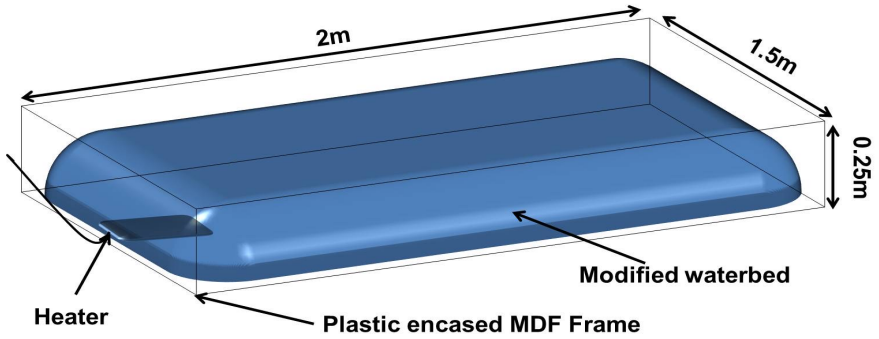


Dry immersion



REST: Restrictive environmental stimulation therapy?

Hyper-buoyancy Flotation (HBF)



Waterbed, partly-filled with saturated, saline water ($1.7gcm^3$) inducing 'horizontal buoyancy'

Provides accessibility for countermeasure evaluation (stature, imaging, loading etc.)

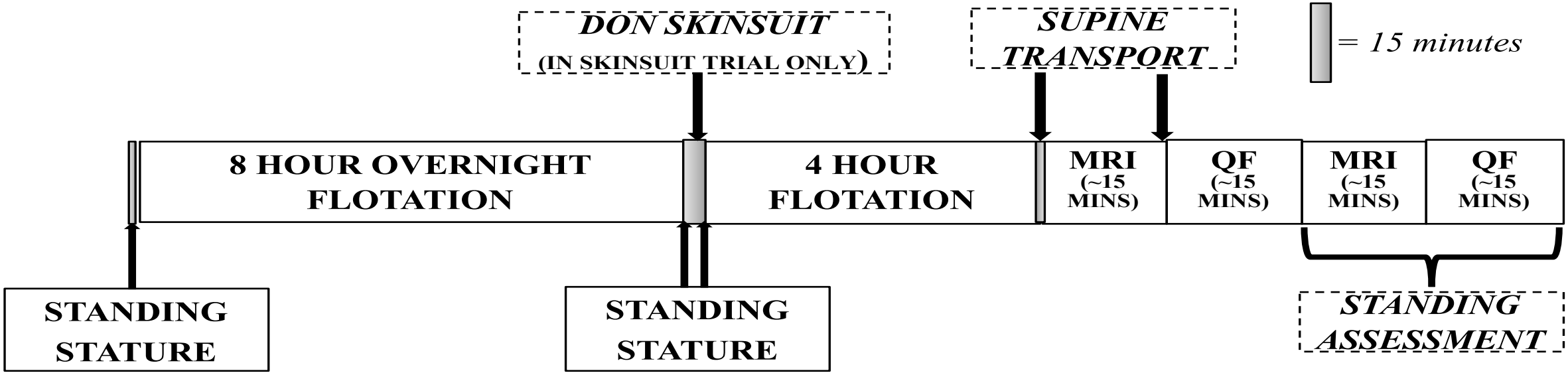
Several prior studies performed to validate HBF

Method – Protocol

Protocol repeated 6 weeks apart with participants acting as own control

Participants arrived at the imaging facility where a HBF was installed within transport (trolley) of the imaging suite

Two types of imaging used: Magnetic resonance (MRI) and Quantitative fluoroscopy (QF) to look at lower spine (lumbar) Geometry [MRI] and kinematics [QF].



Method – Imaging Protocol (Geometry)

- Participants transferred supine to MRI from HBF by trolley
- Lumbar spinal scans taken aligned through IVD:-
- 11 T2 weighted Sagittal slices
- 20 (four blocks of five) axial slices
- Measurements of lumbar curvature, height, IVD height and cross-sectional area taken using commercial software (OsiriX Lite, Pixmeo Sarl, Switzerland).
- Post all supine tests, protocol repeated upright

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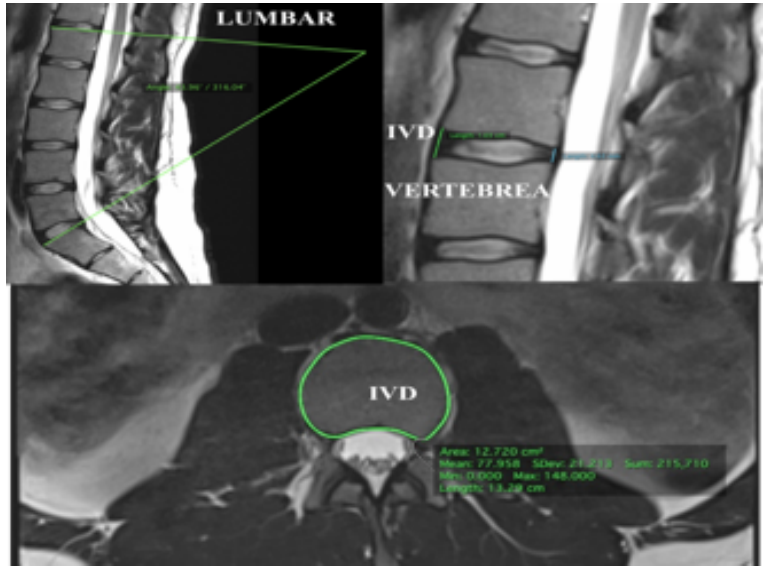

Method – Imaging Protocol (Kinematics)

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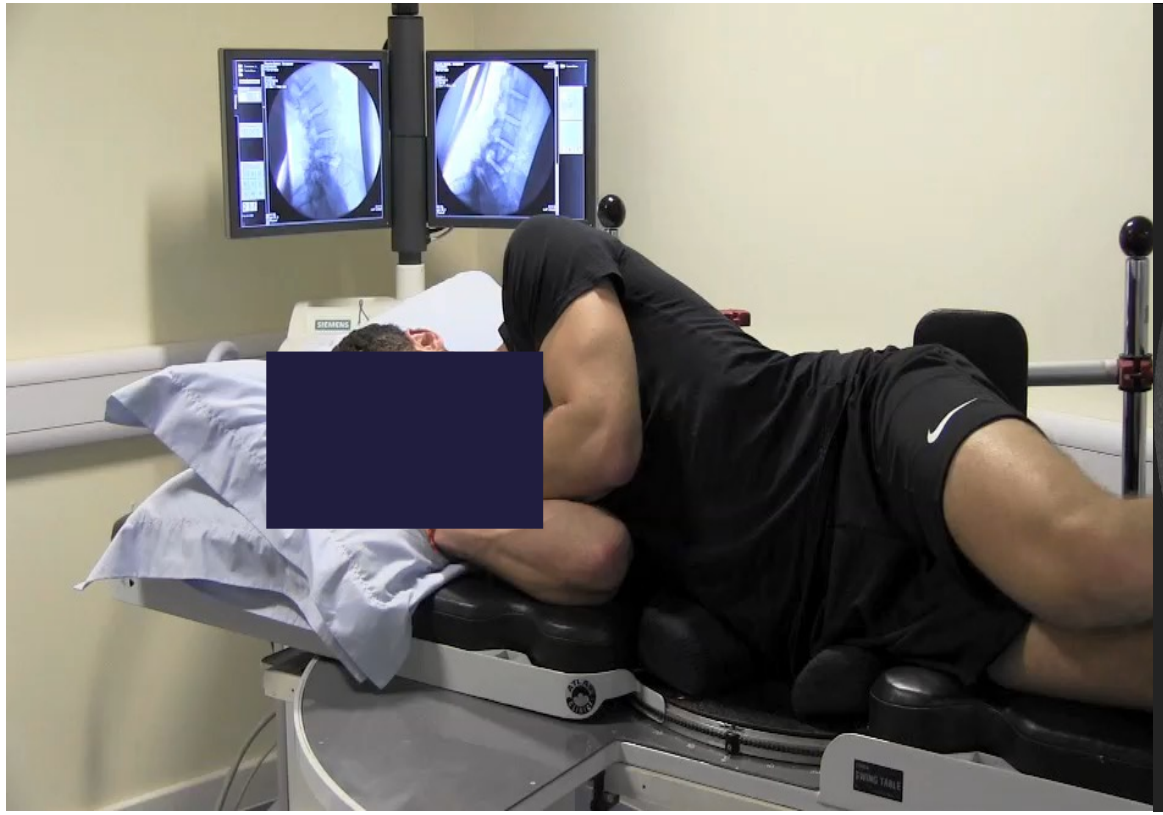
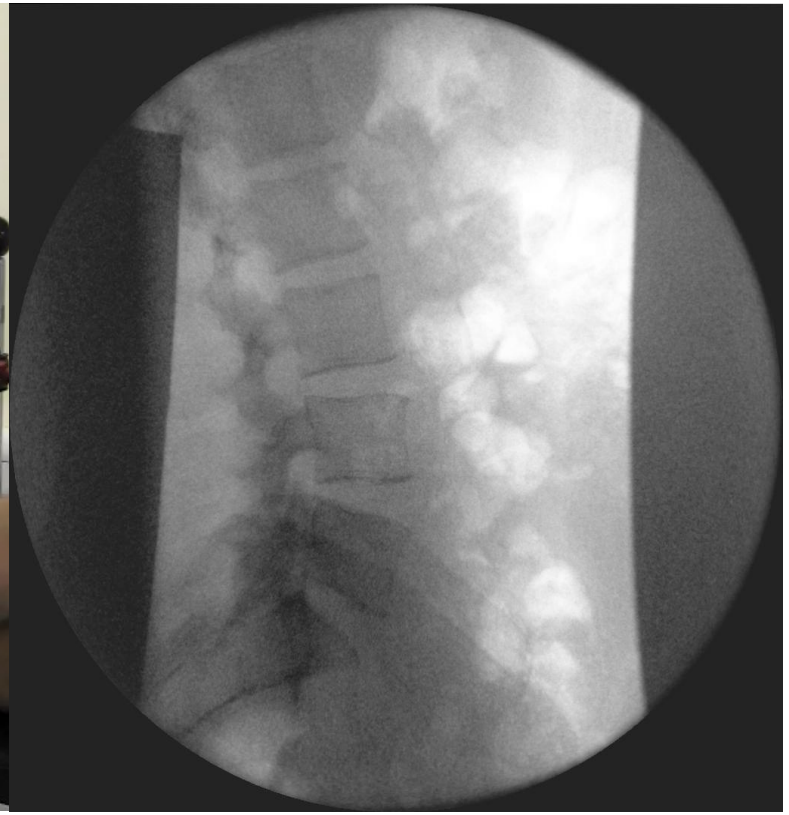
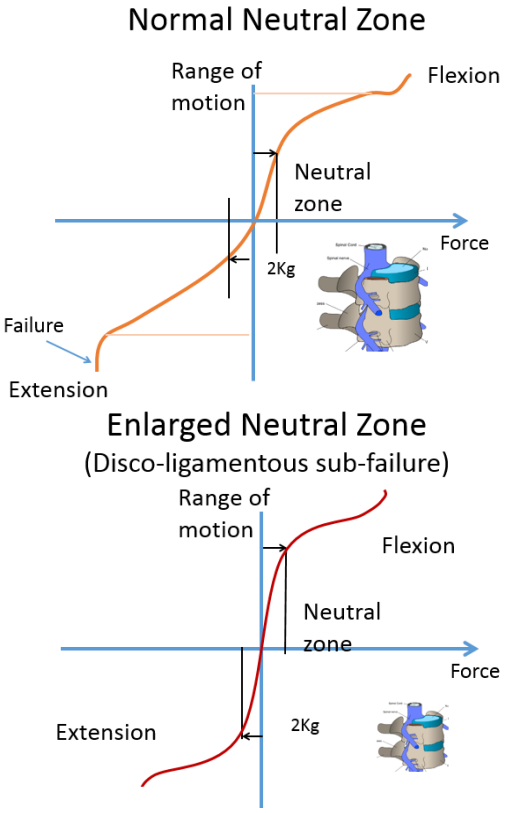
- Imaging performed with a Siemens Arcadis Avantic VC10A digital fluoroscope
- Central ray positioned at L3-4 disc with all vertebrae from L2-S1 in the field of view
- Scans taken in both supine (passive recumbent) and upright (standing) positions:
- **Supine:** 40˚of flexion, followed by 40˚of extension using a computer-controlled motor operated table, which allowed passive motion of the spine
- **Upright:** Standing active flexion 60˚/ extension 20˚)
- Image acquisition at 15Hz synchronised with controller of motor table
- QF image processing/analysis were performed using MATLAB

Method – Imaging Protocol (Kinematics)





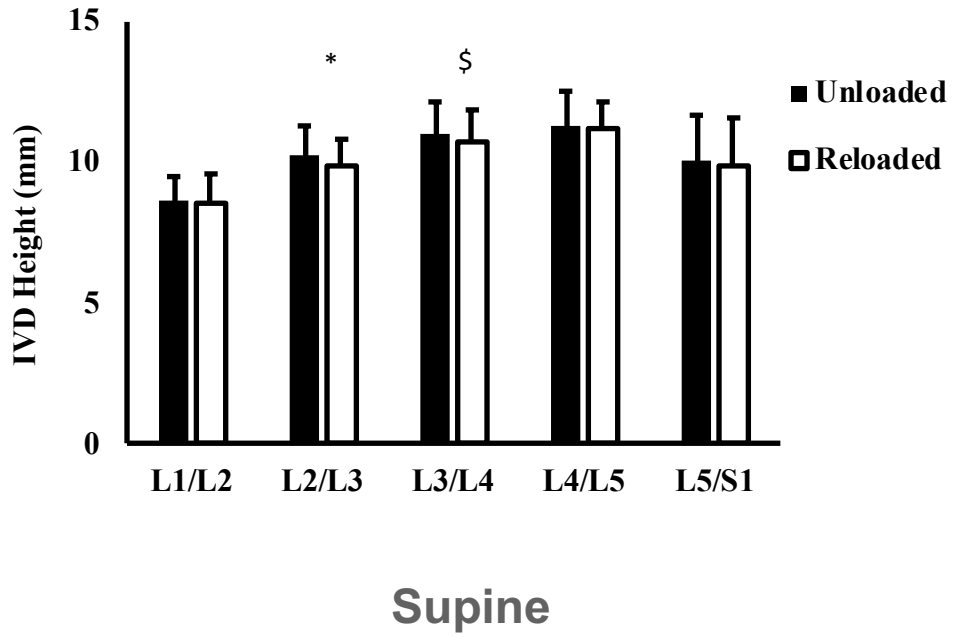


Results - Geometry

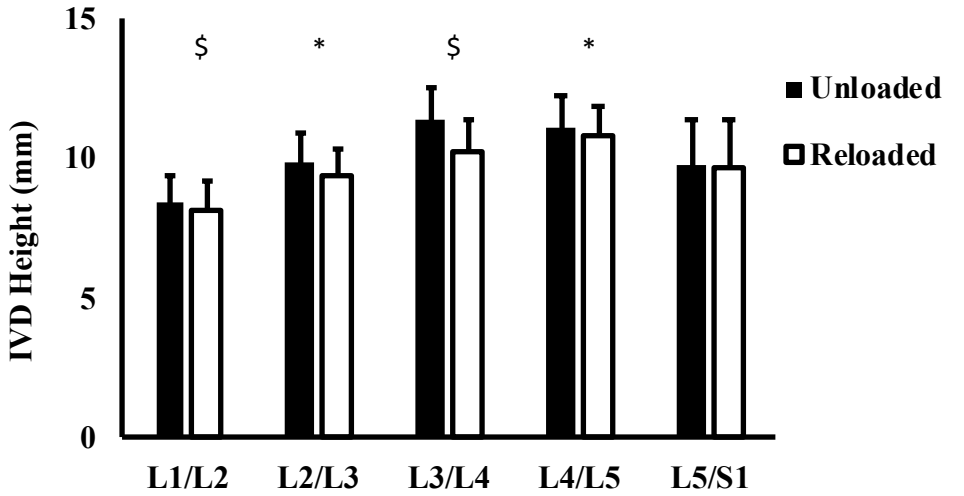
Following 4h Reloading:

- Lower lumbar spine length (p=0.01)
- Greater lordosis (p=0.0001)
- Reduce IVD disk height (more pronounced during upright)

No significant difference in IVD cross-sectional area and volume.



Supine



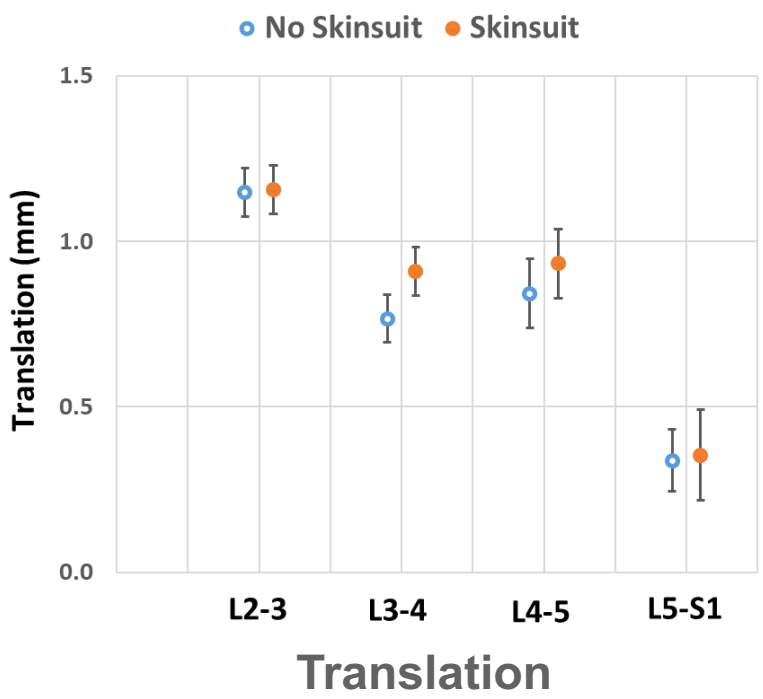
Upright

Results - Kinematics

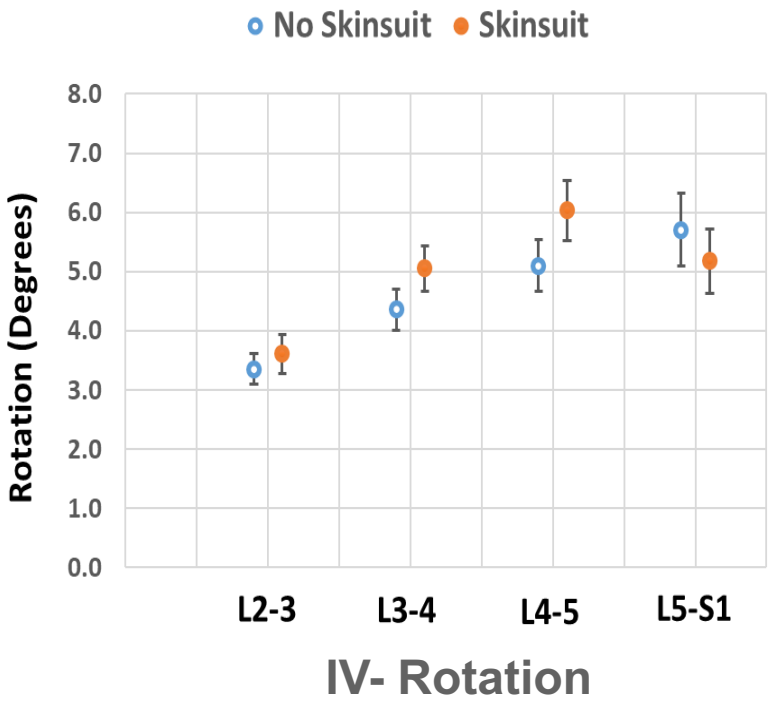
During supine imaging, it was observed:-

- An increased in IV-RoM during flexion at L3-4 (p=0.01) and L4-5 (p=0.003)
- Lower dynamic disc height at L5-S1 (p=0.002)
- More translation at L3-4 (p=0.02)

No significant differences observed during upright, active flexion/extension



Translation



IV- Rotation

Conclusion

Short term (4 hour) wear of the Mk VI SkinSuit appears to restore lumbar mobility and lordosis following a microgravity analogue exposure in a healthy control population and may be an effective countermeasure for post space flight lumbar disc herniation.

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