HSLU Hochschule Luzern

Technik & Architektur
Medical Engineering
Master of Science in Engineering

Master-Thesis Engineering, Fachgebiet Medical Engineering

Determining the lumbar loading patterns and the changes in lordosis before and after prolonged exposure to microgravity

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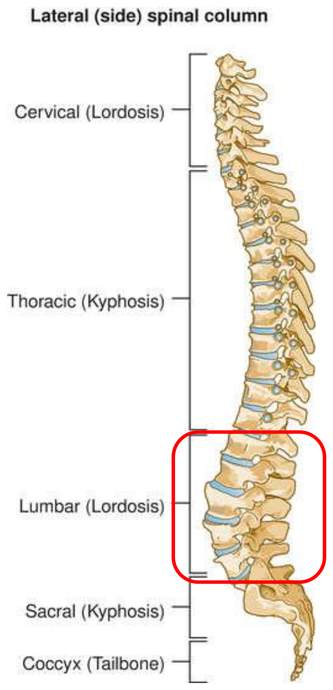
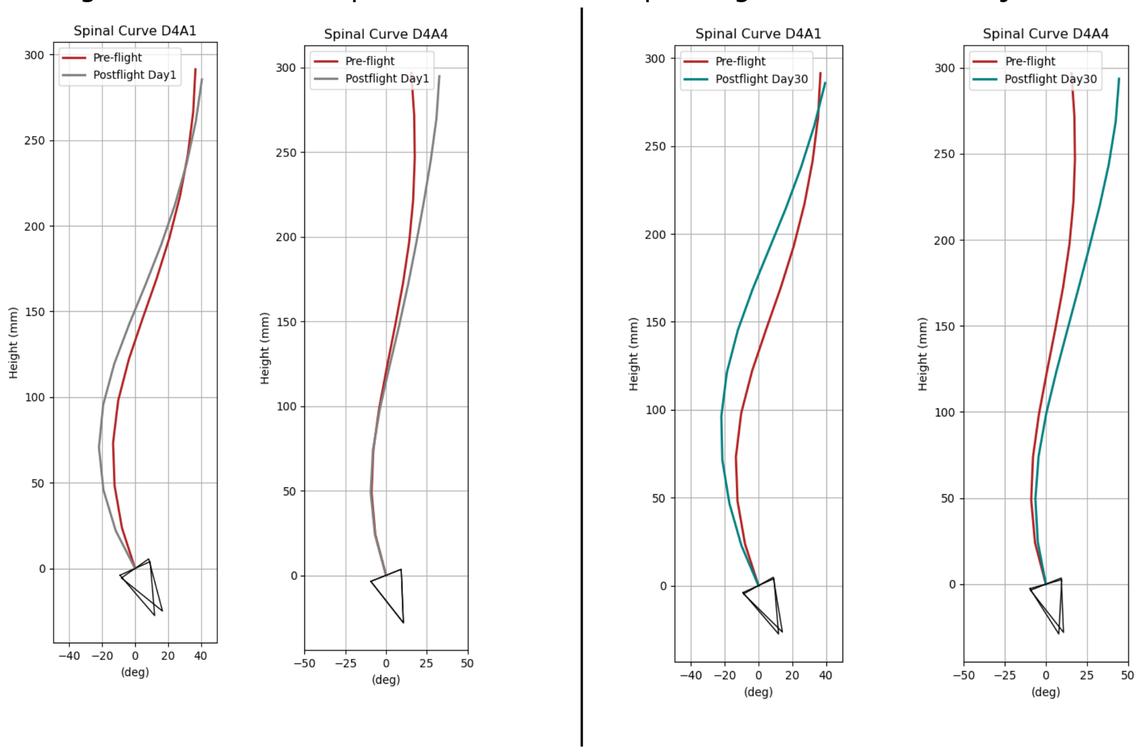
Effects of spaceflight on the spinal column

Lumbar Lordosis	• Flattening of lower back curve • IVD over-hydration
Muscles	• Loss of cross-sectional area • Atrophy • Stiffness
Vertebrae	• Loss of cancellous bone volume • Loss of BMD • Endplate fractures



Biomechanical model adaptation using OpenSIM

Changes in the back shape before and after spaceflight in different subjects



Changes in compressive loads (N) on the lumbar IVDs

	L1-L2	L2-L3	L3-L4	L4-L5
Pre-flight	253±1.89	272±2.08	280±0.32	308±1.33
Day-01 post-flight	249±2.24	271±1.15	292±1.18	308±2
Day-07 post-flight	254±1.65	273±0.73	293±0.36	307±0.63
Day-30 post-flight	254±0.76	274±0.79	293±0.41	307±0.82

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In a 2009 retrospective study, NASA reported that out of 772 astronauts 52% reported a pain the lower back in the first few days of spaceflight, of which 86% was reported to be in the lumbar region. Back pain and stiffness have always been a concern with performance of astronauts in long duration spaceflights. Studies have reported an increase in the muscle stiffness in environments of microgravity along with increased height due to prolonged unloading and flattening of the curvature of the spine. This flattening of the spinal curvature is attributed to the foetal positions assumed by the astronauts in space, combined with disturbed diurnal patterns causing overhydration of IVDs. These cause spinal instability, which on return to Earth's gravitational environment put the astronauts at a higher risk of spine related complications. A higher number of incidences have been reported in intervertebral disc herniations within a year of return from spaceflight in astronauts as compared to general population within the same age brackets on Earth.

This study aims to determine the changes in the spinal curvature and loading patterns on lumbar IVDs before and after a long-term spaceflight. The spinal curvature is measured using a non-invasive surface topology measuring device, Epionics SPINE from Epionics GmbH, Potsdam, Germany. The spinal loads are determined by musculoskeletal modelling using OpenSIM from National Centre for Medical Rehabilitation Research, United States of America.

The data is collected from 6 astronauts of NASA's commercial SpaceX crew, of which 4 have completed their spaceflight and 2 are currently on the International Space Station. The data is collected at 4 time points: pre-flight, Day-01 post-spaceflight, Day-07 post-spaceflight, and Day-30 post-spaceflight.

Varying changes in the lordosis and a consistent increase in the kyphosis are observed post-spaceflight. The increase in kyphosis is a result of compensation due to destabilised spine and atrophied musculature of the back, wherein a backwards lean helps maintain the balance and keeps the spine from collapsing.

Additionally, lumbar flattening is observed post-spaceflight which is consistent with the findings of the available literature. Finally, no significant changes are observed in the loading patterns on the lumbar IVDs indicating the change in spinal curvature does not necessarily affect the compressive loading.

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