

# THE EFFECT OF LOADING RATE ON PORCINE LUMBAR SPINAL SEGMENTS: AN IN-VITRO BIOMECHANICAL STUDY

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## INTRODUCTION

The lumbar spine consists of varying tissues, including bone, cartilage, fibrocartilage, nucleus pulposus, and ligaments. As such, the viscoelastic properties of the lumbar spine are represented by a combination of these different tissue properties. The biomechanical characteristics of spinal specimens are dependent on many factors, including the loading profile, loading history and direction of load application (Chow, et al., 2004). Recommendations for in-vitro biomechanical testing have been established and serve as general guidelines for testing spinal implants (Wilke, et al., 1998).

In order to investigate the effects of spinal implants and therapeutic technologies on spine biomechanics, it is necessary to determine proper testing protocols specific to the specimens being utilized. That is, the mechanical properties are highly dependent upon the specimen being tested (Wilke, et al., 1998). While loading rate of spinal specimens has been studied (Myers, et al., 1991, Adams and Dolan, 1996, and Wilke, et al., 1998), biomechanical variables measured and specimens included do not provide data specific to porcine specimens. Therefore, the purpose of this investigation was to determine the effect of loading rate on the biomechanical properties of porcine functional spinal units (FSU). We hypothesized that increases in loading rate would result in detectable viscoelastic changes.

## METHODS

Three fresh frozen porcine lumbar FSUs were dissected and used for biomechanical testing. Specimens were free of any gross morphologic deformity or pathology. Wood screws were inserted into the cranial and caudal vertebra of the FSU to assist in anchoring the specimen in two-part polyurethane potting solution. Specimens were submerged into the potting solution at the level of the vertebrae midline, parallel to the corresponding intervertebral disc. To ensure adequate hydration, each specimen was sprayed with isotonic saline solution.

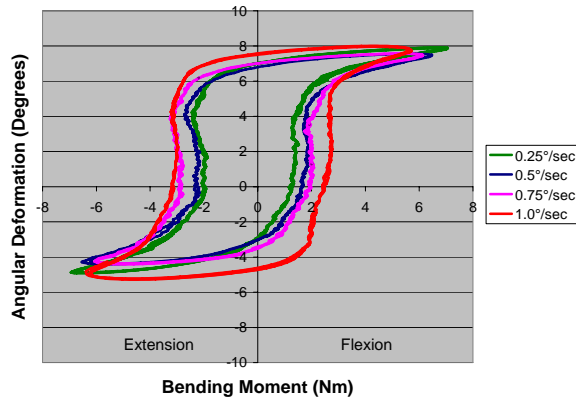
Potted specimens were thawed at room temperature and tightly secured into the fixtures of an eight-axis Bose Kinematic Spine Tester (Bose Corporation, ElectroForce Systems Group, Eden Prairie, MN). The testing protocol consisted of five loading cycles of continuous pure bending moment in each flexion/extension, bilateral, and 45 off-axis, while maintaining a 0N axial load. Loading rate was randomly performed at four angular velocities of 0.25°/sec, 0.5°/sec, 0.75°/sec, and 1.0°/sec, with a load limit set to  $\pm 7.5$ Nm. Time between each loading period was two minutes.

Kinematic and kinetic data were recorded at a sampling rate of 10Hz. Data analysis was performed using Matlab version R2006a (The Mathworks, Inc., Natick, MA). The fourth bending cycle was used to calculate

total range of motion (ROM), hysteresis, and neutral zone (NZ) range.

## RESULTS AND DISCUSSION

A representative load-deformation curve demonstrating changes at different loading rates is displayed in Figure 1.



**Figure 1:** Load-deformation curve of porcine functional spinal unit.

Descriptive statistics including total ROM, hysteresis, and NZ range are summarized in Table 1. Total ROM and NZ range did not change considerably following each loading rate condition (less than 19%); however, there was a pattern of overall decrease in total ROM at greater loading rates, while there was an increase in NZ range at greater loading rates. Hysteresis demonstrated

greater changes (range: 15% – 52%) associated with differing loading rates. These patterns existed across all three loading directions.

## SUMMARY/CONCLUSIONS

Upon observation of biomechanical testing, changes in loading rate from 0.25°/sec to 1.0°/sec had minimal effect on total ROM and NZ range in porcine lumbar specimens. However, due to the viscoelastic properties of the porcine spinal specimens, hysteresis did demonstrate differences between loading rate conditions in all three loading directions. Future work will include a larger sample size, increased loading rates, and further statistical analysis.

## REFERENCES

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**Table 1:** Variables measured at four loading rates for each bending direction (mean  $\pm$  s.d.).

	<b>Flexion/Extension</b>			
<b>Loading Rate:</b>	<b>0.25°/sec</b>	<b>0.5°/sec</b>	<b>0.75°/sec</b>	<b>1.0°/sec</b>
Total ROM [°]:	13.9 $\pm$ 0.9	13.5 $\pm$ 1.0	12.8 $\pm$ 1.4	12.6 $\pm$ 1.0
Hysteresis [Nm°]:	50.8 $\pm$ 5.5	60.2 $\pm$ 9.1	68.0 $\pm$ 13.3	77.3 $\pm$ 6.0
Neutral Zone [°]:	9.9 $\pm$ 1.3	11.3 $\pm$ 1.3	11.3 $\pm$ 1.7	11.7 $\pm$ 1.0
	<b>Bilateral Bending</b>			
Total ROM [°]:	12.8 $\pm$ 1.5	12.2 $\pm$ 1.5	11.8 $\pm$ 0.9	11.4 $\pm$ 1.1
Hysteresis [Nm°]:	48.0 $\pm$ 8.2	55.2 $\pm$ 10.2	62.1 $\pm$ 11.0	69.8 $\pm$ 9.8
Neutral Zone [°]:	10.1 $\pm$ 1.3	10.2 $\pm$ 1.5	10.4 $\pm$ 1.1	10.5 $\pm$ 1.1
	<b>45° Off Axis/Oblique Bending</b>			
Total ROM [°]:	13.6 $\pm$ 0.8	12.8 $\pm$ 0.5	12.5 $\pm$ 0.7	12.3 $\pm$ 0.3
Hysteresis [Nm°]:	50.5 $\pm$ 5.1	58.4 $\pm$ 6.8	67.0 $\pm$ 7.8	76.7 $\pm$ 9.7
Neutral Zone [°]:	10.5 $\pm$ 0.4	10.8 $\pm$ 0.6	11.0 $\pm$ 0.6	11.4 $\pm$ 0.5