

Whiplash kinematics, biomechanics and pathology: what gets injured ?

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Biomechanics & Pathology

- Claimant says, 'my car wasn't damaged.' What are your thoughts?
- *In our work why do we mostly see people who were hit from the rear?*
- Head restraints - good or bad?
- *What effect has modern car design had on the risk of whiplash following low speed rear impact collisions?*
- What does the evidence tell us is injured in whiplash injury?

Biomechanics & Pathology

- Research
 - Volunteers – crash tests / 'sled tests' / x-ray cinematography.
 - 'In the field' crash pulse sensors / insurance records.
 - Crash test dummy –
 - Full – Rear Impact Dummy.
 - Human cadaver – head / full
 - Animal
- } Biomechanics
- } Pathology

Biomechanics: Crash terminology

“Delta V”
‘Change in velocity’



Focusing on *VELOCITY* can be misleading...

Crash test s99-15

Subject: RH

Vc: 36.9 mph

delta V: 17.1 mph

Head acceleration: 10.3 g

Impact vector: frontal w/airbag

Crash test s00-2

Subject: JH

Vc: 7.8 mph

delta V: 5.8 mph

Head acceleration: 12.7 g

Impact vector: rear

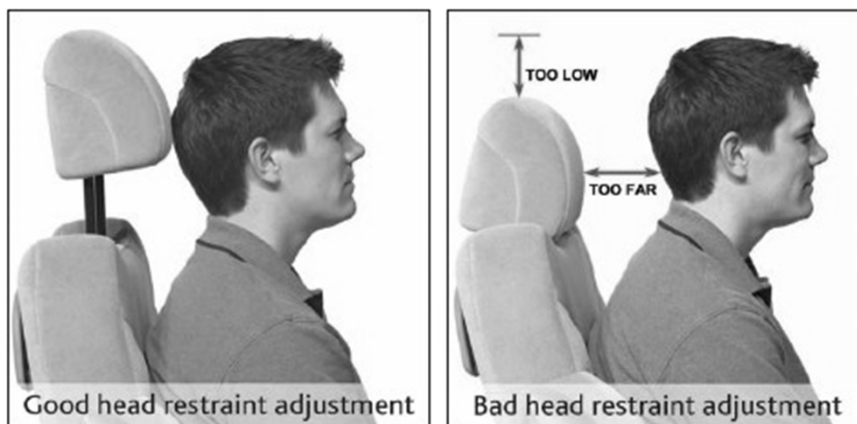
Kinematics

- Sled Tests

- Correctly positioned head restraint reduces peak head acceleration but poorly positioned head restraint causes higher peak accelerations than no head restraint.

(Yoganandan & Pintar 2000)

Head restraint position



Source: Thatcham

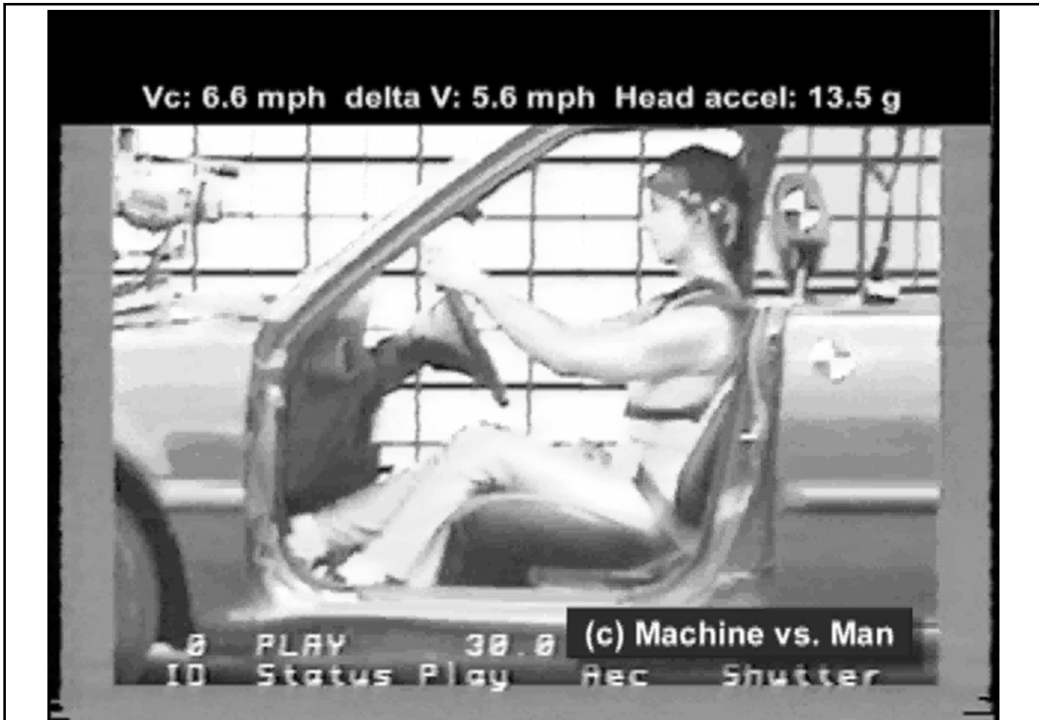
Kinematics

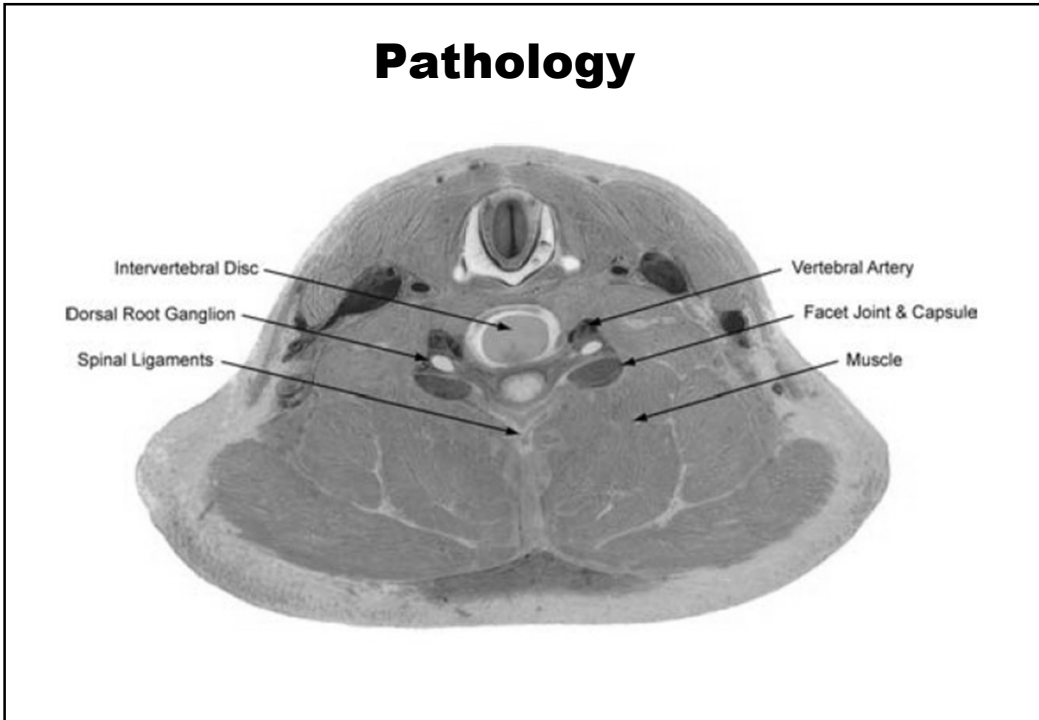
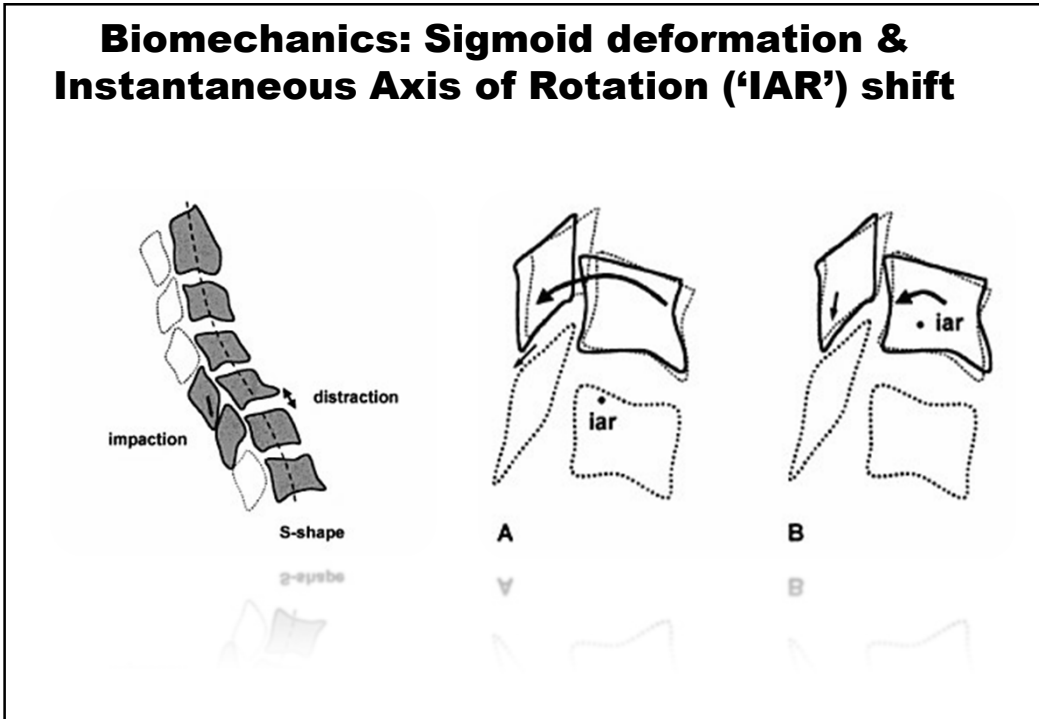
- 'In the field' & insurance records research
 - Greater relative mass of striking vehicle = greater risk of injury
 - Tow bar = 22% greater risk of long term disability.
 - Direction of impact: Largest proportion of all MVC are frontal but rear impact accounts for 25% of injuries.
 - 1980's car = lower risk of long term disability
 - 1990's car = 2.7 x higher long term risk of disability

(Yoganandan & Pintar 2000, SRISD 1998)

Kinematics

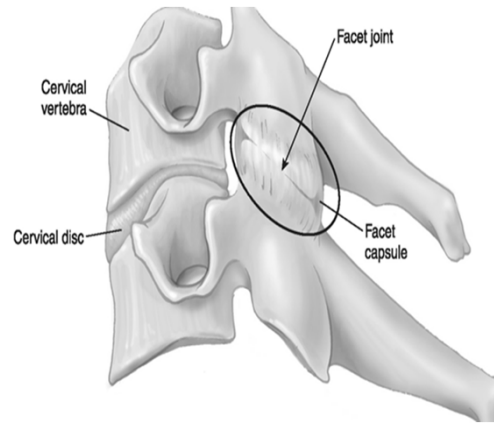
- Major point of contact is seatback
- Lumbar extension 20ms
- Thoracic extension 60ms – 'ramping'
- Sigmoid deformation cervical spine
 - Upper cervical flexion / Lower cervical extension
- Muscle contraction onset 100-125ms after onset of vehicle acceleration
- Full cervical extension upper & lower
- 'Rebound phase' from extension into flexion





Pathology: Facet Joint

- Facet capsule is thin, loose ligament.
- Instantaneous Axis of Rotation change.
- Pinching facet joints.
- Synovial fold pinching.



Pathology: Facet Joint

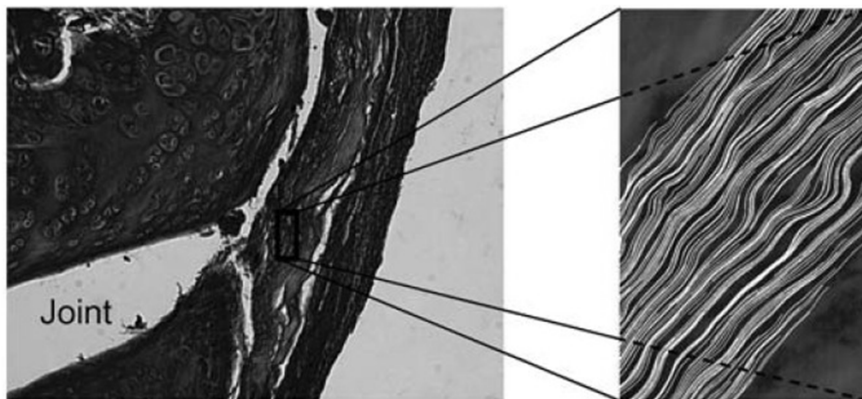


Image Courtesy of Siegmund et al Traffic Injury Prevention 2009

Collagen fibre organisation in rat facet capsular ligament (Masson Trichrome staining)

Pathology: Facet Joint Capsule

- Normal strain 1-10% with ADL.
- Activate nociceptors 13% strain.
- Persistent sensitivity & fibre organisation altered 21% strain.
- Mechanoreceptors & nociceptors saturated 40% strain.
- Cadaveric specimens: strains of 29-40% recorded.
- Neck rotation doubles strain.

(Dong et al 2008; Quinn et al 2007)

Pathology: Facet Joint

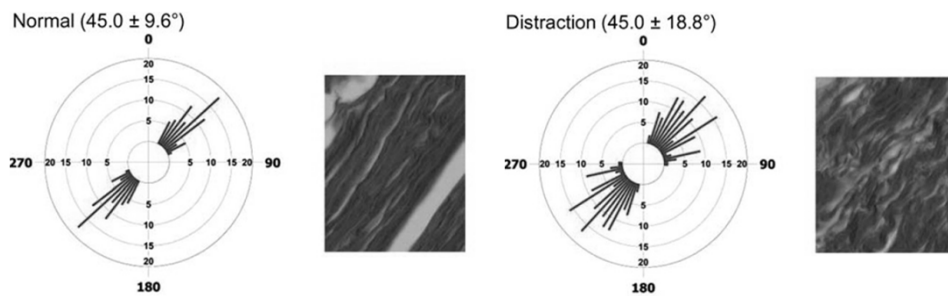
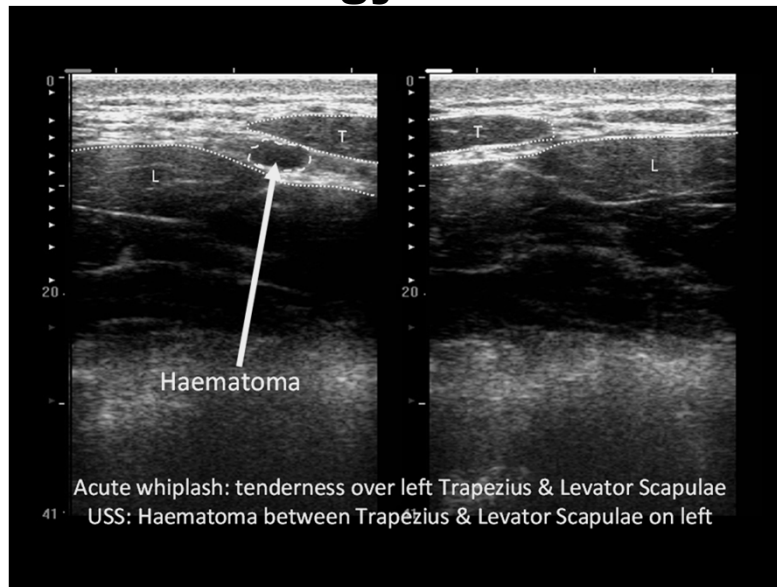


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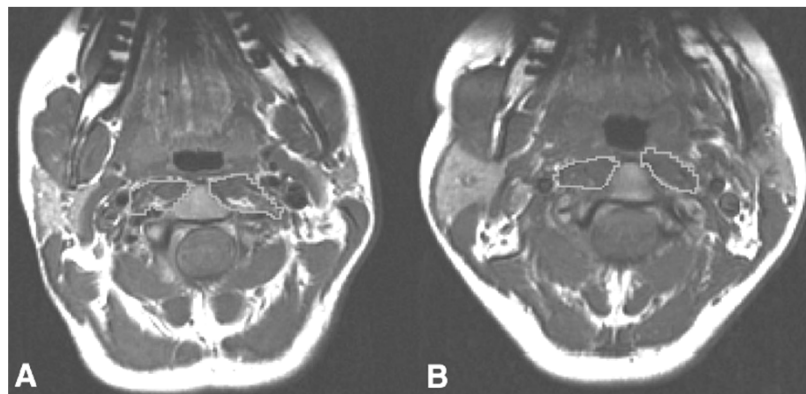
Facet capsular ligament organisation following distraction sufficient to cause persistent pain.

Pathology: Muscle



(Courtesy of Roshier & McNally 2007 University of Nottingham)

Pathology: Muscle



(Elliott et al 2008, 2009, 2010)

Pathology: Muscle

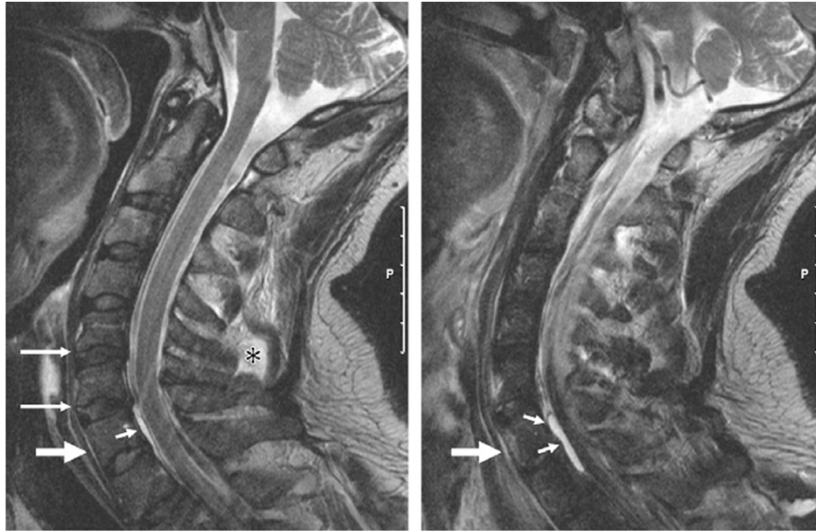
- Muscle fatty infiltrates (MFI) in neck muscles in chronic whiplash (Elliot et al 2008, Elliot et al 2010)
- Not present in atraumatic neck pain or healthy controls (Elliot et al 2008b)
- Poor functional recovery associated with increased MFI at 4 weeks, persisting to 6 months (Elliot et al 2011)

Pathology: MRI findings

- 100 consecutive rear end whiplash injuries
- Uninjured controls
- MRI within 48 hours
- Grade I:
 - No physical signs are found i.e. normal range of motion, normal strength, no swelling.
- Grade II
 - Musculoskeletal signs are found i.e. limited range, spasm or tenderness in neck or shoulders

Are There Cervical Spine MR Imaging Findings Specific for Acute Whiplash?
Anderson et al 2012 Radiology: 262 (2)

Pathology: MRI findings



Are There Cervical Spine MR Imaging Findings Specific for Acute Whiplash?
Anderson et al 2012 Radiology: 262 (2)

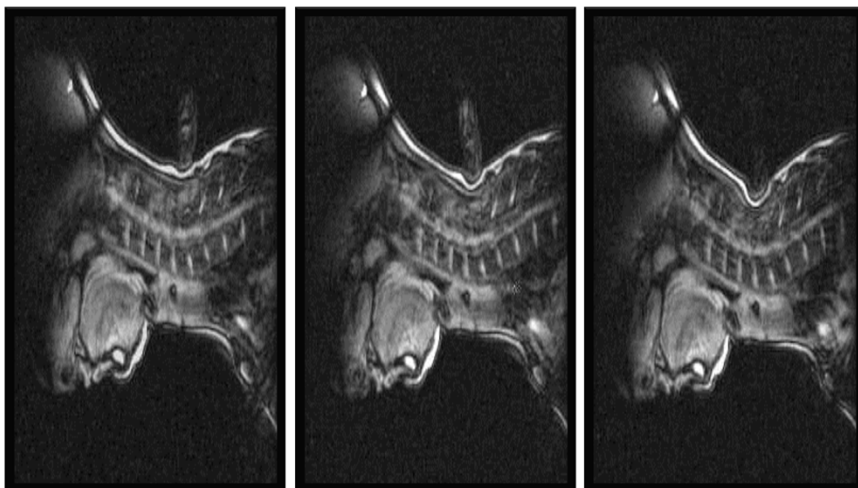
Biomechanics & Pathology

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Facet frictions: a novel approach to whiplash & neck pain

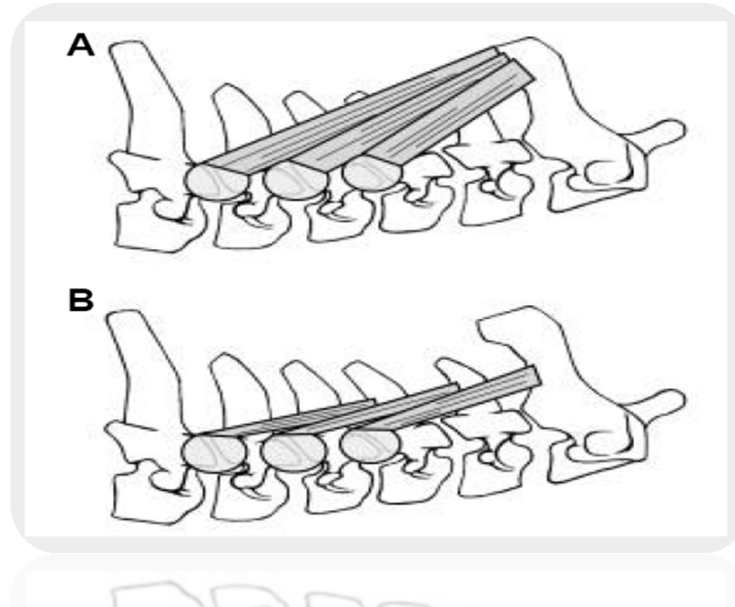
- Spinal mobilisation does not mobilise the spine.
- *Multifidus inserts into facet capsule.*
- Collagen fibre reorganisation in whiplash.
- *Evidence for efficacy of transverse friction in peripheral joint ligaments.*
- Mechanotransduction.

Facet frictions: spinal mobilisation



McGregor A et al ' Cervical spine mobilisation in subjects with chronic neck problems: An interventional study.' J Back & Musculoskeletal Rehab 18 (1) 2005

Facet frictions: multifidus Insertion



Facet frictions: facet collagen disruption

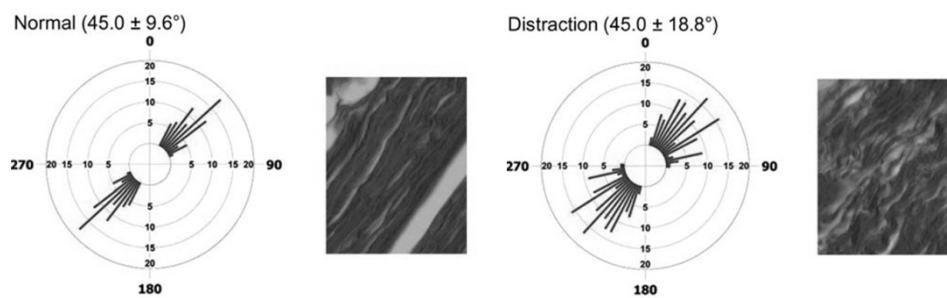


Image Courtesy of Siegmund et al Traffic Injury Prevention 2009

Facet capsular ligament organisation following distraction sufficient to cause persistent pain.

Cross friction increases rate of healing and ligament strength at 4 weeks

