INTRODUCTION

Despite a strong correlation between cyclic mechanical loading and Degenerative Disc Disease (DDD), the mechanistic relationship between the two has yet to be elucidated. Many studies have been conducted to characterize the viscoelastic properties of the intervertebral disc, but no in vivo studies have been conducted which study the effects of cyclic axial compression on disc height loss and the time needed to return the disc to normal height. Characterization of such properties would be beneficial in understanding the potentially detrimental effects of long term exposure to loading, as short term water loss in the intervertebral disc reduces the disc’s ability to resist compression, resulting in larger strains on the fibers of the annulus fibrosus and endplate. We have established a model for applying long-term cyclic compression in the lumbar spine of a rabbit.  The purpose of this study was to quantify disc height loss resulting from in vivo cyclic compression and the time necessary for height restoration. Disc height reduction and recovery were measured at multiple time points during chronic loading to establish the effects of long-term exposure on disc properties.

MATERIALS AND METHODS

We have previously reported on our technique for applying controlled cyclic axial loads to the rabbit lumbar spine. In this study, transfixing pins were placed transversely through two adjacent lumbar vertebral bodies in 10 skeletal maturity New Zealand white rabbits. Stainless steel posts were attached to each end of the pins and extended dorsally from the spine percutaneously. Cyclic axial compression was then applied in vivo via a novel external loading frame across a single intervertebral disc space at 2.5 MPa at a frequency of 0.5 Hz (8 rabbits) and 5.0 Hz (2 rabbits) for two hrs/day, 5 days/week for up to six months. Following a two hour loading session, lateral radiographs were taken every 10 minutes for one hour post-loading. The disc height index (DHI), a ratio of vertebral body length to intervertebral disc height, was measured at each time point. Radiographs were taken once per month to observe the effects of long-term exposure to cyclic compression on disc height reduction and recovery.

RESULTS

Preliminary results indicate that two hours of cyclic axial compression using the designated force and frequency parameters resulted in significant disc height reduction in both healthy and chronically loaded rabbits. Figures 1 and 2 show the disc height recovery in low and high frequency groups, respectively, after one, two, and three months of cyclic loading. In both the low and high frequency groups, DHI reached a plateau fifty minutes post-loading in rabbits that had been subjected to one or two months of cyclic loading. In contrast, rabbits that had been subjected to three months of cyclic loading did not return back to steady state disc height until sixty minutes after cessation of loading. Similarly, the rabbits with three months of cyclic loading had a greater total reduction of disc height at 10 minutes post-loading when compared to the rabbits with only one and two months of previous loading.

In the low-frequency group, three months of cyclic loading resulted in a mean DHI of 66% ten minutes post-loading, while one and two months of cyclic loading resulted in a DHI of 78% and 76%, respectively. In the high-frequency group, three months of cyclic loading resulted in a mean DHI of 66% ten minutes post-loading, while one and two months of cyclic loading resulted in a DHI of 77% and 82%, respectively.

DISCUSSION

The preliminary results of this study suggest that chronic cyclic loading will alter the physical properties of the IVD and its ability to resist and recover from axial loading. Results indicate that long-term cyclic loading will lead to greater disc height loss under load, relative to short term cyclic loading. Preliminary results also indicate that the recovery time for the IVD to return to its steady state height increases as the duration of chronic loading increases.

Previous work has shown that a loss of disc height compromises the compressive resistive capabilities of the nucleus pulposus, increasing the stresses in the annulus fibrosus and endplate. An increase in stress could lead to structural damage of the IVD and endplate, accelerating the disc degeneration cascade. Characterization of disc height reduction and recovery due to cyclic compression at physiological levels is valuable particularly in preventing disc degeneration in the workplace. Frequencies of 0.5 and 5.0 Hz were chosen in this study because of the relevance to frequencies commonly encountered in the workplace.

1 Sanders GP, et al. ORS 2009.