COMPARISON OF THE BIOMECHANICAL RESPONSE OF A LUMBAR MOTION SEGMENT TO LOADING AND UNLOADING WHEN LOADS ARE APPLIED SUDDENLY AND AT NORMAL LIFTING SPEEDS

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INTRODUCTION

Repetitive lifting and sudden or unexpected loading have been attributed to the development of back injuries. Experimental studies have considered the response of the spinal musculature under both types of loading conditions. While it is important to understand how the muscles surrounding the spine react in these situations, it is equally important to understand how the spine itself reacts, specifically how the intervertebral disc behaves, under such conditions. However, studying the response of the various disc tissues to these types of loading conditions is difficult using standard experimental techniques. Therefore, the purpose of this study was to use a previously validated poroelastic finite element model (PEFEM) to compare the biomechanical response of a lumbar motion segment when subjected to physiological loading conditions when applied suddenly and under normal lifting speeds.

METHODS

A previously validated three-dimensional PEFEM of an L4-L5 motion segment in which biological parameters such as swelling pressure and strain dependent permeability and porosity had been included, was used as the basis for this investigation [1]. The loads, compression, AP shear and lateral shear, were determined for a lifting activity in which a box was lifted from elbow height on the right side and placed at elbow height on the left side. This activity was found to have a significant AP shear component (818N) and lateral shear component (1489N) that occur at approximately the same time as the peak compressive load (5083N). While these loads were measured at normal lifting speed, for the sake of comparison the same load magnitudes were assumed for the suddenly applied load analyses. The peak loads were applied using a triangular waveform with the time taken to reach the peak load equal to 0.01sec, 0.1sec to simulate suddenly applied loads and 1sec to simulate the normal lifting speed. In all three analyses, following the release of the peak load a recovery period of 5 sec was modeled in which a constant 400N compressive load was applied.

RESULTS AND DISCUSSION

Figure 1 shows the maximum effective stress in the endplates and annulus and the maximum pore pressure in the nucleus pulposus both when the peak load was applied and following the recovery period. The magnitude of the maximum effective stresses in the endplates and annulus for the two suddenly applied loading cases were very similar when the peak load was applied. When the loads were applied at a normal lifting speed, over 1sec, the magnitudes of these stresses were reduced. A similar effect was observed with respect to the maximum pore pressure in the nucleus. The loss of disc height was greatest when the loads were applied in 1sec (5.06mm), as compared to when the loads were applied in 0.01sec (3.61mm) and 0.01sec (3.62mm). Following the recovery period the maximum stresses and maximum pore pressure in the nucleus were greatly reduced as compared to when the loads were applied at a normal lifting speed. Also, the original disc height was restored following the recovery period in the two suddenly applied loading analyses; however, at a normal lifting speed only 90% was recovered.

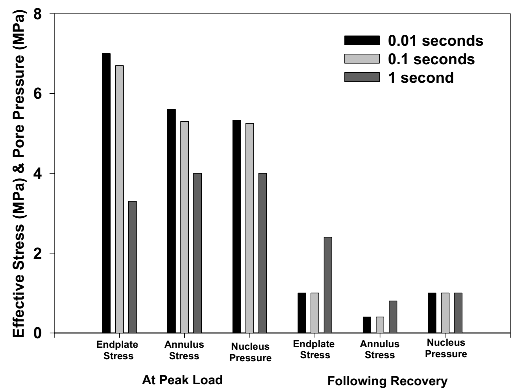

Figure 1: Maximum effective stress in endplates and annulus and maximum nucleus pore pressure at peak load and following the 5 second recovery.

CONCLUSIONS

The results of the current study support that suddenly applied loads do create circumstances that can result in failure of disc tissues, particularly when the peak load is applied. The PEFEM results also suggest that the disc is able to quickly recover from such loads. When the same loads were applied at a rate representative of normal lifting, the stresses in the disc tissues were significantly less when the peak load was applied however, they remained elevated and the total disc height loss was not completely recovered at the end of the recovery period. If this were a repetitive lifting situation, additional fluid would be lost with each subsequent lift. Therefore, the disc tissues must resist more of the applied load in turn resulting in higher stresses in these tissues. Hence, without appropriate time to recover between bouts of lifting, normal lifting speeds also put the disc at risk of injury.

REFERENCES

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