Clinical approaches to sensorimotor control of the neck

- 145pm - 315pm Sensorimotor impairment
- 330pm – 415pm Muscle & motor control dysfunction
- 430pm – 515pm Progressing treatment

Sensorimotor Impairment
In Whiplash Injury & Neck Pain

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Neck pain – Clinical Features

- Subjective:
  - Pain / Neuropathic Pain
  - Disability.
  - Psychological distress / Post-traumatic stress symptoms.
  - Dizziness — (DHI Severe = 100-70 / mod 69-40 / low 39-0)

- Objective:
  - Sensorimotor disturbance.
    - Joint positioning error / Oculomotor control / Postural stability
  - Motor control impairment.
  - Sensory changes.
Sensorimotor impairment: overview

- Symptoms of sensorimotor impairment
- Causes of sensorimotor impairment
- Objective examination:
  - Proprioception / Joint Position Error
  - Oculomotor control
  - Postural Stability

Symptoms of sensorimotor impairment:

- NOT - true vertigo 'illusion of movement' – room spinning.
- Dizziness / giddiness
- Light headedness / feeling off balance
- Unsteadiness
- Walking on cotton wool
- 33% neck pain vs 74% whiplash (Humphreys et al 2002, Treleaven et al 2003)
**Dizziness in whiplash: causes**

- Cervical arterial dysfunction.
- Side effects of medication / anxiety – but no association (Treleaven et al 2006)
- Peripheral vestibular lesions – BPPV
- Sensorimotor dysfunction: ‘cervical afferent disturbance.’

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**Sensorimotor disturbance**

Muscle spindle input augmented with input from visual and vestibular system: Extensive anatomical connections.


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**Sensorimotor disturbance: muscle spindles**

- High density of muscle spindles in small intrinsic deep dorsal and suboccipital muscles (Peck 1984, Richmond & Bakker 1982)
- Localised in slow twitch fibres – role in postural control.
- Important role in postural control
  - LA injected into cervical tissues = ataxia (de Jong et al 1977)
  - Neck muscle vibration = postural control (Pyykkö et al 1989)
  - Neck muscle fatigue = postural control (Gosselin et al 2004)
What is the mechanism affecting cervical afferent activity?

- No evidence of muscle damage in whiplash — "Prolonged symptoms following whiplash injury cannot be explained by biochemically measurable muscle damage." (Scott and Sanderson 2002)
- Fatty infiltration (Elliott et al 2006)
- Cervical muscular fatigue — ‘overactivity’ (Stapley et al 2006).
- Disturbed afferent input — Facet joint mechanoreceptors / DRG trauma
- Stress response & sympathetic nervous system.

Sensorimotor impairment: overview

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- Causes of sensorimotor impairment
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  - Proprioception / Joint Position Error
  - Oculomotor control
  - Postural Stability

Assessing Proprioception

- Goldscheider (1889)
  - 4000 measurements of the smallest joint rotations detectable.
- Sherrington (1900)
  - Defined proprioception as awareness of body position and orientation.
- Contralateral angles: matched and compared or body segment repositioned in space without the aid of vision.
- Problems: No side for comparison.
Sensorimotor control: laser & target

Image courtesy of Research in Sports Medicine from Pinsault & Vuillerme 2009

Assessing Joint Position Error - research

- Reliability of ‘laser & target’ method:
  - N=40 healthy controls, 10 trials 1 hour apart
  - Mean of 8 trials ensures fair to excellent reliability
  - ICC 0.52 to 0.81 for global error
  - Reliability not evaluated in whiplash subjects.
    (Pinsault et al 2008)

Assessing Joint Position Error - research

- Validity of ‘laser & target’ method:
  - mod to strong correlations with Fastrak (Chen et al 2013)

- Reliability of ‘laser & target’ method:
  - Most studies report ICC above 0.75
    (Jørgensen et al 2014)

Image courtesy of Manual Therapy / Elsevier

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Heikkila (1996)  2.73cm ± 1.89cm  4.15cm ± 2.93cm  
Heikkila (1998)  2.79cm ± 1.89cm  3.70cm ± 2.90cm

N= 27, mean of ten trials.

Assessing Joint Position Error - target
Sensorimotor Impairment: Assessment and Management.

Assessing Joint Position Error - research

- JPE increases with age (Vuillerme et al 2007)
- No predictive utility – not related to outcome.
- Dizziness = increased JPE (Treleaven et al 2003)
- Vestibular vs Whiplash subjects = no difference but whiplash group main complaint dizziness / unsteadiness (Treleaven et al 2008)

Assessing Joint Position Error - summary

- Good reliability with laser and target with mean of eight trials.
- Appears to discriminate between normals and whiplash subjects.
- Normal approx. 3cm / Abnormal > 5cm
- May not be a specific test of cervical afferent function.

Sensorimotor disturbance

Muscle spindle input augmented with input from visual and vestibular system: Extensive anatomical connections.

Gosselin et al. (2004)
Schiepatti et al. (2003)
Vuillerme et al. (2005)
Stapley et al. (2006)
Sensorimotor control: oculomotor control

- Oculomotor control in whiplash:
  - 62% impaired (Heikilla 1998)
  - Low level evidence – impaired oculomotor control associated with poor prognosis (Hildingsson et al 1993).
  - Disturbed afferent input vs brain stem involvement.

Sensorimotor control: Smooth Pursuit Test

- Neck in neutral
- Negative test

Sensorimotor control: SPNT

- Smooth Pursuit Neck Torsion Test (Tjell and Rosenhall 1998)

Sensorimotor Impairment: Assessment and Management.

**Sensorimotor control: Smooth Pursuit Neck Torsion Test**

Left Neck Torsion

Positive test: saccades, dizziness.

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**Sensorimotor control: postural stability**

- **Standing balance:**
  - Increased AP sway in whiplash subjects > idiopathic neck pain > normal (Field et al 2008)
  - 50% non dizzy whiplash unable tandem stand eyes closed (Field et al 2008)
  - 74% Dizzy whiplash subjects unable tandem stand eyes closed (Treleaven et al 2008)

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“A battery of balance tests that include comfortable, narrow and tandem stances with eyes open and eyes closed should be included in the routine examination of all neck pain patients even in those not complaining of dizziness or unsteadiness.” (Field et al 2008)
Sensorimotor control assessment

- Postural stability
  - Comfortable / Narrow / Tandem / 1-Leg
  - Eyes Closed
  - Foam
- Joint Position Error
  - Laser & target
- Oculomotor
  - Eye movements: smooth pursuit / SPNT / saccades
  - Gaze stability

Sensorimotor control: SPNT

Smooth Pursuit Neck Torsion Test (Tjell and Rosenhall 1998)


Sensorimotor control assessment

Oculomotor assessment: gaze stability.
Sensorimotor control assessment
Oculomotor assessment: saccades.

Sensorimotor control assessment
➢ Oculomotor assessment: mini-saccades.

"Finger...thumb...."

Case study
Whiplash – Clinical Features

- Subjective:
  - Pain
  - Disability
  - Dizziness.
  - Psychological distress.

- Objective:
  - Sensorimotor disturbance.
    - Joint positioning error / Oculomotor control / Postural stability
  - Muscle & motor dysfunction.
  - Sensory changes - pressure & thermal pain thresholds & ULTT (Sterling et al 2005)

Whiplash – Muscle & Motor Dysfunction

- What motor & muscle changes occur in neck pain?
  - Composition
  - Strength & endurance
  - Co-ordination / timing
  - Re-organisation
  - Sustained contraction

- When do these changes occur?
- Assessing muscle & motor dysfunction.
- Managing muscle & motor dysfunction.
What changes in neck pain? Muscle composition

- Evidence of fibre type changes in muscles of cervical spine in chronic neck pain from Type I (slow-twitch oxidative) to Type IIB (fast-twitch oxidative fibres). (Uhlig et al 1995).

- Larger CSA of multifidus at C3-C7 levels & superficial extensors (ssc. & splen c.) at C3 in chronic whiplash (Elliott et al 2008).

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What changes in neck pain? Muscle composition


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What changes in neck pain? Muscle fatty infiltrates

- Muscle fatty infiltrates (MFI) in neck muscles in chronic whiplash (Elliott 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 (Elliott et al 2011)

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**What changes in neck pain? Muscle fatty infiltrates**

- MFI hypotheses:
  - Expression of fat cells due to injury induced inflammatory response
  - Increase in DNA synthesis leading to transdifferentiation in to adipose tissue
  - Appears unrelated to disuse / ROM
  - Relationship between high initial pain and MFI mediated by post traumatic stress response
  - Increased sympathetic outflow causes vasoconstriction and ischaemia / hypoxia

(Elliot et al 2011)

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**What changes in neck pain? Muscle strength**

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<td>Flexors 74.5N</td>
<td>75.7N</td>
<td>46N</td>
<td>59N</td>
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<tr>
<td>Extensors 93.8N</td>
<td>187.1N</td>
<td>79N</td>
<td>78N</td>
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<tr>
<td>Flexors 56.7N</td>
<td>53.8N</td>
<td>20.6N (Male)</td>
<td>9.8N (Female)</td>
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<tr>
<td>Extensors 67.5N</td>
<td>132N</td>
<td>24.6N (Male)</td>
<td>14.7N (Female)</td>
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**What changes in neck pain? Co-ordination**

Delayed activation of the cervical flexor muscles during a perturbation.

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What changes in neck pain? Co-ordination

What changes in neck pain? Re-organisation

Reorganisation of cervical flexor muscle activity during cranio-cervical flexion.

What changes in neck pain? Re-organisation

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Falla et al 2004
Whiplash – Muscle & Motor Dysfunction

- What motor & muscle changes occur in neck pain?
  - Composition
  - Strength & endurance
  - Co-ordination / timing
  - Re-organisation
  - Sustained contraction
- When do these changes occur?
- Assessing muscle & motor dysfunction.
- Managing muscle & motor dysfunction.

Motor control in neck pain:

- Image courtesy of O'Leary et al 2005

Motor control in neck pain:
Whiplash – Muscle & Motor Dysfunction

• Assessment
  – Cervical flexor / extensor strength / endurance –
    dynamometer / manual @ neutral & 45 degrees
    rotation.
  – 5-stage CCF test for low load ability.
  – CCF (low load) sustained contraction: time to
    failure.

Motor control in neck pain: CCF + sustained

• Deep Neck Flexors (DNF)
  – Pressure biofeedback 5-stage
    craniocervical flexion
  • Starting pressure 20mmHg.
  • Target 22 – 24 – 26 – 28 – 30mmHg.
  • Hold each stage for 10 seconds.
  – Sustained contraction to 120s
    initially

Motor control in neck pain: strength

Neck Flexion: 12 repetitions
Motor control in neck pain: strength

Lower cervical extension – axis through T1.

Craniocervical extension – axis through ears.
Craniocervical rotation with C2 stabilised.

Progressing treatment

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Managing whiplash injury: treatment progression

- Sensorimotor rehabilitation
- Motor control rehabilitation
- Managing neuropathic pain
- Managing post traumatic stress disorder
Sensorimotor Impairment: Assessment and Management.

Sensorimotor rehabilitation
- Postural stability
  - Comfortable / Narrow / Tandem / 1-Leg
  - + Eyes Closed
  - + Foam
- Joint Position Error
  - Laser & target
- Oculomotor
  - Eye movements: smooth pursuit / SPNT / saccades
  - Gaze stability

Sensorimotor control rehabilitation
- Joint Position Error
  - Points in range
- Comfortable / Narrow / Tandem / 1-Leg
  - + Eyes Closed
  - + Foam
- Oculomotor
  - Eye movements: smooth pursuit / SPNT / saccades
  - Gaze stability
Sensorimotor control rehabilitation

“Work on what turns on the dizziness”

- Progression
  - Target: dot – word – business card
  - Position: sit – stand – tandem stand – walking
  - Speed: slow – medium – fast
  - Range: small – medium – large
  - Neck Torsion: neutral – 30 degs – 45 degs
  - Vision: Unrestricted – Restricted Peripheral
  - Duration: 30s 2 x day – 1-2 min 3 x day – 5 min 5 x day
Sensorimotor control: research

• Standing balance improves following treatment localised to the cervical spine in neck pain subjects including whiplash (Karlberg & Magnusson 1996).

• Oculomotor training alone reduces pain and improves ROM (n=60, neck pain, Revel et al 1994)
  – 8 week gaze stability supine and sitting / JPE training.
  – VAS change for training group 21.8mm decrease

Motor control rehabilitation: specificity

Think......
– Low load
– High load

Motor control in neck pain: CCF + sustained

• Deep Neck Flexors (DNF)
  – Pressure biofeedback 5-stage craniocervical flexion
    • Starting pressure 20mmHg.
    • Target 22 – 24 – 26 – 28 - 30mmHg.
    • Hold each stage for 10 seconds.
  – Sustained contraction to 120s
Sensorimotor Impairment: Assessment and Management.

Motor control in neck pain: strength

Poor cranio-cervical flexor control

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Motor control in neck pain: strength

Incline Neck Flexion: if unable to perform neck flexion in supine, incline plinth. Or inflated biofeedback @ 40mm/Hg.

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Motor control in neck pain: strength

Neck Flexion: 2/52 at 12 rep max / twice day then 15 reps x 3 /day

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Motor control rehabilitation:

- Train deep cervical flexors
  - Low load: 10 x 10 secs at each stage 22 to 30 mmHg.
  - Low load holds 120s – max comfortable holding time at target pressure.

- Train cervical flexors & extensors
  - Strenght: 12 rep max.
  - Repeat twice a day for 14 days.
  - Then 3 sets of 15 rep max daily.
Muscle & Motor Dysfunction: strength / endurance vs low load

- Chronic neck pain n=58 female
- NDI 20%
- Endurance head lift vs CCF 6/52
- Both decreased pain
  - Endurance -2.8 NDI
  - CCF -3.5 NDI
- Endurance reduced SCM & AS fatigue

(Falla et al 2006)

Muscle & Motor Dysfunction: proprioception vs low load

- Chronic neck pain n=64 female
- NDI 40%
- Group 1 : Joint position / oculomotor exs 6/52
- Group 2 : CCF 6/52
- Both reduced pain
  - Proprio -8.4 NDI
  - CCF -6.9 NDI
- Both improved proprioception

(Jull et al 2007)
**Muscle & Motor Dysfunction: strengthening.**

- 12 month muscle strengthening vs. endurance vs. controls (n=180, female) (Ylinen et al 2005)
- Decreased pain VAS by 60-70% both active groups & 28% control group
- Significant increase in PPT both active groups (p<0.001, n=180)

*Upper limb:* shrugs, presses, curls, bent over-rows, flies.
Exercise diary.

**Muscle & Motor Dysfunction: strength vs low load**

Fig. 1. Normalized RMS values (mean and standard deviation) for the DIF muscles for each stage of the CFT. Data are presented for the C-CFT training group and strength-training group both pre and post intervention. *Indicates significant difference between pre and post intervention data (p<0.005)*.

(Jull et al 2009)
Muscle & Motor Dysfunction: strength vs low load

Clinical approaches to sensorimotor control of the neck

Edgware Community Hospital - November 2016

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