VARIATION IN AVERAGE AND PEAK LUMBAR DISC STRESSES BY LEVEL DURING FLEXION USING A COMBINED EXPERIMENTAL AND FINITE ELEMENT APPROACH

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INTRODUCTION

Significant effort has been invested in developing FE models in the field of spinal biomechanics. Various loading conditions have been used for investigation of spinal component behavior. However, nearly all previous studies have applied artificially set loads, which make it difficult to compare to real life situations. Accordingly, the aim of this study was to develop a subject-specific component model of entire lumbar spine capable of determining the response to realistic motion under experimental settings. This paper presents the prediction of the lumbar intervertebral disc stress distribution at different levels during flexion using a human subject-linked FEM.

METHODS

The present study was in-depth, not cross-sectional, and a single subject-specific experiment was performed. A 24-year-old male subject was required to lift a 6.8 kg box from 88 cm above the floor and at a horizontal distance of 74 cm from the subject. The box was lifted from its initial position to approximately waist level at an upright standing posture and then returned to the initial position. Lumbar Motion Monitor (LMM) data was collected throughout the experiment to capture the torso angle change with respect to the initial position.

Stresses in the components of the lumbar spine, vertebral bodies, intervertebral discs, and ligaments, were calculated using a newly developed finite element model [1]. The model is capable of simulating large displacement, dynamic, sagittally-symmetric flexion and the components were validated against experimental results. Subject-specific neutral standing position lumbar spine geometry [2] is predicted as the starting point for the calculation, and the movement of the top of T_{12} is determined using LMM [3] measurements from actual flexion motion. The motion of the remainder of the lumbar spine is calculated from the interaction of the top movement, material properties, and geometry within the finite element model.

The computational model was used to determine the internal motion and forces of the lumbar spine based on the LMM measurements collected during the experiment. Maximum values during the flexion task were extracted for the compressive stress at the disc centroid and the maximum compressive and tensile stresses in the annulus.

RESULTS AND DISCUSSION

Results are presented in Figure 1 for the centroidal axial stress in the disc, maximum annular anterior compressive stress, and maximum annular posterior tensile stress for a lifting task. All stresses are normalized to the L_5/S_1 values. The compressive stress is relatively constant for disc levels from L_5/S_1 to L_3/L_4. In contrast, the maximum anterior and posterior stresses are larger for L_5/S_1 and steadily decrease at higher levels. In fact, at the L_1/L_2 level the stress was almost uniform in compression, even on the posterior annulus.

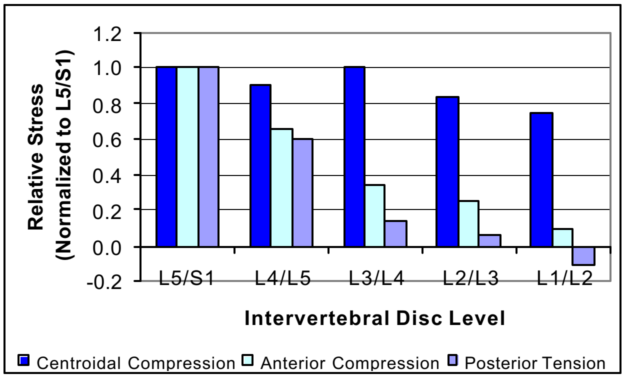

Figure 1: Variation of intervertebral disc stress with level.

The relatively constant centroidal stress is due to the somewhat uniform distribution of purely compressive shortening between the discs. However, the rotation due to bending varies greatly between levels, with the largest rotations observed at L_5/S_1. The larger rotations, and hence bending moments, generate larger stresses at the outer layers of the discs.

CONCLUSIONS

The maximum stress in the disc is known to initiate rupture [4]. Although techniques exist for determining the maximum centroidal compression, experimental methods alone are unable to establish the maximum stresses *in-vivo* due to measuring difficulties. Previous finite element models have investigated the distribution of stress within the disc, but have not considered the full lumbar spine under realistic displacement motions. The present model demonstrates the ability to link experimental and analytical methods and calculate the stress distribution for actual motion.

REFERENCES

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