# PREDICTION OF INTERVERTEBRAL DISC CREEP DURING FLEXION USING A COMBINED EXPERIMENTAL AND FINITE ELEMENT APPROACH

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## INTRODUCTION

Injuries to the spine can occur through acute trauma, or as the result of the accumulation of damage over time. There is no simple explanation due to the multi-factorial character of low back disorders (LBD), but creep of the intervertebral disc has been identified as a predictor of damage [1]. This study presents the prediction of the intervertebral disc creep during flexion using a combined approach of a human subject experiment and finite element model of the lumbar spine.

## METHODS

The present study was in-depth, not cross-sectional, and a single subject-specific experiment was performed. The experiment involved lifting a 6.8 kg box from its initial position, 88 cm above the floor and 74 cm from the subject, to approximately waist level at an upright standing posture and then returning it to the initial position. A 24-year-old male subject was required to repetitively carry out the sagittally symmetric lifting task at 6 lifts/min. for 20 minutes. Lumbar Motion Monitor (LMM) data, capturing the torso angle change with respect to the initial position, was continuously collected for the entire duration of 240 flexion cycles, with rest between the cycles.

A newly developed finite element model [2] was used to calculate the deformations and stresses in the components of the lumbar spine, including the vertebral bodies, intervertebral discs, and ligaments. The model is capable of simulating large displacement, dynamic, sagittally-symmetric flexion and the components were validated against experimental results. The initial model configuration is derived from the subject-specific neutral standing position lumbar spine geometry [3], and the movement of the top of the $T_{12}$ vertebrae is determined using Lumbar Motion Monitor [4] measurements from the actual flexion motion. The finite element model then calculates the motion of the remainder of the lumbar spine from the interaction of the $T_{12}$ movement, material properties, and geometry.

The computational model was used to determine the motion and stress in the lumbar spine based on the LMM measurements collected during the experiment. The axial deformation at each disc level was extracted from the results for further study.

## RESULTS AND DISCUSSION

The axial deformation at the $L_5/S_1$ level over the 20 minutes of repeated flexion is shown in Figure 1. The creep accumulates rapidly at the beginning of the cyclic flexion. The rate of accumulation gradually decreases, with the creep asymptotically approaching a stable value from 15 to 20 minutes into the task. Similar behavior, with slightly different magnitudes, was seen at the other intervertebral disc levels.

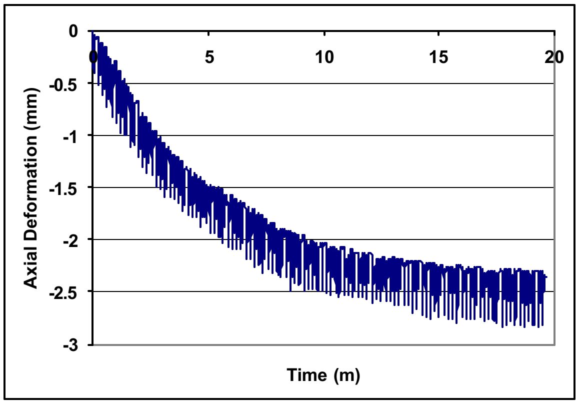


**Figure 1**: Axial deformation (creep) of $L_5/S_1$ intervertebral disc.

Limited data is available that considers cyclic loading on the discs over long periods, as opposed to creep or relaxation loading, and presents sufficient information on the testing methods, specimens, and results as to be useful. One set of such data was obtained in a series of experiments performed for 6 hours of pure compressive loading of an intervertebral disc at 1 Hz [5]. The results showed a trend similar to the current study, with creep gradually stabilizing over the course of the experiment at approximately 2.25 mm.

## CONCLUSIONS

Creep is an important risk dimension for LBD. Repetitive loading can cause damage to the spine at levels below maximum [6] and creep is an indicator of this cumulative effect. In addition, excessive creep can change the distribution of forces in the spine, increasing loads on the facets and decreasing tension on the ligaments, reducing their effectiveness. The present study demonstrates the ability to link experimental and analytical methods and calculate the disc creep for actual repetitive flexion motion.

## REFERENCES

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