

Von Astronaut:innen für Patient:innen: Neue Erkenntnisse der Medizintechnik gegen Rückenschmerzen

Study designed and realized by
Jaap Swanenburg & Marcel Egli

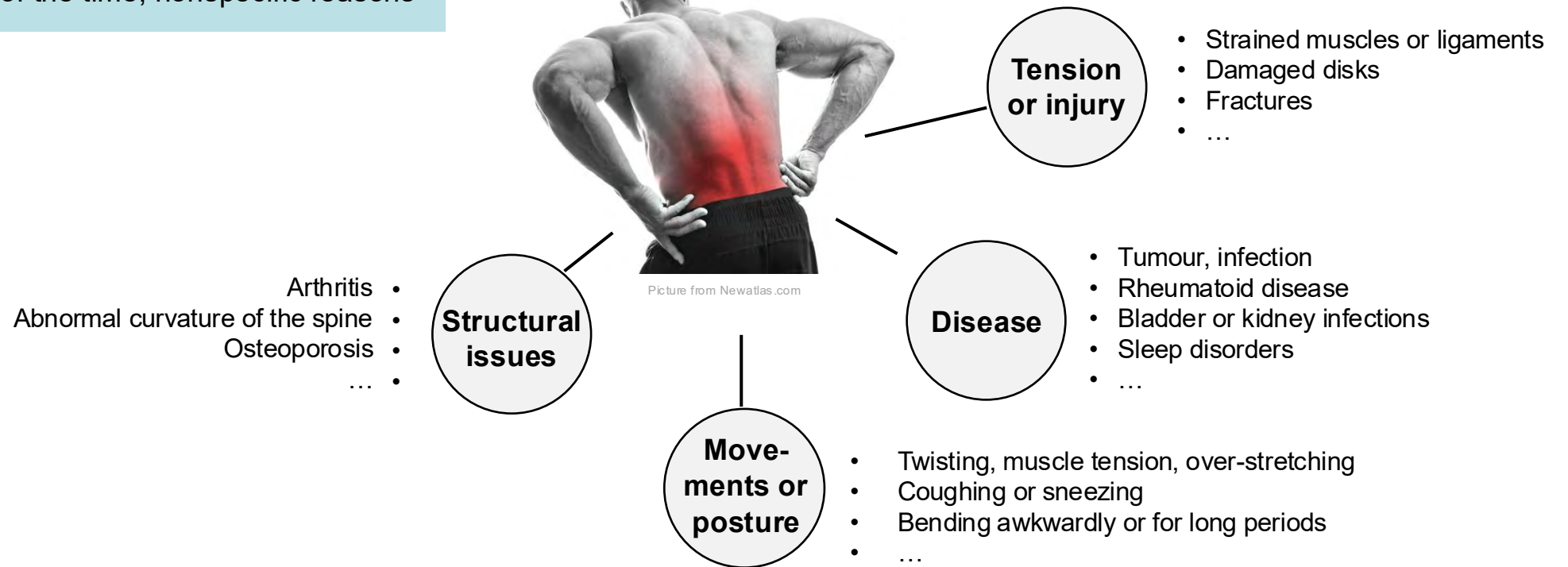


Picture credit: NASA



Origin of low back pain

- Lifetime **prevalence**: **84%**
- Prevalence of **chronic** pain: **23%**
- Most of the time, nonspecific reasons

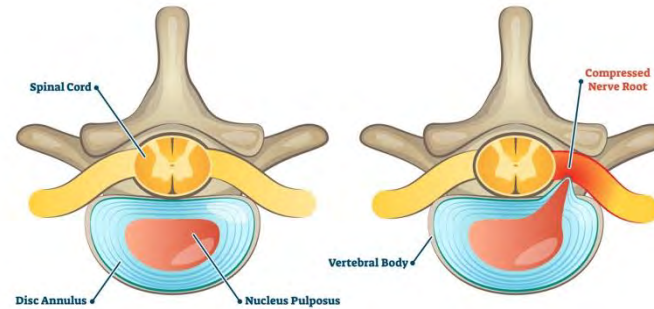


Modified from: <https://mobilephysiotherapyclinic.in>



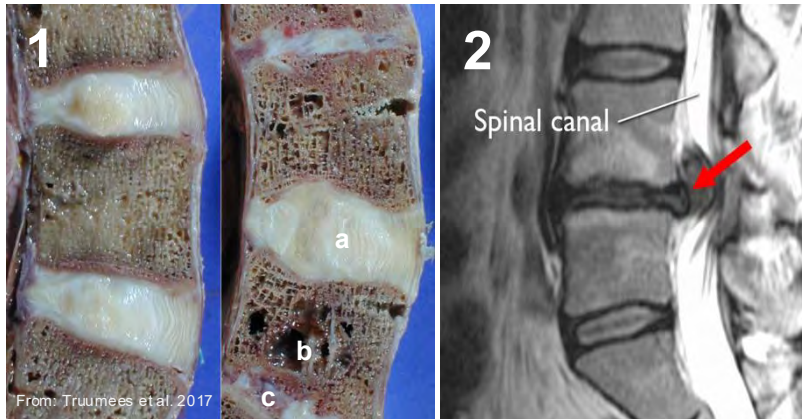
Pathology of the intervertebral disc (IVD)

Low back pain and disc degeneration are often associated



Images from <https://www.williamcapicottomd.com>

- **Disc degeneration** in the lumbar spine is nearly universal after age 50.
- **4.8% of males** and **2.5% of females** older than 35 experience **sciatica** during their lifetime.



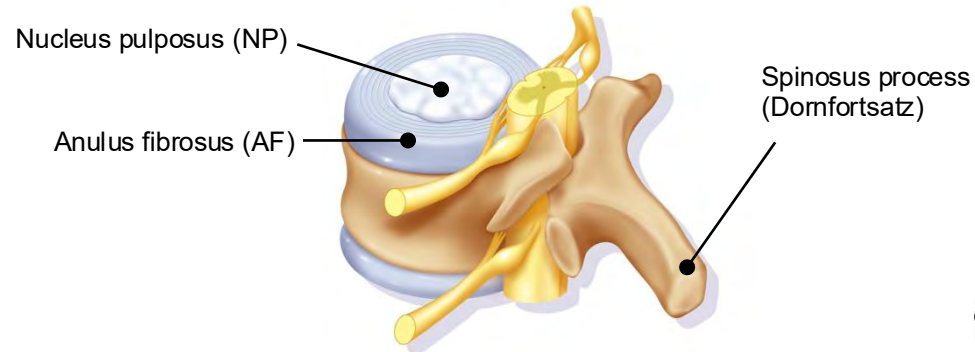
1: (a) swollen IVD, (b) porous vertebrae, (c) degenerated IVD. 2: MRI scan shows a herniated disk in the lower back (red arrow).



Treatment includes recommendations to **stay active**, **paracetamol**, non-steroidal **anti-inflammatory drugs**, spinal **manipulation therapy**, **muscle relaxants**, and weak **opioids**.



Degeneration of the intervertebral disc



Picture from <https://www.verywellhealth.com> (BSIP / UIG / Collection: Universal Images Group / Getty Images)

Section of the bovine tail showing vertebrae, endplates, growth plates, and IVD

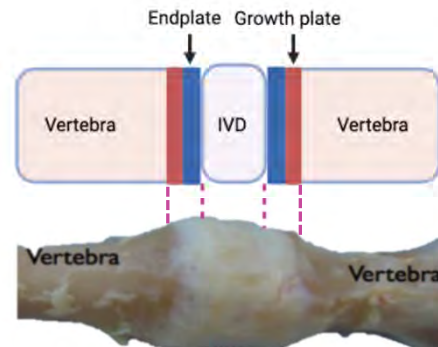
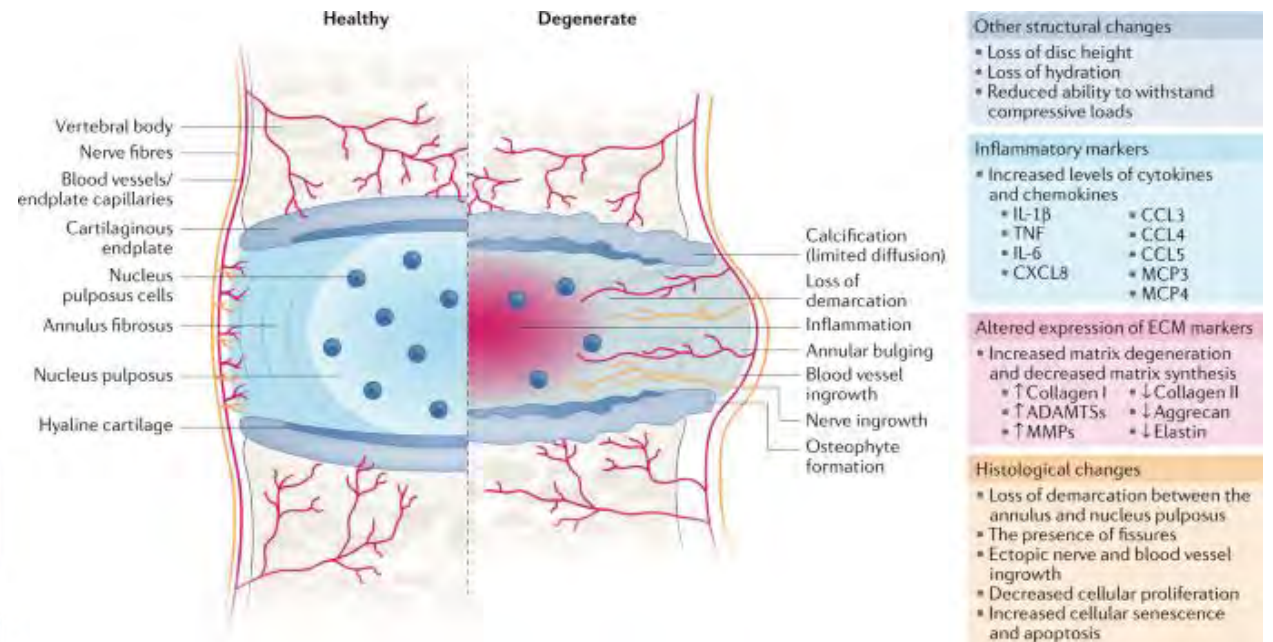


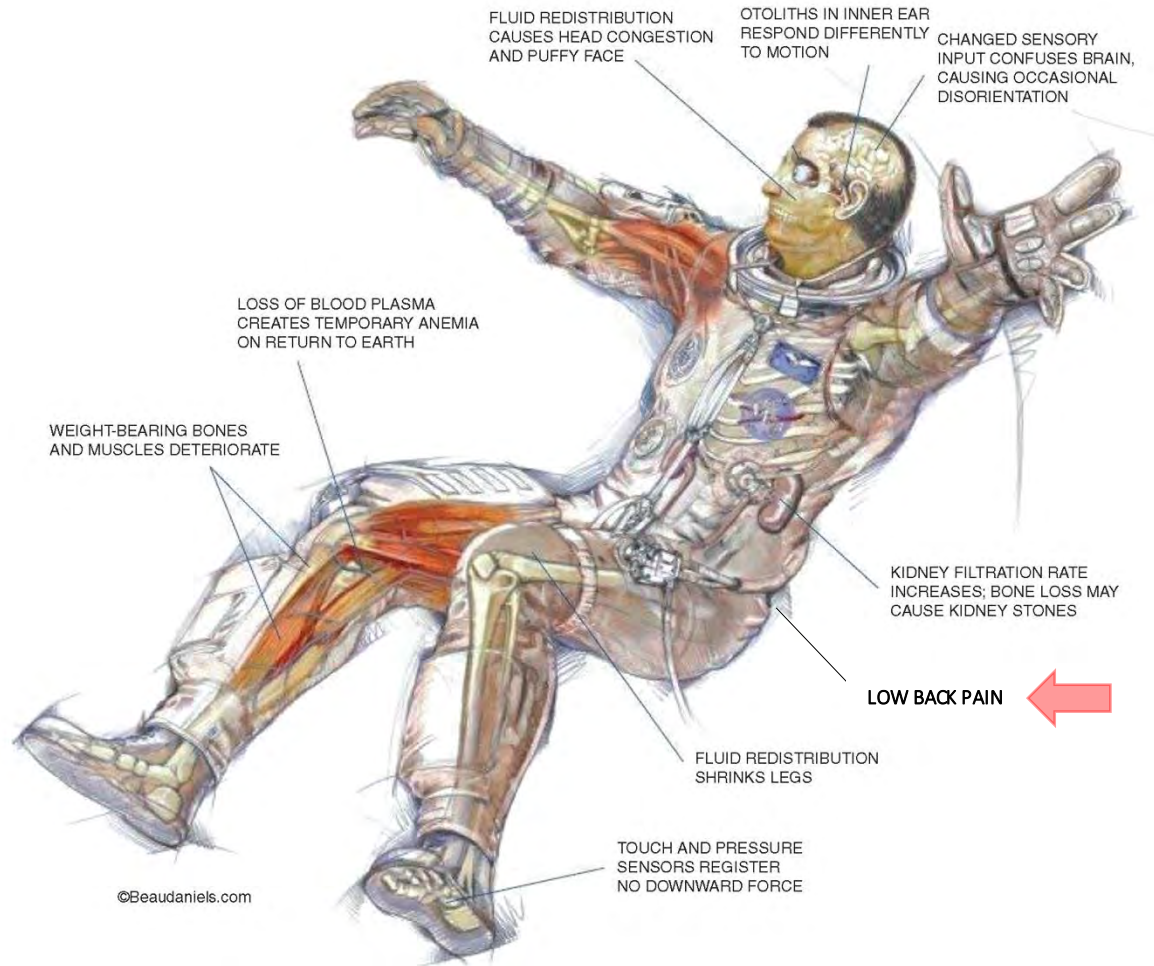
Image credit: Parandé Tayybei, Master's thesis (2021) and Chan and Gantenbein-Ritter (2012).



Picture from Abbie L. et al. (2021) Cell-based strategies for IVD repair: clinical progress and translational obstacles. Nature Reviews Rheumatology DOI: 10.1038/s41584-020-00568-w



Low back pain of humans in space



- **52%** of all the astronauts (n = 772) reported back pain
- Symptoms developed **within the first 2 days**
- **86%** reported **mild pain**
- Pain was located in **86% lumbar**
- Pain was present **at night (75%)**
- Symptoms tend to improve or resolve with the use of **bending the knees to the chest and stretching**

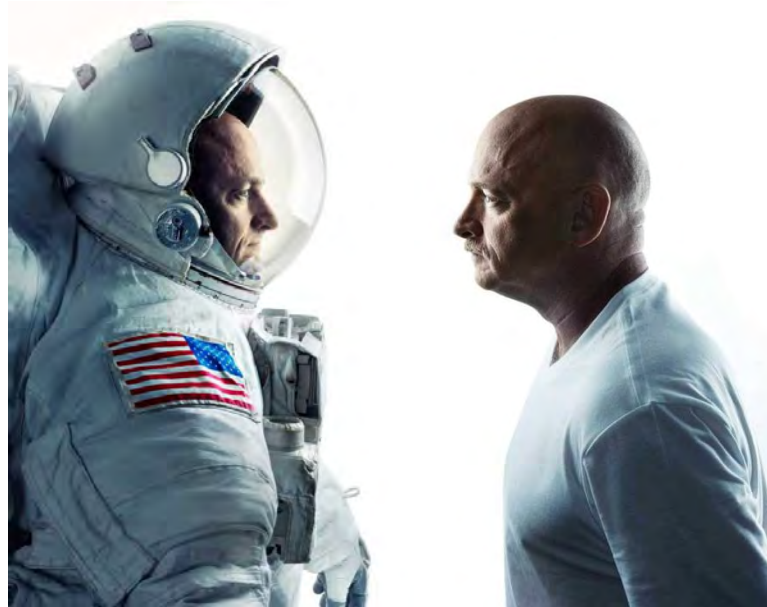
From: Space Adaptation Back Pain: A Retrospective Study Presenter (2009) Eric Kerstman, NASA Johnson Space Center

Adapted from Hodkinson et al. (2017) An overview of space medicine. British Journal of Anaesthesia 119: i143–i153



Study goals – think outside the box!

- Determine **the cause** of low back pain in space
- Elucidate the underlying biomedical **mechanisms involved**
- Define **measures** to prevent low back pain in space or propose **treatments** to reduce the pain



Picture credit: NASA (<https://nasa.tumblr.com>)

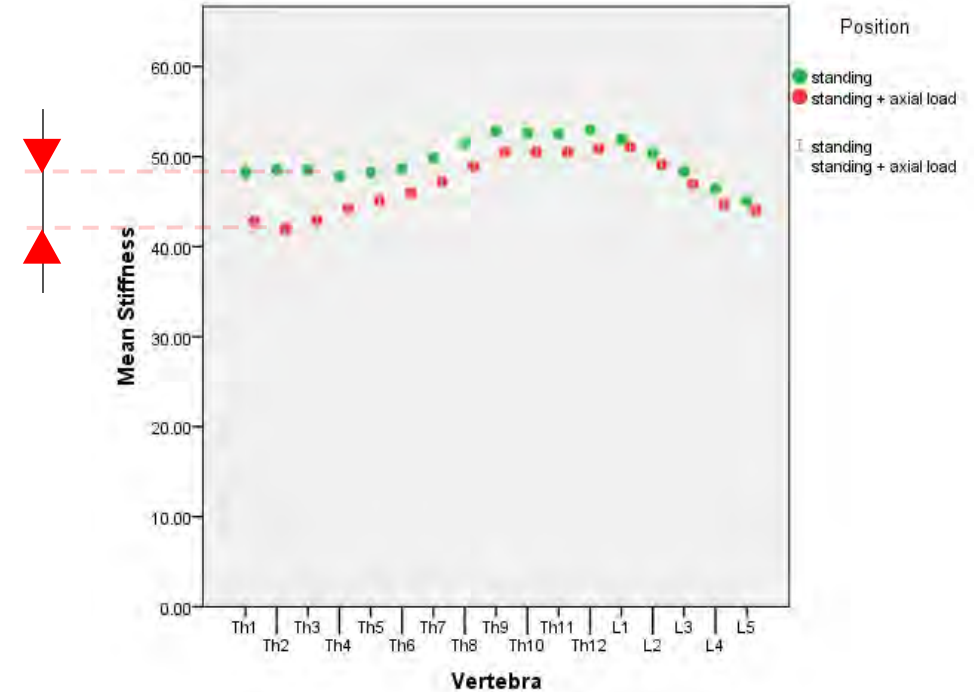
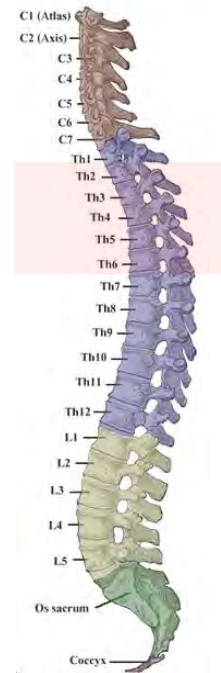
- Learn more about the **degenerative processes** of the IVD
- Finding **regenerative strategies** (either through medication or therapies)
- Helping to find alternative strategies for **IVD replacement**



Study approach: Stiffness



Measuring **spinal stiffness** at 50% body weight (n=100) under 1g-ground conditions

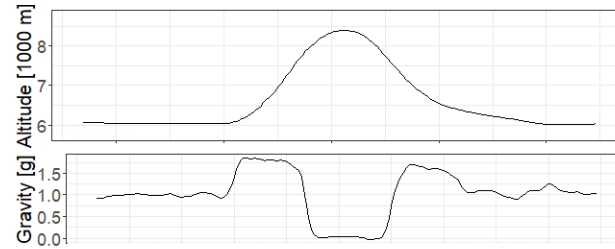




Study approach: Stiffness



Picture credit: ESA



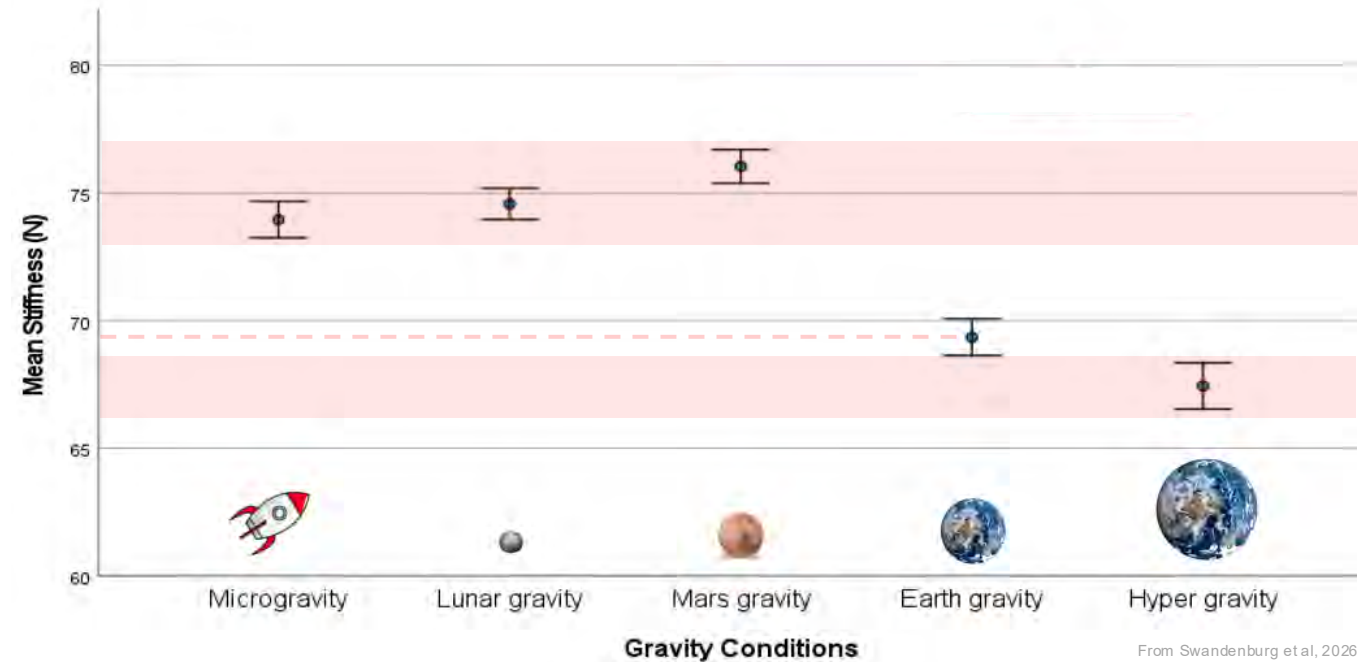
ESA parabolic flight studies

Picture credit: Anita Meinke, 2024



Picture credit: ESA

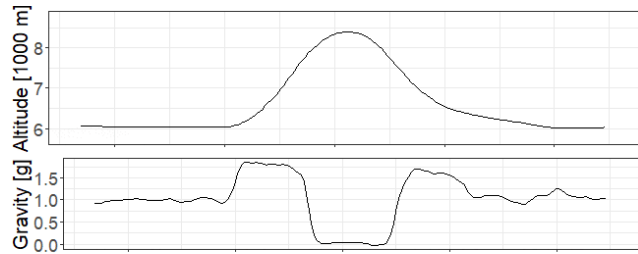
Measuring **spinal stiffness** under 0g, 0.2g, 0.4g, 2g, and 1g ground control



From Swandenburg et al, 2026

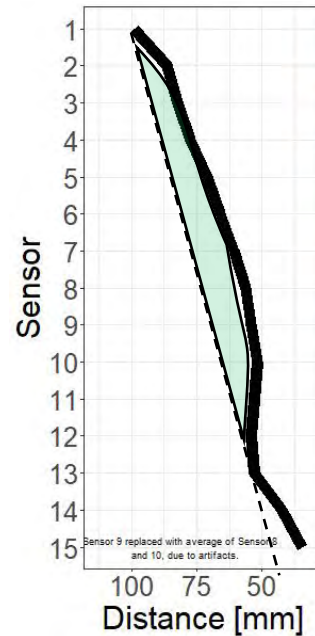
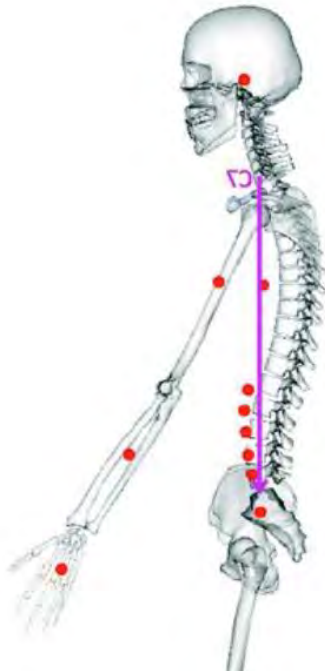


Study approach: Curvature



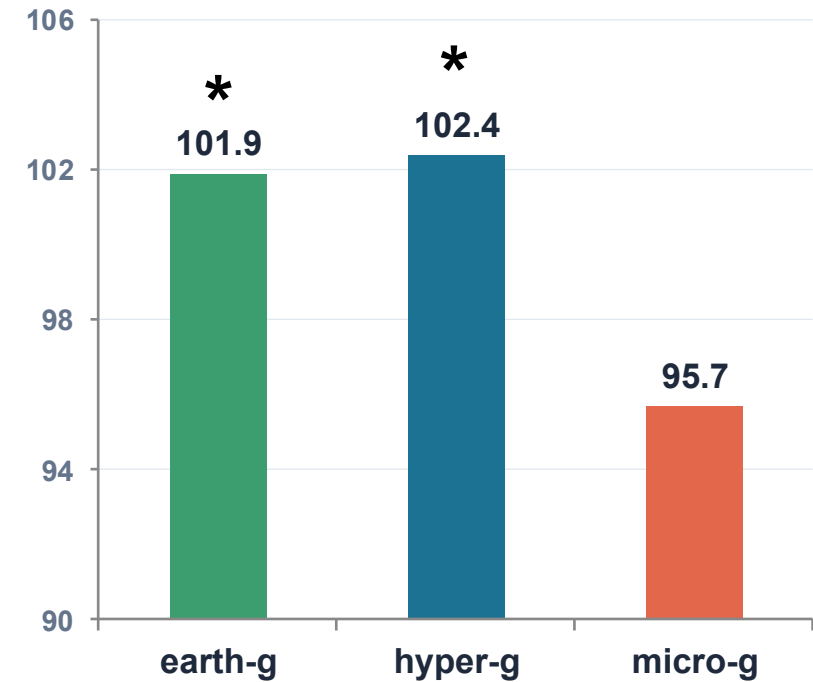
ESA parabolic flight studies

Picture credit: Anita Meinke, 2024



Swandenburg et al, 2025

Area under the Curve (AUC)



Swandenburg et al, 2026

micro-g vs earth-g: flattening ($t(16) = 4.84$, $p = 0.001$)

micro-g vs hyper-g: flattening ($t(16) = 4.91$, $p = 0.001$)

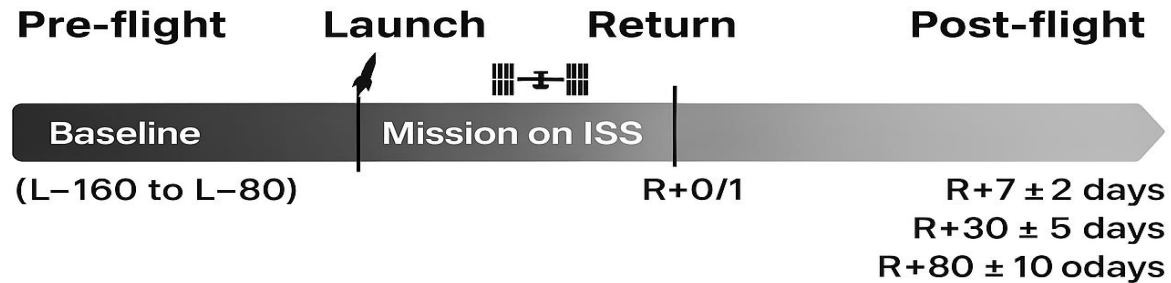


Effects induced by long-term microgravity exposure

Measurements

- Spinal **Stiffness** (L5 –T8)
- Spinal **Curvature**
- Spine **Dynamics**
- **Intervertebral Disc** (IVD) height

SpaceX Crews



Medical Examination Room
at the NASA Johnson Space
Center (JSC), Houston



Picture credit: Marcel Egli



Study approach: Spine dynamics and intervertebral disc

Capturing the **(A) spine dynamics**, as well as **(B) the intervertebral disc (IVD) height and diameter** of astronauts before and after a 6-month stay on board the International Space Station

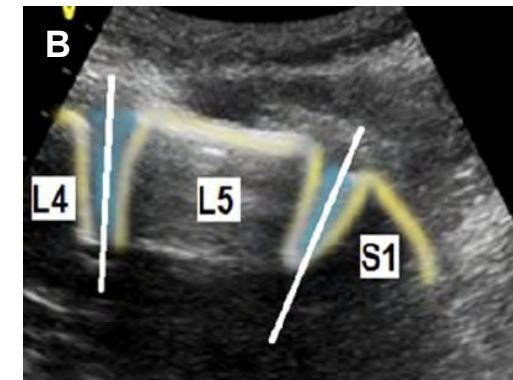


Picture credit: Jaap Swandenburg, 2023



“Epionics SPINE” motion pattern recording system

From: DOI:10.1371/journal.pone.0050135

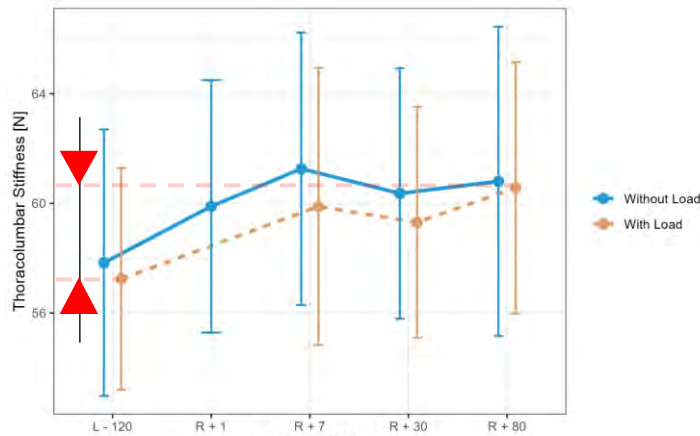


Midline sagittal ultrasound images of the **lower lumbar segment** (blue highlighted)

From Marshburn et al. 2014



Selected results of the astronaut study

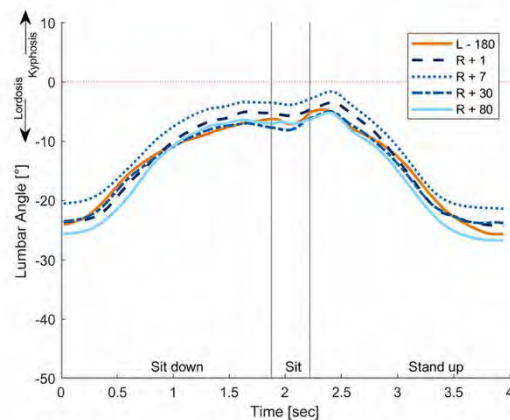


Swandenburg et al, 2026

The spine is **not a passive column**. It is an active, highly sensitive **computational system** that **dramatically alters** its motor strategies outside the 1g environment.

Implications for Countermeasures:

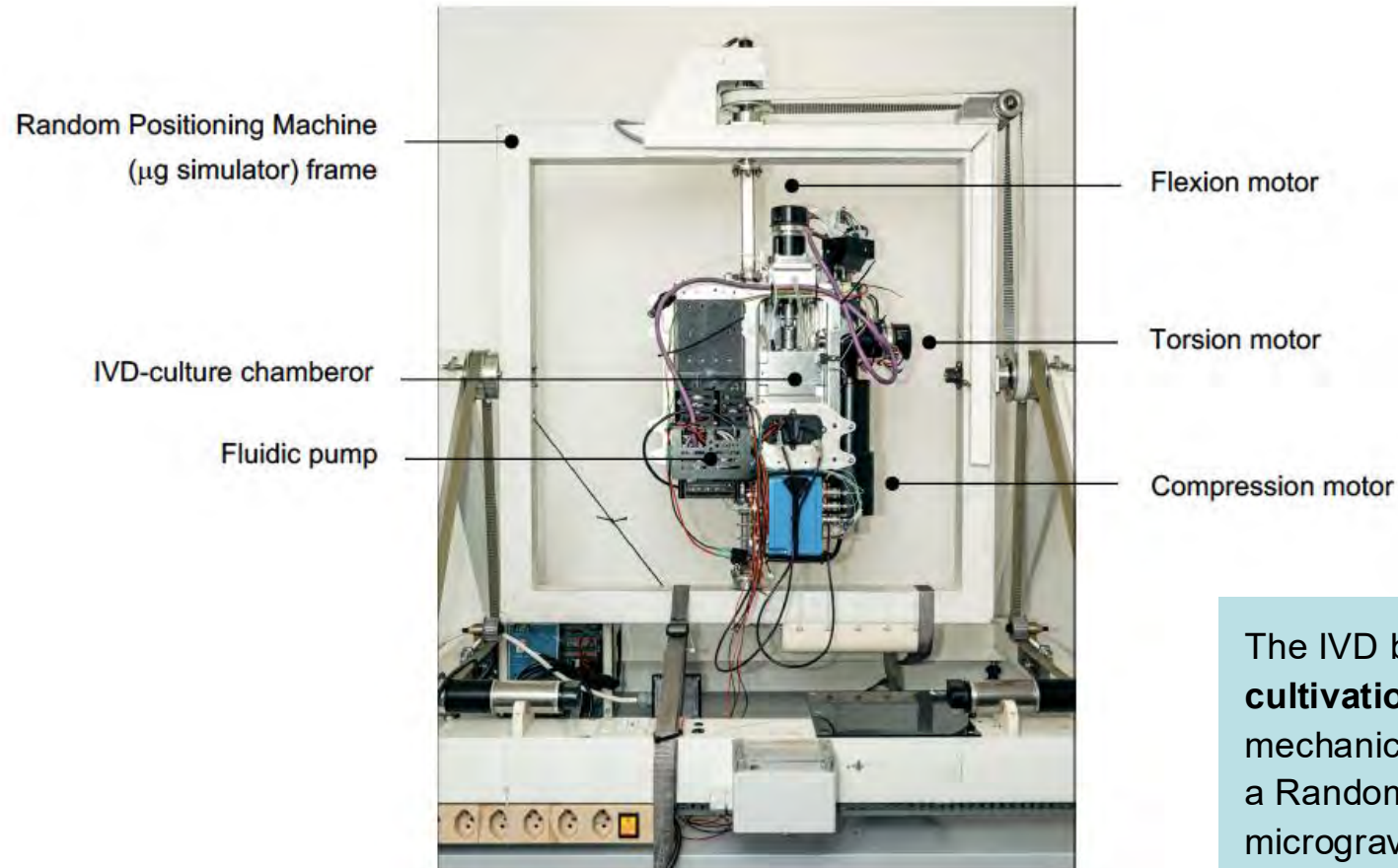
- Applying **physical loading alone** is insufficient
- Chronic low back pain involves **disturbed neuromuscular control** and **altered trunk stiffening strategies**
- Altered spinal mechanics may **affect rehabilitation outcomes**



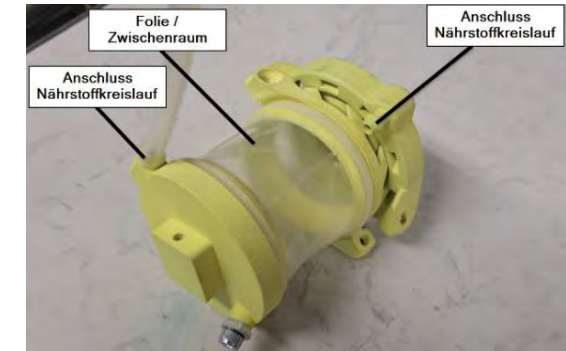
Swandenburg et al, 2026



Investigating mechanical properties of intervertebral discs



Picture credit: Hochschule Luzern, 2025



Picture credit: Reto Bischof, Hochschule Luzern, 2025

Culture chamber of the IVD bioreactor system

The IVD bioreactor system enables the **long-term cultivation of biological samples** under dynamic mechanical conditions. Integrating the system with a Random Positioning Machine simulates microgravity.



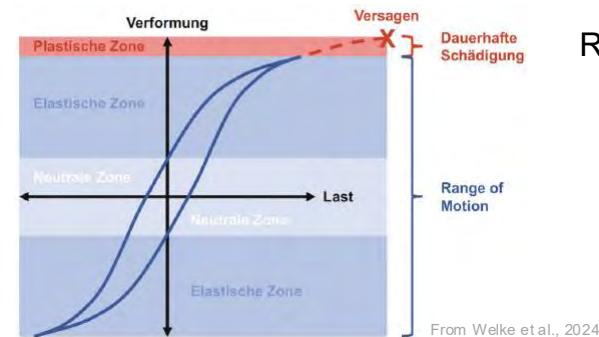
Investigating mechanical properties of intervertebral discs

Karolina Magdalena Piasecka, Bachelor's Thesis FS 2026

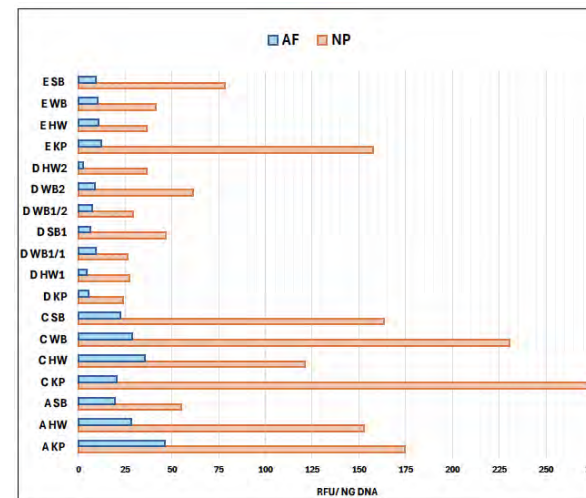


Picture taken by Karolina Magdalena Piasecka

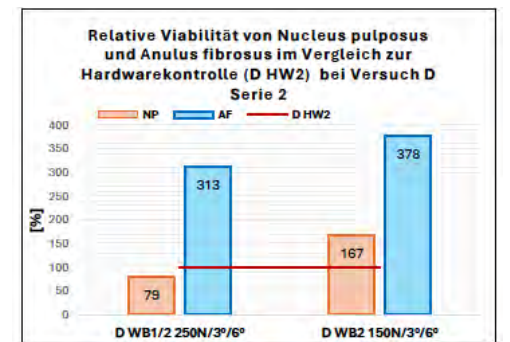
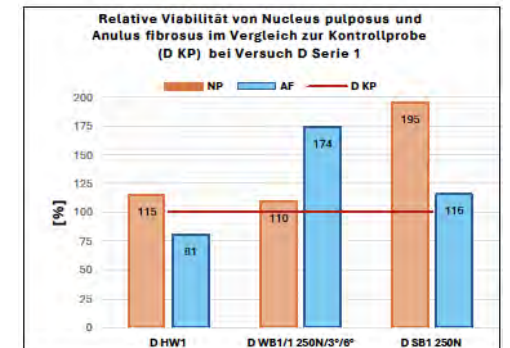
Device for applying a **static, manual load** to the intervertebral disc. (1) Screw nuts for force adjustment, (2) chamber housing the intervertebral disc, (3) force sensor, (4) display



Range of Motion and Neutrale Zone



Results from Karolina Magdalena Piasecka, Bachelor's Thesis FS 2026





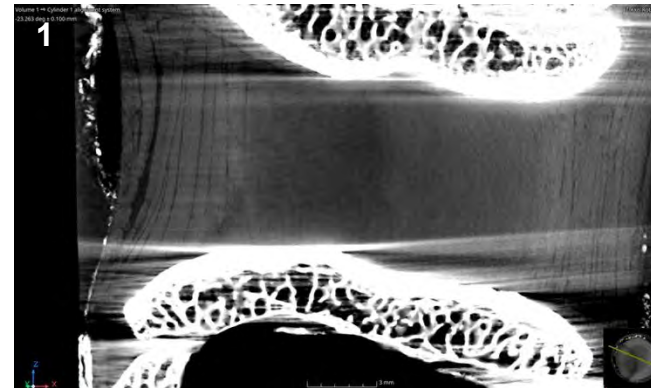
Investigating mechanical properties of intervertebral discs

Lukas Wild, Bachelor's Thesis FS 2026

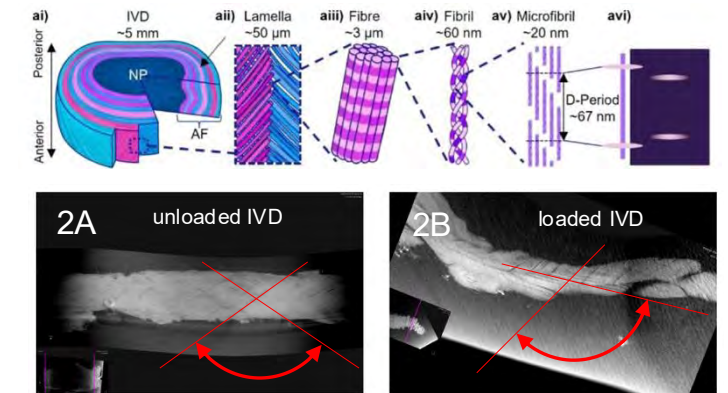


Picture: Lucerne CT Imaging (facility): "Luci" is a computer tomograph measuring 3.5 x 2.0 x 2.5 meters and weighing about 11 tonnes. Department T&A, Hochschule Luzern, 2025

Investigating the **structural differentiation** of the annulus fibrosus (AF) and nucleus pulposus (NP) in bovine intervertebral discs using micro-CT and X-ray diffraction.



Results from Lukas Wild, Bachelor's Thesis FS 2026

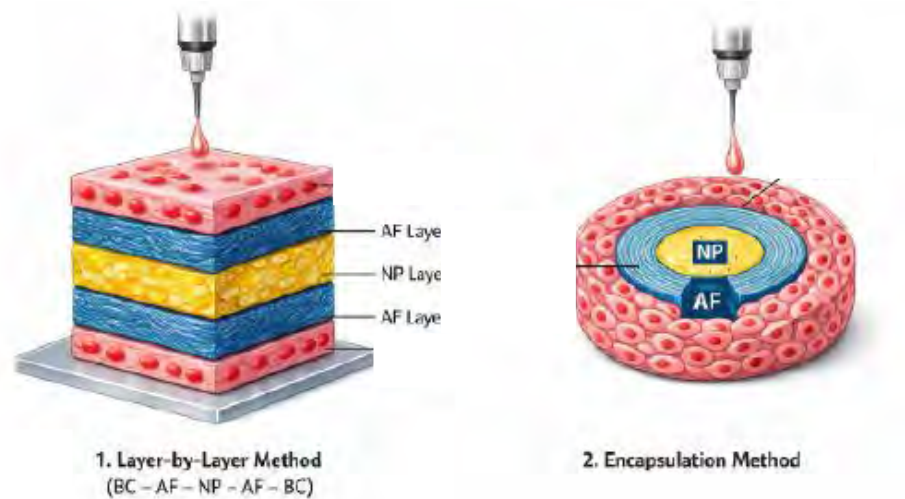


1: Cross-sectional view of an intervertebral disc (IVD) positioned between the superior and inferior vertebral bodies. The concentric lamellar architecture of the annulus fibrosus is visible at the lateral margins. 2: Detailed view of the lamellar structure of the annulus fibrosus in an unloaded (2A) and loaded (2B) IVD, illustrating load-dependent structural deformation.



Intervertebral disc replacement: 3D-bioprintins

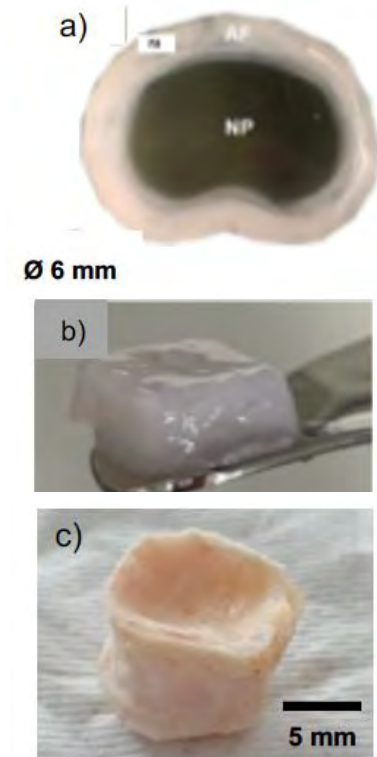
ESA Ground-based research grant:



3D printing strategies for IVD bio-scaffolds: Left: bio-scaffolds contain annulus fibrosus (AF) cells and nucleus pulposus (NP) cells in the center, reflecting the anatomical organization. Right: Ring-layer structure.



3D bioprinter LUMEN X™ Gen 3 in use at the University of Manchester



From: Moxon et al. "3D bioprinting of an intervertebral disc tissue analog with a highly aligned annulus fibrosus via suspended layer additive manufacture (2025) Biofabrication

Pictures of 3D-printed IVDs (a and b) and an isolated bovine IVD for comparison.



Health challenges on the ground

HSLU IDN Gesundheit 2024, zusammen mit Jana Freundt (SA HSLU):
 “Rückenschmerzen beim Pflegepersonal”

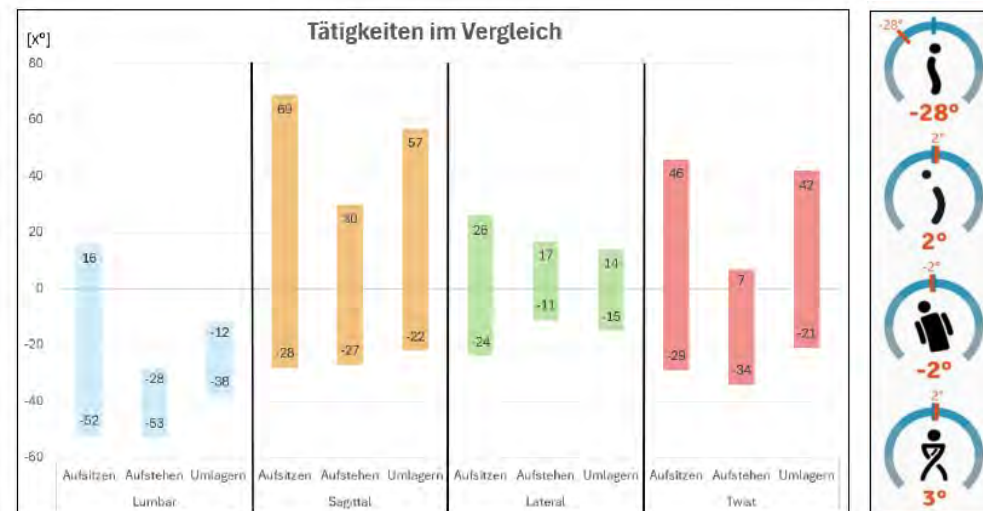


Picture from <https://www.medicals.ch>

Nursing staff
 working at the
 patient's bed

Outcome: Working conditions are increasingly demanding due to **complex patient cases**, shorter stays, cost pressures, and heavier workloads. **Physical strain**, psychological stress, emergencies, and time pressure remain key challenges.

Lorena Schwendener, Bachelor's Thesis FS 2026



	Vorzeichen positiv	Vorzeichen negativ
Lumbar	Vorwärtsbiegung der Lendenwirbelsäule → Front	Rückwärtsbiegung der Lendenwirbelsäule → Back
Sagittal	Vorwärtsbiegung → Front	Rückwärtsbiegung → Back
Lateral	Biegung nach rechts → Right	Biegung nach links → Left
Twist	Rotationsbewegung nach rechts → Right	Rotationsbewegung nach links → Left

Results from: Lorena Schwendener, Bachelor-Thesis FS 2026



Health challenges on the ground

IDN 2025: “Exoskelett-Unterstützung von Pflegefachpersonen”

Technologies could **support care staff with physically demanding tasks in the future**. Pilot studies are exploring the potential of an exoskeleton for everyday care work.

Use of exoskeletons to support nursing personnel at work



Picture from <https://xund.ch/newsroom/aktuelles>

HSLU IDN Gesundheit 2026, zusammen mit Sabrina Köchli (Musik HSLU): “Rückenbeschwerden bei Musiker:innen”



Picture from <https://www.lexikon-der-musik.de>

The **performance of musicians** is highly demanding and involves repeated motion patterns

Investigation of musicians’ **spinal movements during standardized musical performance**. Validated questionnaires assess musculoskeletal complaints, well-being, and self-efficacy.



Health challenges on the ground

ESA / NASA Research Grant Proposal: “Motion pattern of astronauts on board the International Space Station”



Picture credit: ESA

How does **astronaut movement in microgravity** differ from movement on Earth, and what specific biomechanical risks are associated with these altered movement patterns?

Armasuiss Research Grant Proposal: “Military pilots' susceptibility to neck pain” (in preparation)



Picture from Christian Merz

Pilots' necks are often exposed to high g-forces while flying missions



Thank you



Picture credit: NASA