Characterizing the Early Effects of Long-Term Mechanical Loading on the Lumbar Spine

by

Glenn P. Sanders

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Approved:

Eric H. Ledet, Ph.D.

Thesis Advisor

Rensselaer Polytechnic Institute
Troy, New York

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Low back pain is having a substantial social and economic impact on most industrialized nations. Eighty percent of the United States population will experience at least one substantial bout with low back pain in their lifetime and it is the leading cause for work disability in the U.S. In 2004, expenditures for low back pain exceeded $190 Billion in the U.S. alone. The leading cause for low back pain is Degenerative Disc Disease (DDD).

There is a strong correlation between mechanical loading and DDD; however, the mechanism by which mechanical loading leads to disc degeneration remains unclear. Specifically, the relationship between endplate sclerosis and DDD is uncharacterized. Because the degeneration process is most often a long, gradual process taking place over years or decades, it has been difficult to experimentally replicate disc degeneration in an *in vivo* model.

We hypothesize that compressive forces at sub-traumatic levels will lead to endplate sclerosis, a condition often observed concomitant with DDD. Sclerosis has been shown to effectively reduce diffusion through the major nutritional pathway of the avascular intervertebral disc and may thus lead to degeneration. It was the goals of this research to: 1) develop a new model for applying chronic cyclic axial compression at physiological loads to the lumbar spine of a large animal model, and 2) characterize the effects of chronic cyclic loading on the intervertebral disc, endplates, and subchondral bone.

An external load frame was developed to interface with the lumbar spine of a New Zealand white rabbit. Biomechanical tests were conducted to obtain the mechanical properties of a rabbit lumbar motion segment, and thus, the properties needed for the external load frame. A surgical interface was designed to interface the load frame with a single level of the spine *in vivo*.

Cyclic axial compression was applied at physiologically-relevant forces and frequencies for up to 2 hrs/day, 5 days/week, for up to 30 weeks. Radiographs were taken in two week intervals throughout the entire study to assess changes in disc height and/or the development of sclerosis. Clinical and quantitative MRI was used to assess diffusion and overall disc health. MicroCT analysis was conducted to quantify bone density within the endplate and subchondral bone. Decalcified histology was conducted to study the morphological changes in the intervertebral disc, cartilaginous endplate, and

subchondral bone. Finally, gene expression analysis was conducted to characterize the effects of cyclic loading on genes indicative of disc homeostasis and inflammation.

Results show that cyclic loading led to an increase in endplate/subchondral bone density, which corresponded to a decrease in diffusion using quantitative MRI. These changes preceded global degeneration of the intervertebral disc.

These data suggest that endplate sclerosis is caused by cyclic loading, which will cause a decrease of diffusion into the intervertebral disc. This is an important part of the disc degeneration cascade which has previously remained unknown. An improved understanding of the disc degeneration pathology will help establish early diagnostic tools, preventative measures, and improve upon future treatment methods.