

BIOMECHANICAL ROLE OF LUMBAR SPINE LIGAMENTS IN FLEXION AND EXTENSION USING A PARALLEL LINKAGE ROBOTIC TESTING SYSTEM

Kevin A. Gillespie and James P. Dickey

Human Biology and Nutr. Sci., University of Guelph, Guelph, Ontario, CANADA
E-mail: jdickey@uoguelph.ca Web: www.uoguelph.ca/hb+ns/dickey.htm

INTRODUCTION

This *in vitro* study examined the functional mechanical characteristics of the spinal ligaments that resist flexion and the interaction between the supraspinous and interspinous ligaments. To accurately quantify the mechanical contribution of each ligament to the resistance of flexion, the kinematics from one trial must be repeated during subsequent trials (Woo et al., 1999). A parallel linkage robotic manipulator was developed to record and replicate the dynamic flexion-extension motion of the spine (Gillespie et al., 2000).

METHODS

Four porcine spinal specimens consisting of six lumbar vertebrae (L2- L7) were used. The spine segment was preflexed to 10 Nm, and the spinous processes of the three vertebrae at each end were bolted together. This allowed unconstrained movement at one motion segment while prestressing the supraspinous ligament, which spans multiple segments. The ends of the spine segment were fixed in pots by using dental plaster and mounted inside the robotic manipulator on top of the six degree of freedom load transducer (Figure 1).

The robotic manipulator was operated in load control to respond to the natural movement profile of the spine. A compressive force was first applied 15 cm anterior to the centre of the spine causing the

spine segment to travel dynamically through to 10 Nm of flexion moment. Then a compressive force was applied 15 cm posterior to the centre of the spine caused the spine to travel dynamically into extension. Four cycles of the flexion-extension path of the spine were recorded by the robotic manipulator so that the kinematics could be precisely replicated during subsequent cycles. Data was extracted from the fourth cycle for analysis.

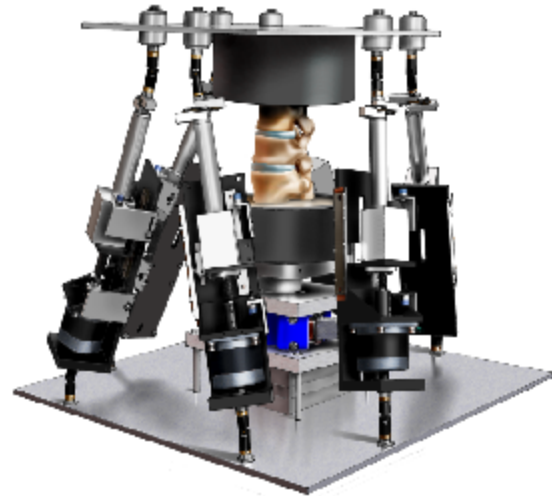


Figure 1: Porcine lumbar spine mounted within parallel linkage robotic manipulator

Repeated serial dissection tests were performed, which involved the intact spine, supra-spinous-interspinous ligament interactions cut, supra-spinous ligament (SSL) cut, interspinous ligament (ISL) cut, ligamentum flavum (LF) cut, and facet capsules (FJC) being removed, allowing 5 minutes rest between conditions. Stiffness was calculated from the linear portion of

each condition. A repeated measures ANOVA ($P < 0.05$) with Tukey's post hoc test was used to assess statistical significance.

RESULTS AND DISCUSSION

A typical moment-angle curve for one specimen with six trials of serial dissection is shown in figure 2. The percent stiffness following each successive dissection is presented in figure 3.

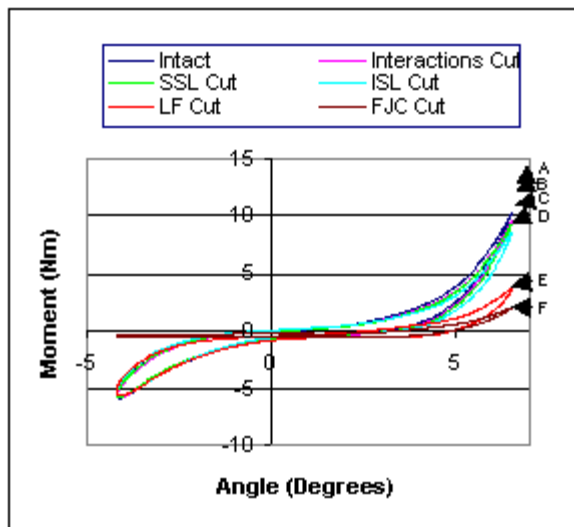


Figure 2: Representative moment-angle plot for a serial dissection involving an intact lumbar spine (A), supraspinous\interspinous interactions cut (B), supraspinous cut (C), interspinous cut (D), ligamentum flavum cut (E) and facet joints removed (F)

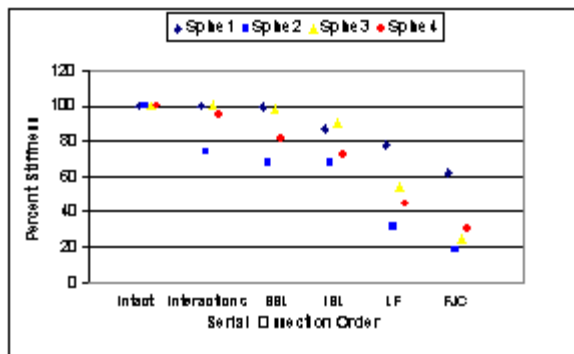


Figure 3: Plot of percent total stiffness for the six conditions of the serial dissection

The stiffness of the spine was not significantly changed by cutting the interactions between the supraspinous and interspinous ligaments, nor cutting the supraspinous and interspinous ligaments. Cutting the ligamentum flavum resulted in a significant decrease in stiffness, however, removing the facet joints did not further reduce the stiffness. The role of the facet joints does, however, seem to be important during extension. The stiffness of the spine in extension was significantly reduced after the facet joints were removed.

Although cutting the interactions between the supraspinous and interspinous ligaments did not significantly reduce the stiffness, the variability between specimens may indicate that these interactions make a contribution to the joint stiffness (Dumas et al., 1987). It is hypothesized that the location of the cut intended to sever the interactions is crucial

The results of the present study are in agreement with previously published work, demonstrating the ligamentum flavum's large contribution to stiffness (Dumas et al., 1987), and the relatively small contribution of the supraspinous and interspinous ligaments (Abumi et al., 1990). The importance of maintaining the kinematics of a joint, while altering its structure, can not be over emphasized. The parallel linkage robotic manipulator used in this study is ideally suited for this purpose.

REFERENCES

- Abumi, K. et al. (1990). *Spine*, **15**, 1142-7.
- Dumas, G.A. et al. (1987). *J. Biomech.*, **20**, 301-310.
- Gillespie, K.A. et al. (2000). *Archives of Phys. and Biochem.*, **108**, 106.
- Woo, S.L-Y. et al. (1999). *J. Sci. Med. Sport*, **2**, 283-297.