CAN REPETITIVE SHEAR LOADING OF SPINAL MOTION SEGMENTS CAUSE DISC INJURY?

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INTRODUCTION

The lumbar spine, especially at the L5S1 level, is subjected to substantial anterior directed shear forces during many activities [1]. In vitro experiments have shown that shear loading of spinal segments can cause bony failure, most often of the pars interarticularis [2,3]. However, the intervertebral disc (IVD) has been reported to contribute significantly to shear stiffness [3] and may thus also be at risk of failure. Two in vitro experiments using porcine lumbar spine segments were performed to establish whether soft tissue damage could occur in repetitive shear loading.

METHODS

In experiment 1, 14 lumbar spines of immature pigs (80 kg) obtained from the slaughterhouse were fresh frozen. Maximum shear strength of the T13L1 segment was tested at a strain rate of 0.1 mm/s, while the segment was loaded with a compression force of 1600 N (800 N for 5 younger specimens tested in experiment 2). L2L3 and L4L5 segments were loaded with a sinusoidal varying shear force (0.5 Hz) between 20 and 80% of the strength of the corresponding T13L1 segment, while again the segment was statically loaded in compression. Shear displacement and force were continuously recorded at 10 Hz. The posterior elements (PE) were removed in half of the segments, leaving the IVD as the only structure providing shear resistance. The groups with and without PE consisted of equal numbers of L2L3 and L4L5 segments.

In experiment 2, 12 lumbar spines of immature pigs (40-80 kg) were used. The protocol was similar to experiment 1, except that all segments were left intact and that half of the segments were tested in the neutral position and half were tested in a 10 degrees flexed position.

The deformation within the initial cycles was determined as an indicator of shear stiffness. The time to failure (obvious discontinuity in overall deformation as well as range of deformation within the cycles; see Figure 1) was determined. Furthermore the deformation within the cycles just preceding failure and just after failure were compared to indicate changes in stiffness.

L4L5 and L2L3 segments from the same specimen were treated as dependent observations and all tests were done using a Wilcoxon matched pairs test.

RESULTS AND DISCUSSION

Shear strength of the T13L1 segments ranged from 1062 to 1985 N in experiment 1 and 428 to 2282 N in experiment 2, where spines of 40 kg animals were included.

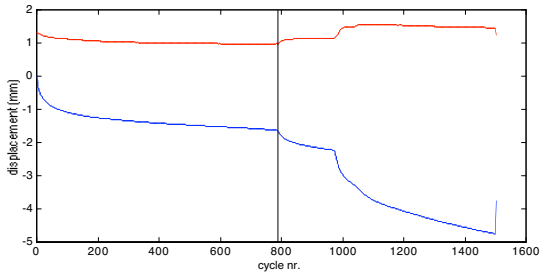

Figure 1: Mean (blue) and amplitude (red) of deformation in each of 1500 subsequent loading cycles in anterior shear of an intact segment in a neutral position. The vertical line at cycle 789 indicates the instant of failure.

In experiment 1, shear loading caused a larger deformation (1.5 vs. 1.0 mm, $p = 0.013$) during the initial cycles, when PE had been removed. In the group with PE, 6 segments did not fail within 1500 cycles. In the group without PE, 3 segments did not fail. Time to failure of the specimens that did fail was 3.3 times longer ($p = 0.017$) in the group with PE. In this group, deformation within cycles after failure was larger than that preceding failure, indicating a loss of stiffness. Whereas in the group without PE, deformation within cycles decreased after failure, indicating increased stiffness. The results suggest bony failure in the segments with PE, which was confirmed by inspection of the specimen after testing. However, when PE were removed, soft tissue injury occurred already after relatively few cycles.

Since the IVD may be less protected by the PE when the specimen is flexed, experiment 2 compared specimens tested in flexed and neutral positions. However, for none of the variables studied were significant differences found between the flexed and neutrally positioned segments.

CONCLUSIONS

Although repetitive anterior shear forces are capable of inducing IVD damage in porcine spine segments, this appears not to occur when PE are present, not even when the segment is flexed close to maximal flexion.

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ACKNOWLEDGEMENTS

The help of our students Jaap Jansen, Stijn van Huijstee and Maddy van Straalen in data collection is gratefully acknowledged.