Clinical approaches to sensorimotor control of the neck

Edgware Community Hospital - November 2016

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Chris Worsfold

- 30 years clinical & research experience
  - Full time clinician
- *Teaching*
  - *Schools, Hospitals, Conferences*
- Expert Witness
  - Clinical Negligence
  - Personal Injury
- *15 peer reviewed publications*
- Whiplash Reform / CSP
  - Gave evidence in Parliament (2013)
  - Ministry of Justice / Government advisor (2013-15)
  - Director of MedCo (2015)
- *Appeared on…*

BBC one · CLAIMED AND SHAMED · BBC TWO · BBC RADIO 4 · BBC PARLIAMENT

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Clinical approaches to sensorimotor control of the neck

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

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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.

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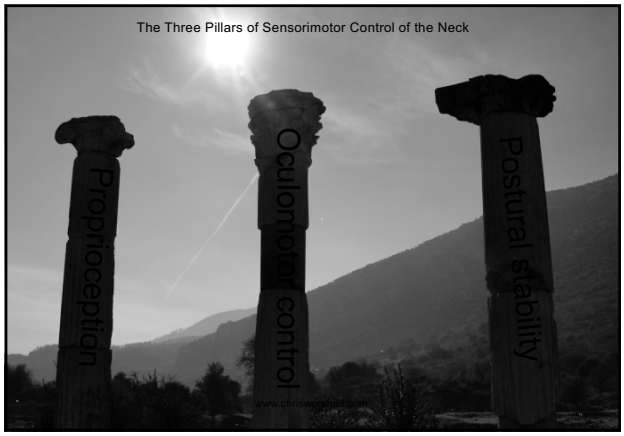

Sensorimotor impairment: overview

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

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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)

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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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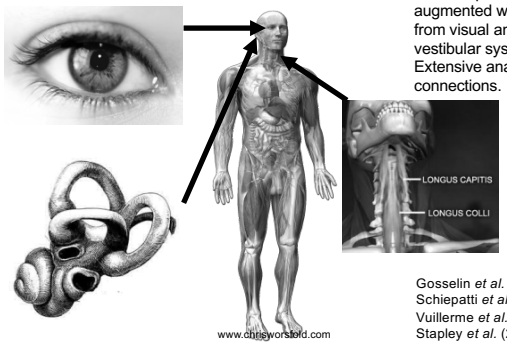
Sensorimotor disturbance



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

Gosselin *et al.* (2004)
Schiepatti *et al.*(2003)
Vuillerme *et al.*(2005)
Stapley *et al.* (2006)

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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 (deJong et al 1977)
  - Neck muscle vibration = postural control (Pyykko et al 1989)
  - Neck muscle fatigue = postural control (Gosselin et al 2004)

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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.

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Sensorimotor impairment: overview

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  - Proprioception / Joint Position Error
  - Oculomotor control
  - Postural Stability

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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.

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Sensorimotor control: laser & target

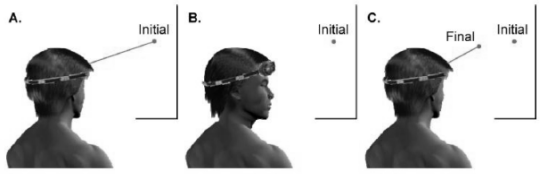

Image courtesy of Research in Sports Medicine from Pinsault & Vuillerme 2009

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Assessing Joint Position Error - research

- Reliabililty 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)

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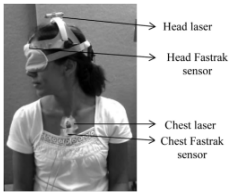
Assessing Joint Position Error - research

- 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)



From Chen et al 2013
Courtesy of Manual Therapy / Elsevier

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Evidence of Impaired Proprioception in Chronic, Idiopathic Neck Pain: Systematic Review and Meta-Analysis

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T.R. Stanton, BScPT, MScRS, PhD, The Sansom Institute for Health Research, The University of South Australia, School of Health Sciences, GPO Box 2471, Adelaide, South Australia 5001; Pain-Adelaide Consortium, Adelaide

Background. Despite common use of proprioceptive retraining interventions in people with chronic, idiopathic neck pain, evidence that proprioceptive dysfunction exists in this population is lacking. Determining whether proprioceptive dysfunction exists in people with chronic neck pain has clear implications for treatment prescription.

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Systematic review

Joint position sense error in people with neck pain: A systematic review

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Assessing Joint Position Error - research

	Healthy Controls	Whiplash
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.

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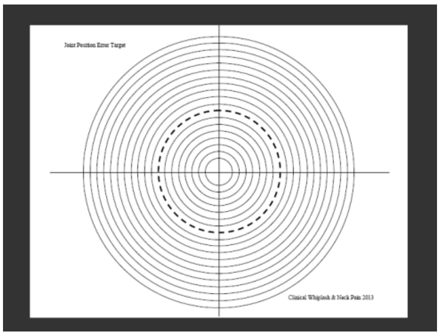
Assessing Joint Position Error - target



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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)

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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.

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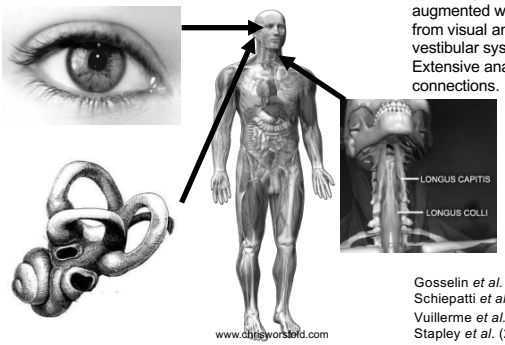
Sensorimotor disturbance



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Stapley *et al.* (2006)

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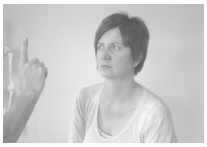
Sensorimotor control: oculomotor control

- 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.



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Sensorimotor control: Smooth Pursuit Test

Neck in neutral

Negative test

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Sensorimotor control: SPNT

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

Images courtesy of 'Whiplash, Headache and Neck Pain,' Jull et al. Churchill Livingstone Elsevier, 2008.

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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)

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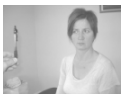
Sensorimotor control assessment

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



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Sensorimotor control: SPNT

Smooth Pursuit Neck Torsion Test (Tjell and Rosenhall 1998)


Images courtesy of 'Whiplash, Headache and Neck Pain,' Jull et al. Churchill Livingstone Elsevier, 2008.

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Sensorimotor control assessment

Oculomotor assessment: gaze stability.

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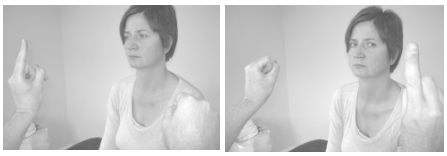
Sensorimotor control assessment

Oculomotor assessment: saccades.



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Sensorimotor control assessment

- Oculomotor assessment: mini-saccades.

"Finger..... thumb....."

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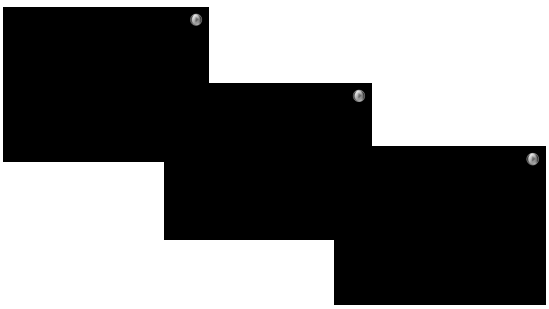
Case study



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Muscle & motor control dysfunction

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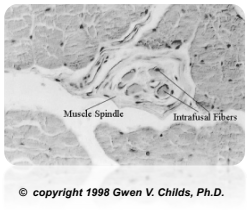

Whiplash – Clinical Features

- 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)

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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.

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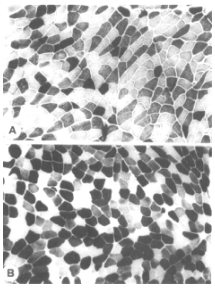
What changes in neck pain? Muscle composition

- 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).



Biopsy specimens from Sternomastoid
A=short duration of symptom, 12 months,
B=long duration of symptoms, 36 months
Type IIB fibres A= 6% vs B=44% (Uhlig et al 1995)

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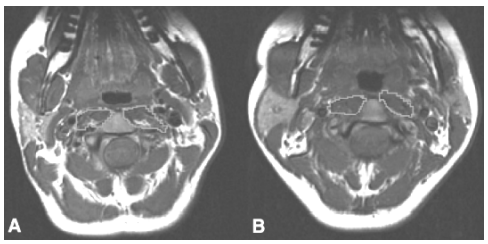
What changes in neck pain? Muscle composition



(Elliott et al 2008, 2009, 2010)

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What changes in neck pain? Muscle fatty infiltrates

- 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)

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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

Isometric Cervical Strength Normals:

Cervical Muscle Group	Chiu et al (2002)	Ylinen et al (2004)	Vernon (1999)	Jordan et al (1999)
Flexors	74.5N	75.7N	46N	59N
Extensors	93.3N	187.1N	79N	78N

Isometric Cervical Strength Neck Pain:

Cervical Muscle Group	Chiu et al (2002)	Ylinen et al (2004)	Prushansky et al (2005)
Flexors	56.7N	53.8N	20.6N (Male) 9.8N (Female)
Extensors	67.5N	132N	24.6N (Male) 14.7N (Female)

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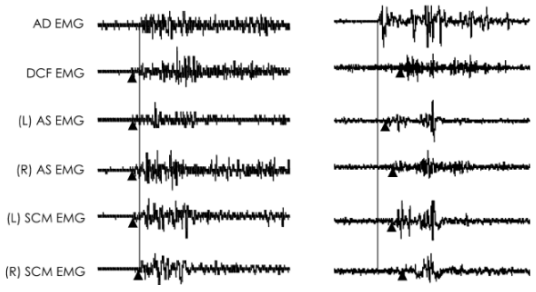
What changes in neck pain? Co-ordination

Delayed activation of the cervical flexor muscles during a perturbation.



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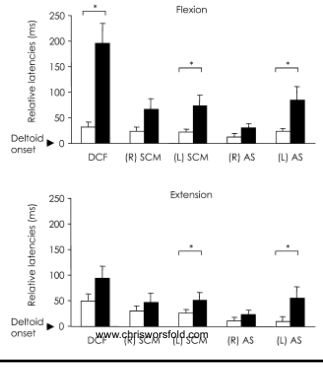
Falla et al 2004

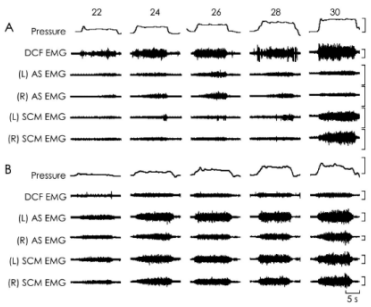
What changes in neck pain? Co-ordination



Falla et al 2004

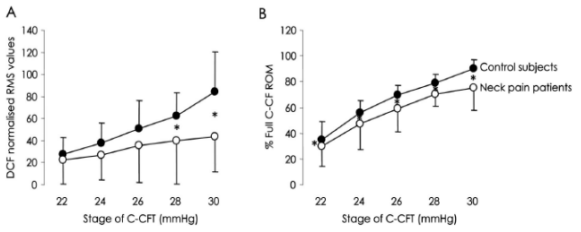
What changes in neck pain? Re-organisation

Reorganisation of cervical flexor muscle activity during craniocervical flexion.



Falla et al 2004

What changes in neck pain? Re-organisation



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.

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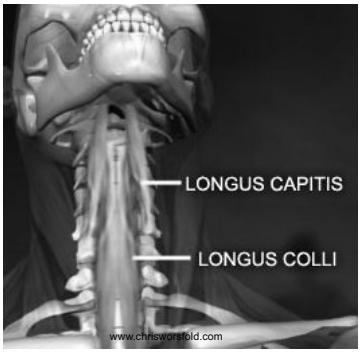
Motor control in neck pain:



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Motor control in neck pain:

Image courtesy of O'Leary et al 2005

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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.

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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

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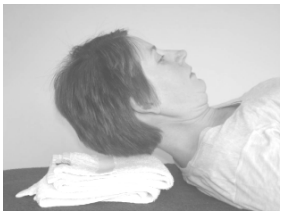
Motor control in neck pain: strength



Neck Flexion: 12 repetitions

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Motor control in neck pain: strength

Poor cranio-cervical flexor control

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Lower cervical extension – axis through T1.


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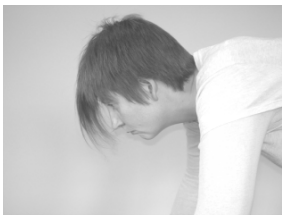
Craniocervical extension – axis through ears.

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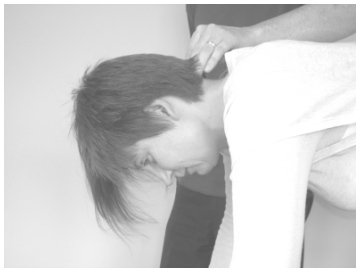
Craniocervical rotation with C2 stabilised.



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Progressing treatment

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Managing whiplash injury: treatment progression

- Sensorimotor rehabilitation
- Motor control rehabilitation
- Managing neuropathic pain
- Managing post traumatic stress disorder

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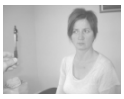
Sensorimotor rehabilitation

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



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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

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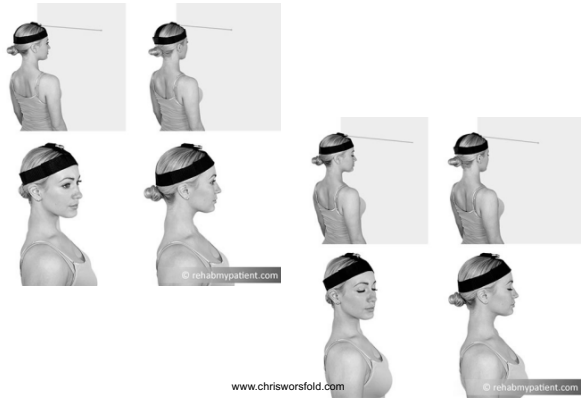

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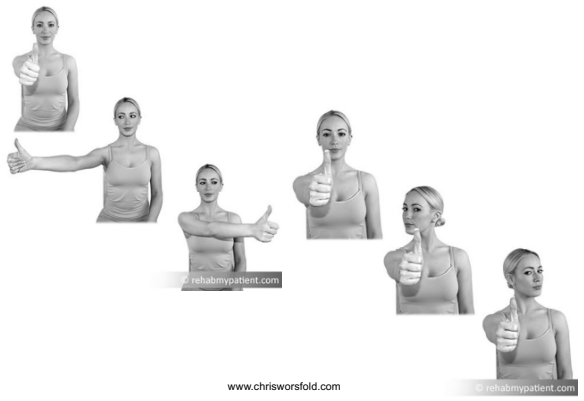

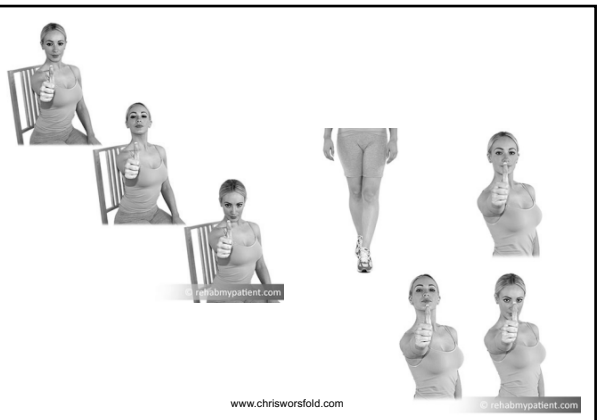

Sensorimotor control rehabilitation

"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

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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

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Motor control rehabilitation: specificity

Think.....
- Low load
- High load

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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

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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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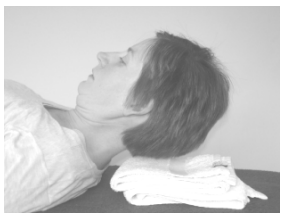
Motor control in neck pain: strength



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
  - Strength 12 rep max.
  - Repeat twice a day for 14 days.
  - Then 3 sets of 15 rep max daily.

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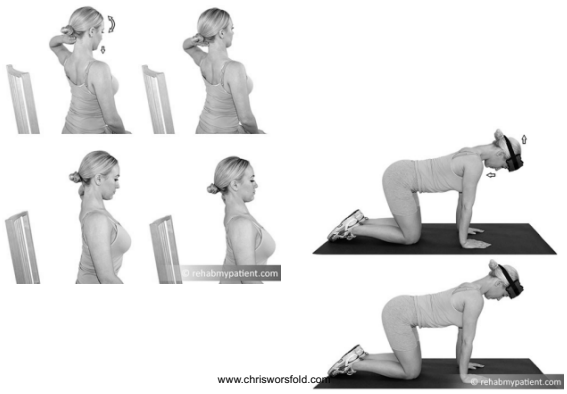

Muscle & Motor Dysfunction: strength / endurance vs low load

- 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)

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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)

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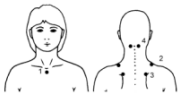
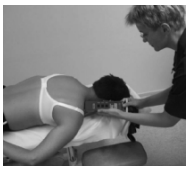
Muscle & Motor Dysfunction: strengthening.

- 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)





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Ylinen et al (2005) Protocol: 3x week: 3 sets 20 reps. <u>Upper limb</u>: shrugs, presses, curls, bent over-rows, flies. <u>Lower limb</u>: squats, sit-ups and back extension. Neck & shoulder stretches 20mins. Aerobic exercise 30 mins. Exercise diary.

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Muscle & Motor Dysfunction: strength vs low load

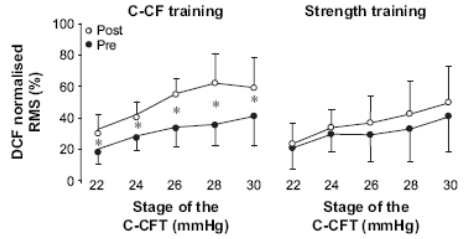

Fig. 1. Normalised RMS values (mean and standard deviation) for the DCF muscles for each stage of the CCFT. Data are presented for the C-CF retraining group and strength-training group both pre and post intervention. *indicates significant difference between pre and post intervention data ($P < 0.05$).

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(Jull et al 2009)

Muscle & Motor Dysfunction: strength vs low load

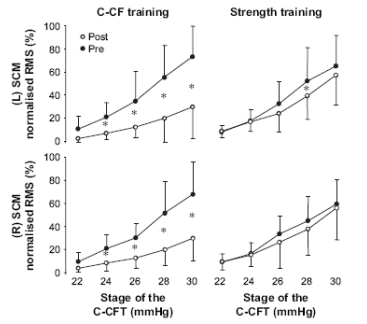

Fig. 2. Normalised RMS values (mean and standard deviation) for the left and right SCM muscles for each stage of the CCFT. Data are presented for the C-CF training group and strength-training group both pre and post intervention. *indicates significant difference between pre and post intervention data ($P < 0.05$).

(Jull et al 2009)

Clinical approaches to sensorimotor control of the neck

Edgware Community Hospital - November 2016

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