ACUTE TORSIONAL FAILURE: DO PHYSIOLOGICAL LOADING RATES EFFECT THE SPINE'S LIMIT?

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INTRODUCTION

In performing many work tasks and daily activities, the lumbar spine is routinely exposed to axial rotational motions and moments. From the anatomical structure of the spine it can be postulated that the facet joints function as the primary resistance of any applied axial rotation/moment. Damage to the facet joints can be one source of pain. However, previous work investigating acute axial rotational failure tolerances of functional spinal units (FSUs) was performed using variable compressive loads and applied moments making evaluation of failure difficult (Adams and Hutton, 1981; Farfan, 1969; Farfan et al., 1970). Yingling et al. (1997) have shown the rate of loading effect the ultimate strength and mode of failure in FSUs in acute compressive failure testing.

Without failure limits it is impossible to contextualize failure results that occur in various loading conditions. Defined limits will also enable the comparison of different experimental outcomes. Therefore, the failure point due to axial rotation needs to be quantified as well as how other factors can mitigate the failure point. The purpose of this study was to investigate how loading rate mitigates acute rotational failure of FSUs in a neutral posture.

METHODS

Eighteen porcine cervical spine FSUs (C3/4) were axial loaded with 1500N of compressive force combined with one of two axial twisting rates, either 2°/s or 6°/s. Specimen preparation involved removal of the surrounding muscle tissue leaving the osteoligamentous structures of the FSUs. The FSUs were secured to aluminum cups via 16-gauge wire and dental plaster (Callaghan & McGIll, 2001). To enable radiographic documentation of the nucleus pulposus, it was injected with approximately 0.7mL of a radio-opaque mixture. The FSUs were mounted into a custom three-axis servo-hydraulic dynamic testing system. The specimens were preloaded with 300N of compression in a neutral posture for 15 minutes to precondition the specimens and counter any swelling that had occurred postmortem. The specimens were then subjected to 1500N of compression and the ranges of motion (RoM) were quantified by flexing-extending just beyond the neutral zone five times at a rate of 0.5°/s, followed by left and right axial twist motions at a rate of 0.7°/s.

The specimens were randomly assigned to loading rate and testing direction groups. Following the RoM testing, failure testing to the right or left was performed. The rest of the protocol involved a second RoM test, failure in the opposite direction, and a final RoM test. The FSUs were X-rayed prior to and following failure testing. Both macroscopic and radiographic damage to the FSU were recorded. Figure 1 exhibits the type of failure data collected. The angle at failure coincides with the time when the peak moment was recorded.

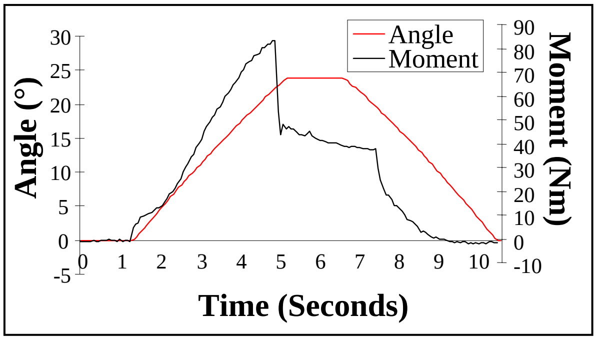

Figure 1: A representative failure curve. Shown is a failure to the right, at a loading rate of 6°/s.

RESULTS AND DISCUSSION

There were no statistical differences between left/right direction of failure for the moment (*P*=0.811) or angle (*P*=0.313) as shown in Figure 2. There were also no statistical differences between the failure moment (*P*=0.506) or angle (*P*=0.411) for the two loading rates of 2°/s, and 6°/s. The specimens failed at 73.4 ±17.3 Nm and 73.2 ±18.2 Nm of axial moment in the 2°/s, and 6°/s respectively. The peak angle at failure for 2°/s was 20.2 ±3.7° and was 19.9 ± 3.2° for the 6°/s loading rate.

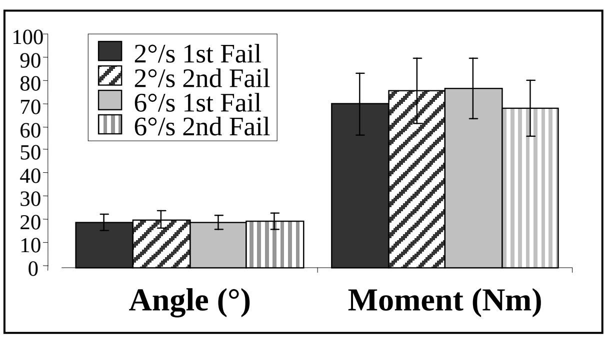

Figure 2: The angle and moment values for the 2°/s and 6°/s rotational loading are subdivided into the first failure (solid) and second failure (striped) for the specimens.

All of the specimens failed at the junction of the laminae with the superior articular facets on the C4 vertebra. The failure occurred when the facet joint was compressed due to the applied rotation. There was no observable disruption of the annular fibres of the intervertebral disc, and there was no movement of the nucleus pulposus.

Farfan (1969) reported that intact FSUs, under approximately 427N, failed with 32.7Nm range 26.0-39.5Nm) of applied axial moment. Based on this data, the porcine specimens in this study would likely be within the range of human FSUs, if they were also loaded with 1500N of compression. The angular displacement at failure reported by Farfan et al. (1970) for human FSUs was 22.6°. The porcine specimens in this study failed at similar angles.

SUMMARY/CONCLUSIONS

There was no effect of physiological loading rate on the failure data or damage observed. This suggests acute torsional failure may not be sensitive to loading rate. This work will be useful in contributing to understanding the mechanical characteristics and injury mechanisms of the spine when exposed to twisting motions/moments of varying rates.

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