

Mechanical Evidence of Cervical Facet Capsule Injury During Whiplash

A Cadaveric Study Using Combined Shear, Compression, and Extension Loading

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FROM ABSTRACT:

Study Design.

A comparison of cervical facet capsule strain fields in cadaveric motion segments exposed to whiplash-like loads and failure loads.

Objectives.

To compare the maximum principal strain in the facet capsular ligament under combined shear, bending, and compressive loads with those required to injure the ligament.

Summary of Background Data.

The cervical facet capsular ligament is thought to be an anatomic site for whiplash injury, although the mechanism of its injury remains unclear.

Methods.

Motion segments from seven female donors were exposed to quasi-static flexibility tests using posterior shear loads of 135 N applied to the superior vertebra under four compressive axial preloads up to 325 N.

The right facet joint was then isolated and failed in posterior shear loading.

The Lagrangian strain field in the right facet capsular ligament was calculated from capsular displacements determined by stereophotogrammetry.

Statistical analyses examined the effect of axial compression on motion segment flexibility, and compared maximum principal capsular strain between the flexibility and failure tests.

Results.

Capsular strain increased with applied shear load but did not vary with axial compressive load.

The maximum principal strain reached during the flexibility tests was $61\% \pm 33\%$ of that observed in subcatastrophic failures of the isolated joints.

Two specimens reached strains in their flexibility tests that were larger than their corresponding strains at subcatastrophic failure in the failure tests.

Conclusions.

The cervical facet capsular ligaments may be injured under whiplash-like loads of combined shear, bending, and compression.

The results provide a mechanical basis for injury caused by whiplash loading.

THESE AUTHORS ALSO NOTE:

The frequency of whiplash injuries has increased over the past few decades.

Although most whiplash injuries resolve relatively quickly, some produce prolonged symptoms consisting of neck and back pain, headaches, dizziness, blurred vision, paresthesias, and cognitive difficulties.

Symptoms of short duration are generally thought to be related to muscle injury.

Debate still exists regarding the anatomic site of injury that causes chronic whiplash injury symptoms.

In a double-blind, placebo-controlled study, Lord et al showed that the cervical facet joints were the source of neck pain in 60% of a population with chronic pain after whiplash exposure. (Lord SM, Barnsley L, Wallis BJ, et al. Chronic cervical zygapophyseal joint pain after whiplash: a placebo-controlled prevalence study. *Spine* 1996; 21: 1737–45). To date, this is the only controlled clinical study to isolate the anatomic injury site.

The facet capsular ligaments contain free (nociceptive) nerve endings.

Experimental studies have suggested that excessive facet capsular strain may be related to whiplash injury.

“During whiplash exposures, shear forces and extension moments develop in the neck as the torso is accelerated forward relative to a stationary head, and axial compression of the neck develops from both muscle contraction and straightening of the thoracic kyphosis during occupant/seatback interaction.”

"The primary hypothesis of this study was that the facet capsular strains during combined whiplash-like loads are large with respect to the strains required to cause injury in the facet capsular ligaments."

Materials and Methods

The authors used thirteen motion segments from seven female donors (50 ± 10 yr): seven C3–C4 and six C5–C6 segments. The grade of intervertebral disc degeneration was between 2 and 4 (3.2 ± 0.7); (grades 1–5; 1 = normal; 5 = severely degenerated).

These unembalmed human cadaveric cervical spines were free from other obvious spinal disorders or diseases that could have adversely affected their structural properties.

Discussion

"Cervical motion segments were quasi-statically tested using combined loads similar to those measured during whiplash loading to quantify intervertebral flexibility and maximum principal strain in the facet capsule."

The range of axial compressive preloads used in this study were comparable to those used during staged rear-end collisions with human volunteers.

"The applied forces and moments used in the current study were similar to, and did not exceed, those that might be expected in vivo under whiplash loading at a speed change of 8 km/h." [$8 \text{ km/h} \times .62 = \mathbf{5 \text{ m/h}}$].

Muscle forces can alter spinal kinematics and therefore capsular strain; however, the applied forces were chosen to account for the potential contribution of muscle to spinal kinematics. The absence of muscle forces remains a limitation of the cadaver model.

Recent evidence has shown that muscles insert directly onto as much as 25% of the capsular ligament.

"Although the effect of direct muscle insertion would likely increase the strains in the capsular ligament, the significance of direct muscle mediated capsular ligament strain remains unknown."

On average, the facet capsule is not injured by the intervertebral loads and motions that have been observed in human subjects exposed to staged rear-end collisions.

“Of considerable interest, however, were the two specimens that exceeded their subcatastrophic failure strains under the whiplash-like loads of the flexibility tests.” **[IMPORTANT]**

“These findings suggest that capsular ligament fibers within these two specimens experienced subcatastrophic failures under the whiplash-like loading of the flexibility test.”

“Given the presence of nociceptive nerve endings in the cervical facet capsule ligament, such subcatastrophic failures suggest a mechanical hypothesis for the development of pain observed in some clinical populations.”

“Assuming the ratio of flexibility strains to initial failure strains is normally distributed, then approximately 7.3% of specimens exposed to these spinal loads will undergo subcatastrophic failure of a facet capsular ligament.”

“In the current sample, 2 of 13 (15%) specimens and 2 of 7 donors (28%) reached this level.”

“Interestingly, interspecimen variability in maximum principal strain was larger for subcatastrophic failure tests than flexibility tests. This difference suggests that markedly different clinical outcomes might occur in different individuals under otherwise similar loading conditions.” **[IMPORTANT]**

“Moreover, the relative insensitivity of maximum principal strain to increasing posterior shear suggests that relatively low posterior shear loads could exceed the threshold for subcatastrophic failure in some individuals.”

“Therefore, based on the data presented here, the risk of facet capsular ligament injury may be related more to individual differences in subcatastrophic failure thresholds than to the magnitude of the loads to which an individual is exposed.” **[VERY IMPORTANT]**

“In summary, the maximum principal strain in the cervical facet capsular ligament was measured under loads similar to those generated during whiplash and under loads that produced ligament injury.”

“Based on these data, the cervical facet capsular ligaments are, on average, uninjured during whiplash-like loading.”

“A small proportion of individuals, however, may experience facet capsular ligament injury under loading conditions similar to those generated during whiplash.” **[Important: 7.3 %- 28%]**

“The results of the present study provide a biomechanical basis for suggesting that facet capsular ligament injury plays a role in the pathoanatomy of the whiplash syndrome.”

Key Points From the authors:

“In a small sample of the population, facet capsular ligament strains under simulated whiplash loads exceeded the strain at subcatastrophic failure of the ligament.”

KEY POINTS FROM DAN MURPHY:

- (1) These authors affirm that the cervical facet capsular ligament is probably the primary anatomic site for whiplash injury and for prolonged whiplash injury symptoms.
- (2) Prolonged whiplash injury symptoms include neck and back pain, headaches, dizziness, blurred vision, paresthesias, and cognitive difficulties.
- (3) Whiplash injuries symptoms that resolve relatively quickly, are probably related to muscle injury.
- (4) The authors suggest that approximately 7.3% of those exposed to spinal loads created by a 5 m/h collision will undergo subcatastrophic failure of a facet capsular ligament. This number could be as high as 15% to 28%.
- (5) This mechanical facet capsular ligament failure would result in pain because of the presence of nociceptive nerve endings in the cervical facet capsule ligaments.
- (6) Because of interspecimen variability, difference in injury can result in markedly different clinical outcomes in different individuals under similar loading conditions.
- (7) Relatively low posterior shear loads could exceed the threshold for subcatastrophic failure in some individuals. This supports that some will suffer injury at low impact speeds.
- (8) The risk of facet capsular ligament injury is more related to individual differences than to the magnitude of the loads to which an individual is exposed.