OBJECTIVES

- Describe the proposed mechanisms of a whiplash injury due to Motor Vehicle Crash (MVC)
- Describe the presence of physical and psychological impairments and prognosis of Whiplash Associated Disorder (WAD)
  - Sensorimotor, MRI muscular changes, psychological
- Describe evidence based management for patients with traumatic neck pain
- Describe future investigations aimed at lessening transition from acute to chronic pain

Symptom Generators?

Understanding Mechanisms

Collisions Occur Very Quickly

They occur in just 1/4 of a second. There is not enough time for an occupant to "brace" against the rapid motion.
Normal vs. Abnormal Motion

Normal Flexion/Extension: Smooth, even motion of all spinal segments
Abnormal S-Shaped Curve: Dramatic movement in just a few spinal segments

Facet Spearing Mechanism
“Open-Book”

Hyper-extension
Facet Spearing

Motion During a Collision

As the car seatback pushes the torso forward, the spine moves forward, resulting in a straightening of the thoracic and cervical spine.

Head remains stationary
Seatback pushes torso forward

Motion During a Collision

At this point in the collision, the car seat is rapidly pushing the occupant’s torso forward, while the head remains stationary due to inertia.

This difference in motion between the neck and torso results in an S-shaped curve, where abnormal bending takes place. This rapid bending in just a few joints can result in ligament damage.

Injury Causing Motion

50 milliseconds
Spine Straightens
Head remains stationary

75 milliseconds
S-Shaped Curve
At about 150 milliseconds, the torso has pulled so far forward on the lower neck that the head is forced backwards over the head restraint. Depending on the severity of the collision, the ligaments in the front portion of the spine can be injured during this phase of the collision.

Conclusions

- Differential acceleration/deceleration between head and torso
- Abnormal non-physiological movement in spinal vertebrae
- Implications for injury to myriad of disparate tissues and development of persistent symptoms
- Females > Males?

Prognostic Indicators

- Initial pain intensity
- Age
- Gender

Cote et al (2001)
Hendricks et al (2005)

Treatments investigated to date have NOT decreased the incidence of chronicity

Gennis et al 1996
Borchgrevink et al 1998
Soderland et al 2000
Prospective Longitudinal Study Design

- 80 subjects < 1 month of injury
  - Pain & disability (NDI), motor, sensory, psychological function

Outcome (6 months)
- Pain & disability · NDI

Measures of Motor Function

Active Cervical Range of Movement (ROM)

Joint Position Error

EMG superficial neck flexor muscles during test of cranio-cervical flexion

Quantitative sensory tests

Heat & cold pain thresholds

Pressure pain thresholds

Psychological tests

- GHQ-28
  - Somatic symptoms
  - Anxiety/insomnia
  - Social function
  - Severe depression

- TSK
  - fear of movement/reinjury

- Impact of events scale (IES)
  - Posttraumatic stress symptoms
    - Intrusion
    - Avoidance

Whiplash Groups
Logistic Regression Analysis

<table>
<thead>
<tr>
<th>Group</th>
<th>NDI</th>
<th>n</th>
<th>Age (SE)</th>
<th>%Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recovered</td>
<td>&lt; 8</td>
<td>29</td>
<td>29.3 (11.72)</td>
<td>50 %</td>
</tr>
<tr>
<td>Milder</td>
<td>10-28</td>
<td>30</td>
<td>34.3 (12.6)</td>
<td>77 %</td>
</tr>
<tr>
<td>Mod/severe</td>
<td>&gt; 30</td>
<td>17</td>
<td>43.7 (13.6)</td>
<td>94 %</td>
</tr>
</tbody>
</table>

Cold pain threshold

---

James Elliott, 2005
Predictors of Membership to Moderate/severe Group (>30 NDI)

<table>
<thead>
<tr>
<th>Variable</th>
<th>OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial NDI</td>
<td>1.1 (1.07 – 1.12)</td>
</tr>
<tr>
<td>Age</td>
<td>1.13 (1.08 – 1.23)</td>
</tr>
<tr>
<td>Cold pain threshold</td>
<td>0.6</td>
</tr>
<tr>
<td>IES (total score) – posttraumatic stress reaction</td>
<td>1.11 (1.08 – 1.2)</td>
</tr>
</tbody>
</table>

(P < 0.05)

Implications for Management of Moderate/Severe Group

- Early multiprofessional approach will be optimal
- Adequate early pain management
- Specific psychological intervention
- Specific rehabilitation of motor deficits
  - (Non – pain provocative)

Prediction of Poor Outcome Following Whiplash Injury

- High initial pain & disability
- Restricted neck movement
- Older age
  - Cold hyperalgesia
  - Sympathetic changes
- Female
  - Moderate levels of acute posttraumatic stress

Prediction of Milder Symptoms vs Recovery Following Whiplash Injury

- High initial pain & disability
  - Psychological distress
    - Impaired muscle function

Implications for Management of Milder Symptom Group

- Early intervention will be optimal
- Specific rehabilitation of motor deficits
  - Efficacy in both chronic WAD and idiopathic neck pain
- Psychological support
  - Decrease in psychological distress parallels decreasing pain & disability

Sterling et al 2003 Pain

GHQ - 28

NDI

Sterling et al (2003b) Pain
The next stage: VALIDATION

The value of the prognostic indicators must be validated in large confirmatory studies with pre-stated hypotheses

Bland & Altman 1998

Whiplash Injury
- large cohort (multicentre)
- cohorts under different insurance schemes
- different countries

Clinical Presentation

<table>
<thead>
<tr>
<th>Grade</th>
<th>Clinical Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No complaint about neck pain, no physical signs</td>
</tr>
<tr>
<td>I</td>
<td>Neck complaint of pain, stiffness or tenderness only, no physical signs</td>
</tr>
</tbody>
</table>
| II    | Neck complaint and musculoskeletal signs including:

- Decreased range of movement
- Point tenderness

- Decreased or absent deep tendon reflexes
- Muscle weakness
- Sensory deficits

| III   | Neck complaint and fracture or dislocation |

Quebec Task Force Classification of Whiplash Associated Disorders (WAD) (Spitzer et al., 1995)

The University of Queensland, Australia
Whiplash and Diagnostic Lab
Centre for Magnetic Resonance

Magnetic Resonance Imaging Analysis of the Cervical Musculature in Whiplash Associated Disorders (WAD): A Measure of Fat within Muscle

James M. Elliott
PT, MS
Doctoral Candidate
The University of Queensland, Australia
Whiplash and Diagnostic Lab
Centre for Magnetic Resonance

Magnetic Resonance Imaging Analysis of the Cervical Musculature in Whiplash Associated Disorders (WAD): A Measure of Fat within Muscle

WAD Cost
10-30% will continue to have symptoms at two-years
$230.6 billion USD
(Blincoe et al., 2002)

Radiological Marker of Muscle Changes

James Elliott, 2005
Do Muscle Changes on MRI Correlate with Symptoms?

Hides et al., 1994, 1996; Kader et al, 2000

Upper Cervical Musculature

Preliminary evidence of atrophy and fatty infiltration in the upper cervical region in patients with persistent neck pain

Hallgren et al, 1994; McPartland et al, 1997; Andary et al, 1998

RTUS in WAD


What needs to be answered?

Presence of paraspinal muscular alterations has been observed clinically with MRI and RTUS

What do we know?

• Elliott, Galloway, Jull, Noteboom, Gibbon

• Study #1
  Magnetic Resonance Imaging Analysis of the Upper Cervical Extensor Musculature in an Asymptomatic Cohort: An Index of Fat within Muscle
  Elliott, Galloway, Jull, Noteboom, Gibbon

• Study #2
  MRI Study of the Cross-Sectional Area of the Cervical Extensor Musculature in an Asymptomatic Cohort
  Elliott, Jull, Noteboom, Durbridge, Gibbon
  Clin Anat 2005-in press

• Study #3
  Fatty Infiltration in the Cervical Extensor Muscles in Persistent Whiplash Associated Disorders: A MRI Analysis

PURPOSE

1. To quantify fatty infiltrate in the cervical extensor musculature in subjects suffering from persistent WAD and healthy control subjects

2. To determine if muscular fat varies across group, side, segmental level and muscle
<table>
<thead>
<tr>
<th>Cervical Paraspinal Musculature</th>
<th>Multifidus</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Multifidus" /></td>
<td><img src="image2" alt="Multifidus" /></td>
</tr>
<tr>
<td>Semispinalis Cervicis</td>
<td>Semispinalis Capitis</td>
</tr>
<tr>
<td><img src="image3" alt="Semispinalis Cervicis" /></td>
<td><img src="image4" alt="Semispinalis Capitis" /></td>
</tr>
<tr>
<td>Splenius Capitis</td>
<td>Upper Trapezius</td>
</tr>
<tr>
<td><img src="image5" alt="Splenius Capitis" /></td>
<td><img src="image6" alt="Upper Trapezius" /></td>
</tr>
</tbody>
</table>
**Summary**

- Significant widespread signal changes were observed in all extensor muscles and all levels for the WAD group compared to the healthy control subjects.

- The rectus capitis posterior minor, major and the multifidii at the C3 segmental level demonstrated the largest amount of signal change/fatty infiltration in the WAD group.
**Mechanisms**

- Acute inflammatory response?
  - Pre-inflamatory factors?
    - Lefaucheur et al., 1996; Floss et al., 1997; Dulor et al., 1998; Eliav et al., 1999; Nukuda et al., 2000; Hodges et al., 2000; Hodges et al., 2006
- Pre-ganglionic?
  - Hayashi et al., 2002
- Denervation?
  - Fleckenstein et al., 1993; Haig, 2002
- Variable disuse?
  - Type I vs Type II fibers; spindle density distribution
    - Uhlig et al., 1995; Eldred et al., 1997; Richmond et al., 1999; Kulkarni et al., 2001; Boyd et al., 2002; Liu et al., 2003

**Cervical Spine: Issues in Rehabilitation**

**Development of a New Clinical Test**

- Cranio-cervical flexion test
  - A test of the anatomical action of longus capitus, longus colli (slight flattening of the cervical lordosis)
  - 5 staged test of increasing inner range (target pressures)
  - Assess the stage that can be achieved
  - Record altered patterns of muscle use
  - Assess low load endurance capacity

**Ultimate goal - best practice in acute WAD to lessen transition to persistent pain and disability**
Cervical Spine: Issues in Rehabilitation

Prof Gwendolen Jull
Division of Physiotherapy
The University of Queensland, Australia

Exercise is an important aspect of management of cervical disorders
Exercise has been shown to have beneficial effects for neck pain
Stretching exercises  
Relaxation therapy

Endurance training  
Strengthening exercises

Proprioceptive training  
Gymnastics

Specific motor control training

Research has identified specific impairments in the muscle system of the neck pain patient

- Altered co-ordination between the deep and superficial flexors in the task of cranio-cervical flexion  
  Falla, Jull, Hodges 2004

- Neck flexors have delayed onsets in response to a perturbation, with the delay most significant in the deep neck flexors  
  Falla, Jull, Hodges 2004

- Reduced strength  
  Amiri, Jull, Saxton 2004

- Neck pain patients exhibit altered kinaesthetic sense  
  Kristjansson, D’Allalba and Jull 2003
  Treleaven, Jull, Sterling 2003
Question:
Do these impairments respond to general exercise such as strengthening regimes?

How do physiological features in the muscle system change with exercise

Is specific exercise required?

Jull, Falla, Hodges, Vicenzino

Undertook a series of experiments to evaluate the physiological factors that change with a specific exercise and to compare different exercise modalities

Study 1

Questions:
1. Does CCF training change the co-ordination of the anterior neck muscles
2. Is a strengthening regime sufficient to change co-ordination?

Exercise model:
Training the cranio-cervical flexion action

Comparisons
1. Strengthening regime
2. Proprioceptive regime

Subjects: chronic neck pain (<15/50 NDI)  n=46

Randomised:
- Cranio-cervical flexion training
- Progressive resistance program

6 week training regime
- supervised 1/week

Cranio-cervical flexion training

• correct pattern
• trained holding capacity, 30mmHg

Strength training

• 12→15 reps of a weight able to lift 12 times  (2 weeks)
• 3 x 10 reps  Set 1 ½ 10 RM load
(Weeks 4-6)  Set 2 ¾ 10 RM load
Set 3 10RM load

Altered co-ordination of neck flexors in neck pain
Outcome measures

Cognitive task
Cranio-cervical flexion test

Automatic task
Muscle response to perturbation with arm movement

Falla, Jull, Hodges 2004

Cranio-cervical flexion task

Deep neck flexor muscles

Change in timing of the deep cervical flexors

C-CF Training
Strength training

Arm Flex
Arm Ext

Change in timing of the deep cervical flexors

Arm Flex
Arm Ext
83.5%
16.5%

89%
11%

55%
45%

55%
45%

Pre
Post
Pre
Post

Pre
Post

Pre
Post

Pre
Post

Pre
Post
Study 2

**Strength Measures**

<table>
<thead>
<tr>
<th>Strength</th>
<th>CCF</th>
<th>Pre</th>
<th>Post</th>
</tr>
</thead>
<tbody>
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<td></td>
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</table>

Conclusions

**CCF training versus strength training**

- Task specificity is required to change the pattern of muscle co-ordination and enhance the activity of the DNF in the CCF action
- Evidence of the enhanced deep cervical muscle function in an automatic task (earlier) with CCF training
- CCF training does not increase the strength of the cervical flexors, strength training is required

Study 3

**Questions:**

1. Is kinaesthetic performance improved by CCF training?
2. Is a specific eye-head co-ordination program required (Revel et al 1994)

Subjects: chronic neck pain (>15/50 NDI) 
n=64 JPE > CI for normal population
- 3.0° L Rot
- 3.6° R Rot
- 3.2° Ext

Randomised:
- Cranio-cervical flexion training
- Kinaesthetic training program
- 6 week training regime
- supervised 1/week

**Outcome measure:**

Joint position error (absolute error)
- NHP – extension
  - rotation from left
  - rotation from right

**Cranio-cervical flexion training**

- Head relocation
- Gaze stability
- Eye follow
- Eye – co-ordination

**Kinaesthetic training program**
Conclusions

- Both CCF and Kinaesthetic training improve joint position sense
- Both include specific relocation practice
- Greater benefits are evident in rotation with specific kinaesthetic training
- Some support for the inclusion of specific training for cervical proprioception

Summary

- Gaining a greater understanding of the impairments associated with neck pain
- Complex interactions of pathophysiologival events in the neuromuscular system
- Exercise design: address the specific impairments

Summary

- Evidence of physical and psychological impairments exist in those who report moderate/severe symptoms and these occur soon after whiplash injury.
- A need exists to provide evidence for the efficacy of early intervention consisting of a multi-disciplinary pain management approach.
- Outcome measures are a necessity
New Directions in Planar Imaging

Classical plane CONTROL

New plane

New plane

New plane

Patient Control
The upper cervical region is typically NOT included in a standard MRI of the cervical spine.