A SYSTEMATIC REVIEW OF THE LITERATURE ON MUSCLE STRENGTHENING OF THE CERVICAL SPINE USING THE CRANIO – CERVICAL FLEXION TEST AND EXERCISES

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INTRODUCTION

Many forms of exercise have been used in physiotherapy for a large variety of pathologies and complaints since the beginning of the physiotherapy profession.

The effective management of patients with neck pain is considered to be exercise although a consensus on the optimal exercise programme is lacking. There is also a lack of studies on the exact nature of muscle impairment in patients with neck pain.

However a very specific type of exercise has been developed over the last 10 years, initially for acute and chronic low back pain, but more recently also for acute and chronic neck complaints.

The exercise is used for pain control and prevention of further episodes which can be obtained by training the muscle control of the spinal segments. The objective is to improve control of the active segmental stabilisation, thus protecting the joints from stress and further injury. The development of these specific exercises is based on work in the laboratory but also on patients with spinal pain, using the mechanisms involved in providing muscular support for the motion segment and the muscle control necessary in segmental stabilisation.

Chronic neck pain is becoming more prevalent in modern society and it is estimated that 67% of individuals will suffer an episode of neck pain at some stage in their life (Cote 1998). It is indicated that the prevalence rate will continue to rise due to the increasing sedentary life style and use of computer technology. It is not only vital to have effective management for the relief of these symptoms but probably more important to obtain results in the prevention of recurrent episodes of neck pain in order to reduce costs and personal suffering.

The osteoligamentous structures are considered to be responsible for 20% of the mechanical stability of the cervical spine whereas the remaining 80% is controlled by the surrounding musculature (Panjabi 1998). Ligamentous stabilisation occurs mainly at end range, whereas the muscles provide support in neutral positions and mid-range postures, those usually used in functional activities.

Evidence suggests that in the presence of neck pain, due to injury or pathology, the muscles play a greater role in control of these positions. Dysfunction of the deep cervical flexor muscles with a reduction in strength and endurance capabilities have been demonstrated, which indicates the need to address the assessment and rehabilitation of these muscles during treatment of these patients. Thus it is necessary to first detect, record and analyse specific muscle dysfunction in order to develop a suitable rehabilitation programme.

BACKGROUND OF THE EXERCISE PROGRAMME

Mechanisms for muscular support:

The stabilising function of the muscle system provides protection for the spinal articular structures by reducing joint displacement, by helping stress absorption and by protecting the joint cartilage.

Active joint stabilisation has been found to be due to several muscle recruitment strategies:

1. Early pre programmed recruitment is one of these complex strategies. Certain muscles are recruited prior to a specific action to make sure that the joint is functionally prepared to support that particular motion.
2. Muscle stiffness regulation is another strategy used in joint stabilisation. This mechanism gives more stability by using the increased muscle stiffness during the co contraction of the agonist and antagonist muscles which work around that joint. It is thought that this phenomenon is important even in situations of minimal muscle contraction, as low as 25% of the maximum voluntary contraction is able to give maximum joint stiffness (Hoffer and Andreassen 1981). It is also thought that feedback from the joint and ligament afferents, through their effects on the gamma spindle systems and their influence on the alpha motorneurones, may help control muscle stiffness. The tonic slow twitch muscle fibres are controlled by the alpha motorneurones and it appears that these units are closely related to joint stability control.
3. Another important strategy in muscular control of joint stability is the understanding of the functional difference between local and global muscles. The large torque producing muscles which link the pelvis to the thoracic cage for example are described as global muscles. Their main function is to provide general trunk stabilisation, balance external loads and thus reduce the resulting forces on the spine. Those muscles attached directly to the vertebrae are the local muscles. Their function is considered to be important for segmental stability and control of the vertebral segment positions.

Vertebral segmental stability:

Stability of the vertebral segments is provided by osseous, ligamentous and muscle restraints. Any structure of the motion segment may be affected by injury or degenerative disease and can result in abnormal segmental movement and muscular dysfunction. Panjabi (1992) described the neutral zone of the vertebral segment as the sensitive area where there is little resistance through the passive structures to the small range of joint displacement. He suggests that small movements in this area may increase with injury, muscular dysfunction or disc degeneration. The local muscle system for example of the lumbar spine, through their attachment to the lumbar vertebrae, probably have the greatest capacity to affect segmental stiffness through control of the neutral zone. There have been a number of studies investigating the contribution of various back muscles to active segmental stabilisation. These have shown that the lumbar multifidus especially contributes to the control of the neutral zone.

The role of the abdominal muscles in the treatment of low back pain has been considered important for many years. Initially the rehabilitation consisted of strengthening the muscles as a group and the importance of the various different components of the muscle group was not fully investigated. Recently considerable research has studied the role of the transversus abdominis and demonstrated its considerable importance in lumbar stabilisation. EMG activity has shown that this muscle contracts prior to upper limb movements, which was not the case with the other abdominal muscles, which demonstrates the different functional role of these muscles.

Thus both lumbar multifidus and transversus abdominis have been shown to be important components in the local muscle system which has a primary role in lumbar segmental stability.

Dysfunction in the local muscle system:

Patients with low back pain are likely to have a disturbance in the stabilising function of the antigravity trunk muscles. The tonic fibres of these muscles are important in antigravity posture support and control. Disuse and reflex or pain inhibition due to low back pain or injury have been shown to affect these fibres (Richardson & Jull, 1994; Baugher, 1984). The sort of exercise needed to rehabilitate the supporting and stabilising role of these antigravity muscles depends on the type of dysfunction present. Several authors have demonstrated through research that there is a link between dysfunction in the local muscle system and back pain (Hides, 1994; Rantanen, 1993; Biederman, 1991; Hodges & Richardson, 1995).

Thus the discovery of the importance of the local muscle system in its role as a stabiliser of the lumbar spine as well as the evidence of their dysfunction in patients with low back pain, prompted the design of a new therapeutic rehabilitation of these stabilising muscles.

<u>Exercise design:</u>

The development of this exercise regime was based on work both in the clinic as well as in the laboratory and includes :

- the type of muscle contraction;
- body position;
- level of resistance;
- number of repetitions;
- ability to hold the contraction;
- various methods of progression.

1. <u>Type of muscle contraction</u>:

   Isometric exercise was found to be most beneficial for the deep local muscles due to the functional demands of these muscles. Co-contraction exercises involving the agonist and antagonist muscles have also been found to be useful in their rehabilitation. As the tonic motor fibres are mostly responsible for the control of joint stability and both the disuse and reflex inhibition are most likely to affect these fibres, prolonged tonic holding at a low level maximum voluntary contraction (MVC) is indicated.

2. Body position:

   Initially minimal external loading positions are used as the local stabilising muscles work independently. Prone lying or four point kneeling are used for the lumbar spine, where there is body weight support and no extra external resistance, as well as reducing the risk of provoking pain or reflex inhibition. The supine position is used initially for the cervical spine.

3. Level of resistance:

   Only low levels of muscle contraction are required because tonic fibres operate at levels below MVC, approximately by 30-40%. Also only low levels of muscle force are indicated (only about 25% MVC) to obtain increased muscle stiffness, which are needed to enhance the spinal stability necessary for joint support.

4. Number of repetitions:

   Maximum benefit from the localised and specific exercise is gained by repeating it as many times as possible throughout the day.

5. Holding ability:

   The isometric co-contraction exercise of the deep muscles needs retraining as it is a specific motor skill and again needs to be repeated throughout the day to improve the holding ability.

6. Methods of progression:

   There are various stages of progression:

   a) increasing the holding time;
   b) increasing the number of repetitions;
   c) increasing loads to minimal body weight;
   d) progress to more functional body positions with increased external loads;
   e) performing the exercise with a static neutral spine and then progressing to other static positions at more extremes of range;

f) maintaining the co-contraction of the deep muscles during dynamic functional movements.

Evidence of efficacy of the concept:

Over the last ten years evidence of the link between this concept of motor control and deep muscle training to increase the local segmental stability and consequent pain relief has emerged. In chronic low back pain patients with radiological diagnosis of spondylolysis or spondylolythesis the patients who completed the specific exercise programme as opposed to general exercises, demonstrated a greater reduction in pain and better functional ability (O'Sullivan, 1994). Furthermore patients with acute, first episode low back pain were shown to require a programme of re-education of co-contraction of the deep muscles in order to restore the multifidus to its pre-injury size, with less recurrences (Hides, 1995).

The success of this therapeutic exercise programme has been and is still being studied scientifically and, as a result of the increased knowledge, as well as the benefit of pain relief in the patients, it has been developed further and over the last few years has also been used in treating the cervical spine.

OBJECTIVE OF THIS PAPER :

Object of this paper is a scientific review of the literature published on a specific exercise regime in reference to the cervical spine using the cranio-cervical flexion test and exercises.

The object of this review is to present the evidence of the effect of this exercise regime in the management of mechanical neck disorders, and to assess the support of the exercise method in its effectiveness in treating mechanical neck disorders.

METHOD OF THE SEARCH STRATEGY :

The databases searched were :

CINAHL (Medscape and Medline), MEDLINE and PUBMED.

The Keywords used were :

Neck or cervical and cranio-cervical flexion test

However the search produced a large number of articles but limited number of trials on the specific topic.

The results of this search process are presented in Table 1

Table 1: Results of search

No.	Search	result
1	Medline	3186
2	Medscape	1407
3	Pubmed	5
4	Spine Journal	1

Therefore in order to obtain the scientific studies published on this subject the various authors names had to be included in the research method.

Therefore the search was limited to the subject described above as well as some of the authors names who have developed, researched and published the limited number of papers produced on the cervical spine examining the evidence on the effect of this

particular rehabilitation protocol. This result was further helped by searching two renowned journals in the spinal and physiotherapy fields.
Furthermore the search was limited to the studies published between January 1992 and July 2005 in the English language.
The results of this search process are in Table 2 and are the studies assessed in this paper.

Table 2 : Results of search

No.	Search	Author and/or topic	Result
1	Pubmed	Falla and cervical spine	5
		Jull and cranio-cervical flexion test	7
		Sterling and cranio-cervical flexion test	4
2	Spine	Jull	7
		Falla	1
3	Manual Therapy	Cranio-cervical flexion test	3

ANATOMY OF CERVICAL FLEXORS :

It is estimated that 80% of mechanical stability of the cervical spine is provided by the surrounding musculature (Panjabi). The muscles give dynamic support during activities around the neutral and mid-range positions, which are those used in everyday functional tasks. The role of the deep cervical flexor muscles (Longus colli, Longus Capitis, Rectus Capitis Anterior and Rectus Capitis Lateralis) which are histologically and morphologically designed to give support to the cervical lordosis and the cervical joints, has recently become evident. Local muscular instability has been found where deep muscle activity is required to stabilise the spine, especially in the mid range functional position (Winters). Longus Colli maintains the support and control of the cervical curve against the buckling force due to the weight of the head and the powerful neck extensors (Panjabi, Mayoux-Benhamou).

The deep cervical muscles :

The deep cervical flexor muscles (Fig. 1) are :

Longus colli.

Rectus capitis anterior.

Longus capitis.

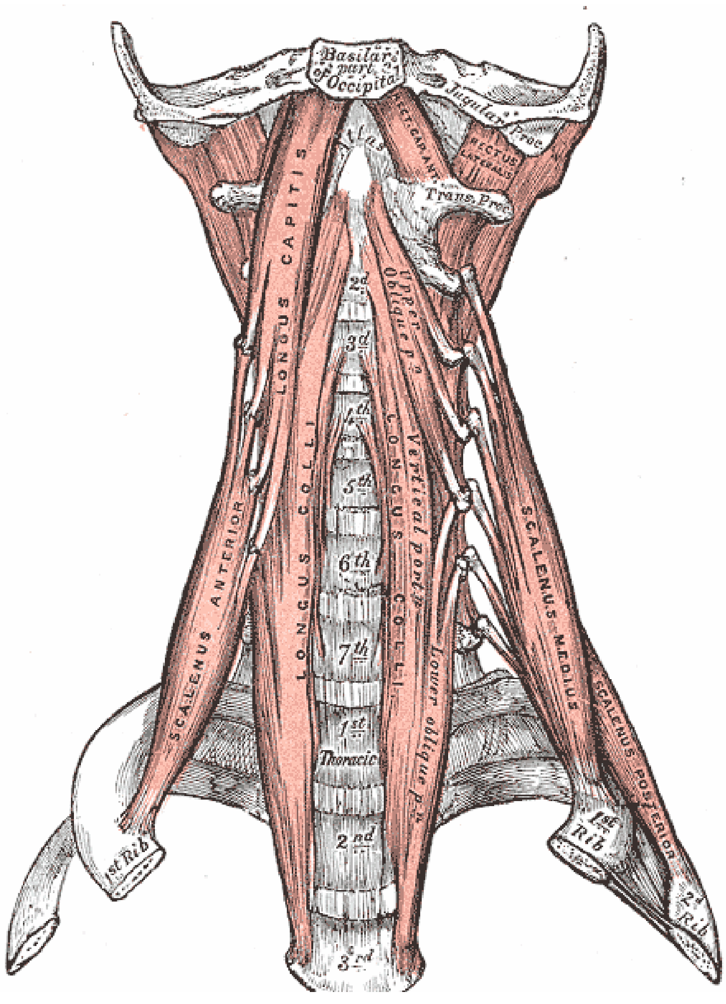
Rectus capitis lateralis.

These muscles have a close relationship with the cervical spine and articular elements. Longus colli maintains the support and control of the cervical curve

The Longus colli is situated on the anterior surface of the vertebral column, between the atlas and the third thoracic vertebra. It is broad in the middle, narrow and pointed at either end, and consists of three portions, a superior oblique, an inferior oblique, and a vertical. The superior oblique portion arises from the anterior tubercles of the transverse processes of the third, fourth, and fifth cervical vertebræ and, ascending obliquely with a medial inclination, is inserted by a narrow tendon into the tubercle on the anterior arch of the atlas. The inferior oblique portion, the smallest part of the muscle, arises from the front of the bodies of the first two or three thoracic vertebræ; and, ascending obliquely in a lateral direction, is inserted into the anterior tubercles of the transverse processes of the fifth and sixth cervical vertebræ. The vertical portion arises, below, from the front of the bodies of the upper three thoracic and lower three cervical vertebræ, and is inserted into the front of the bodies of the second, third, and fourth cervical vertebræ.

The Longus capitis (Rectus capitis anticus major), broad and thick above, narrow below, arises by four tendinous slips, from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and ascends, converging toward its fellow of the opposite side, to be inserted into the inferior surface of the basilar part of the occipital bone.

Fig. 1 : Anterior view of the cervical spine (Gray's Anatomy)



The Rectus capitis anterior (Rectus capitis anticus minor) is a short, flat muscle, situated immediately behind the upper part of the Longus capitis. It arises from the anterior surface of the lateral mass of the atlas, and from the root of its transverse process, and passing obliquely upward and medialward, is inserted into the inferior surface of the basilar part of the occipital bone immediately in front of the foramen magnum.

The Rectus capitis lateralis, a short, flat muscle, arises from the upper surface of the transverse process of the atlas, and is inserted into the under surface of the jugular process of the occipital bone.

Nerve supply : The Rectus capitis anterior and the Rectus capitis lateralis are supplied from the loop between the first and second cervical nerves; the Longus capitis, by branches from the first, second, and third cervical; the Longus colli, by branches from the second to the seventh cervical nerves.

Actions : The Longus capitis and Rectus capitis anterior are the direct antagonists of the muscles at the back of the neck, serving to restore the head to its natural position after it has been drawn backward. These muscles also flex the head, and from their obliquity, rotate it, so as to turn the face to one or the other side. The Rectus lateralis, acting on one side, bends the head laterally. The Longus colli flexes and slightly rotates the cervical portion of the vertebral column.

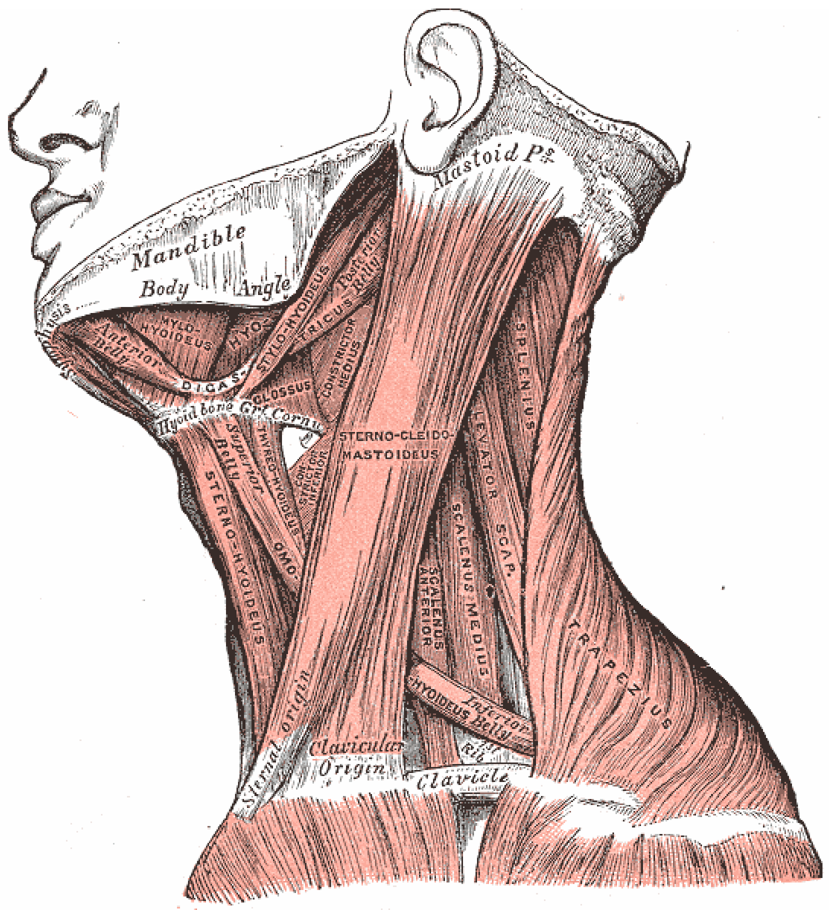
The superficial cervical muscles :

The Sternocleidomastoideus muscle (Fig. 2 and 3) passes obliquely across the side of the neck. It is thick and narrow at its central part, but broader and thinner at either end. It arises from the sternum and clavicle by two heads. The medial or sternal head is a rounded fasciculus, tendinous in front, fleshy behind, which arises from the upper part of the anterior surface of the manubrium sterni, and is directed upward, lateralward, and backward. The lateral or clavicular head, composed of fleshy and aponeurotic fibers, arises from the superior border and anterior surface of the medial third of the clavicle; it is directed almost vertically upward. The two heads are separated from one another at their origins by a triangular interval, but gradually blend, below the middle of the neck, into a thick, rounded muscle which is inserted, by a strong tendon, into the lateral surface of the mastoid process, from its apex to its superior border, and by a thin aponeurosis into the lateral half of the superior nuchal line of the occipital bone.

Nerve supply : The Sternocleidomastoideus is supplied by the accessory nerve and branches from the anterior divisions of the second and third cervical nerves.

Actions : When only one Sternocleidomastoideus acts, it draws the head toward the shoulder of the same side, assisted by the Splenius and the Obliquus capitis inferior of the opposite side. At the same time it rotates the head so as to carry the face toward the opposite side. Acting together from their sternoclavicular attachments the muscles will flex the cervical part of the vertebral column. If the head be fixed, the two muscles assist in elevating the thorax in forced inspiration.

Fig. 2 : Lateral View showing Sternocleidomastoid (Gray's Anatomy)



The lateral vertebral muscles (Fig. 1 and 2) are :

Scalenus anterior.

Scalenus medius.

Scalenus posterior.

The Scalenus anterior (Scalenus anticus) lies deeply at the side of the neck, behind the Sternocleidomastoideus. It arises from the anterior tubercles of the transverse processes of the third, fourth, fifth, and sixth cervical vertebræ, and descending, almost vertically, is inserted by a narrow, flat tendon into the scalene tubercle on the inner border of the first rib, and into the ridge on the upper surface of the rib in front of the subclavian groove.

The Scalenus medius, the largest and longest of the three Scaleni, arises from the posterior tubercles of the transverse processes of the lower six cervical vertebræ, and descending along the side of the vertebral column, is inserted by a broad attachment into the upper surface of the first rib, between the tubercle and the subclavian groove.

The Scalenus posterior (Scalenus posticus), the smallest and most deeply seated of the three Scaleni, arises, by two or three separate tendons, from the posterior tubercles of the transverse processes of the lower two or three cervical vertebræ, and is inserted by a thin tendon into the outer surface of the second rib, behind the attachment of the Serratus anterior. It is occasionally blended with the Scalenus medius.

Variations : The Scaleni muscles vary considerably in their attachments and in the arrangement of their fibers. A slip from the Scalenus anticus may pass behind the subclavian artery. The Scalenus posticus may be absent or extend to the third rib. The Scalenus pleuralis muscle extends from the transverse process of the seventh cervical vertebra to the fascia supporting the dome of the pleura and inner border of first rib.

Nerve supply : The Scaleni are supplied by branches from the second to the seventh cervical nerves.

Actions : When the Scaleni act from above, they elevate the first and second ribs, and are, therefore, inspiratory muscles. Acting from below, they bend the vertebral column to one or other side; if the muscles of both sides act, the vertebral column is slightly flexed.

Fig. 3 : Anterior view showing Sternocleidomastoid (from Gray's Anatomy)

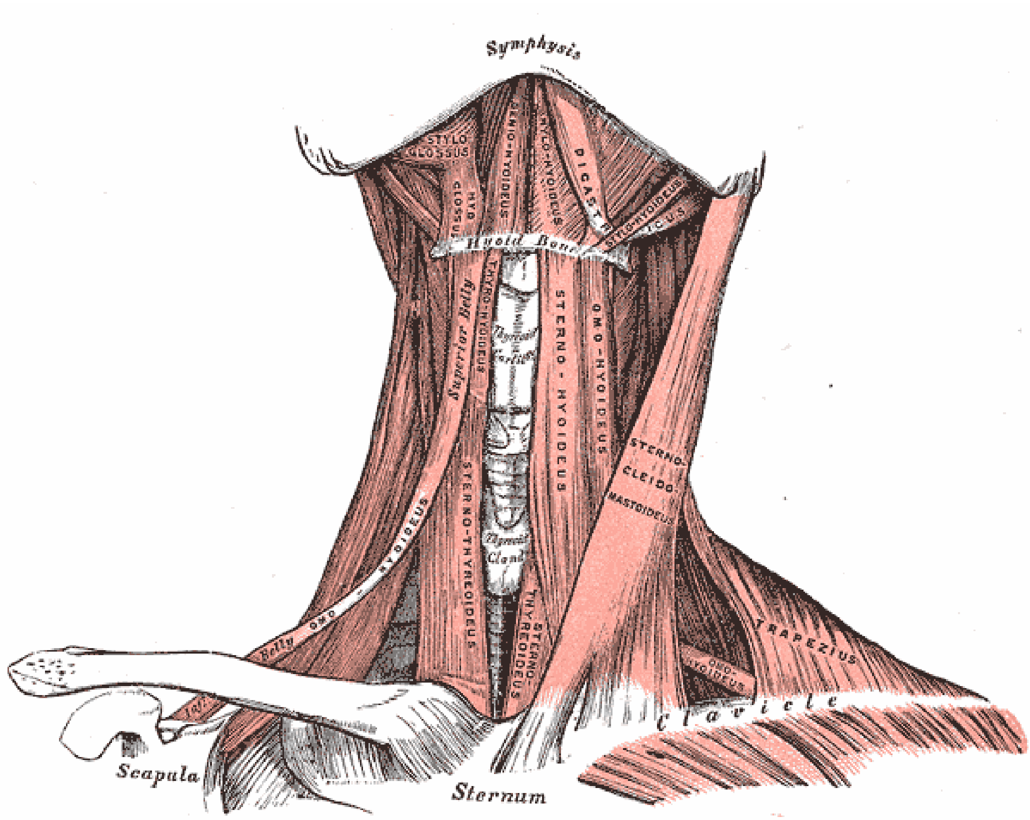


Fig. 4 : Transverse section showing relationship of these muscles with other anatomical structures (from Gray's Anatomy)

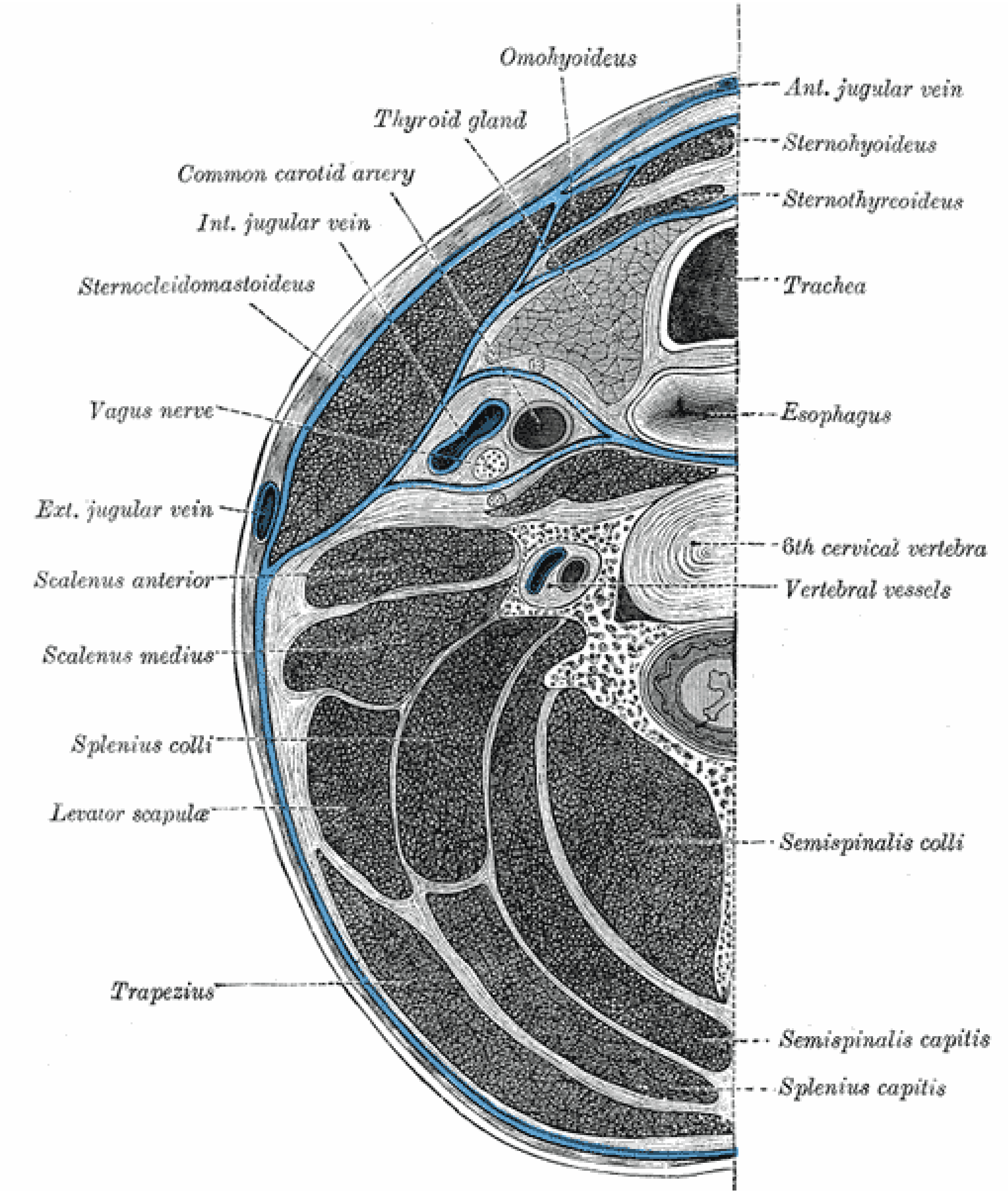
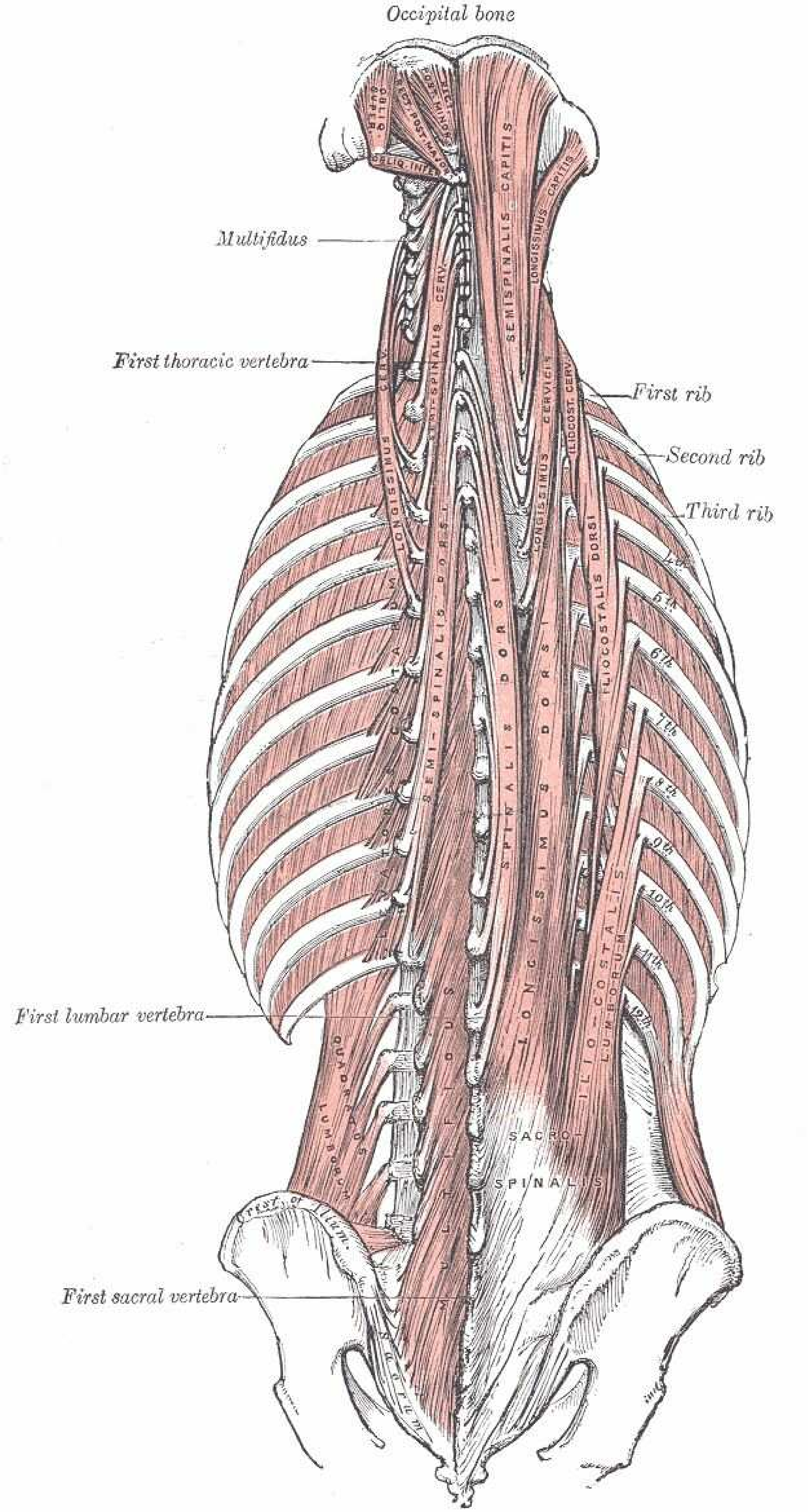


Fig. 5 : Posterior view of the spinal column (from Gray's Anatomy)



ASSESSMENT AND REHABILITATION PROTOCOL

Description of cranio-cervical flexion test (CCFT) and exercises :

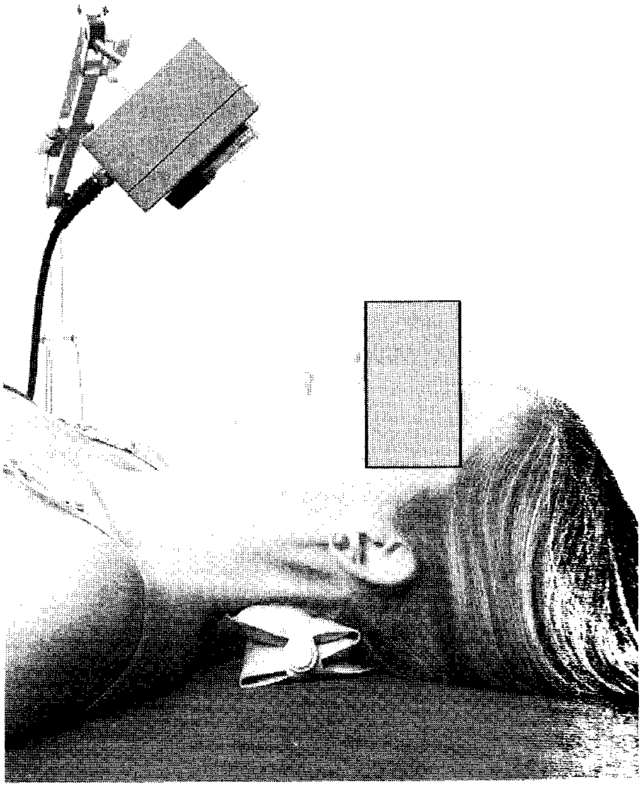
The CCFT assess the function of the deep cervical flexor muscles. It specifically aims to examine the anatomical action of longus capitis in synergy with longus colli, rather than that of sternocleidomastoid (SCM) and anterior scalene muscles, which flex the neck but not the head (Jull 2002).

The test consists of an increasingly inner range cranio-cervical flexion which the subject performs in five progressive increments in the supine position. The patient is helped by the use of feedback from a pressure unit (Stabilizer, Chatternooga, USA) positioned behind the neck which guides the progressive flattening of the cervical lordosis performed by longus colli (Cholewicki).

The subjects are positioned in crook lying with a padded head support which consisted of a force measuring device. The subjects' cranio-cervical and cervical spine are placed in a mid-position with the forehead and chin in a horizontal line and the tragus of the ear in line with the neck longitudinally so that it lies parallel with the plinth.

The force measuring device comprises of a pressure sensor placed between the resting surface and the back of the neck and is pre-inflated to a baseline of 20 mmHg. Each subject is required to perform progressive repetitions of cranio-cervical flexion and to increase the pressure by 2 mmHg for 5 times; i.e. from 22 mmHg to 30 mmHg. Each target pressure is maintained for 5 – 10 seconds with a rest usually of 10 seconds between each position. Through a connection between the pressure sensor and a transducer the electrical signals can be amplified and relayed to a visual feedback device and to a data acquisition device. The feedback device consists of an electronic voltmeter with markings from 20 to 30 mmHg at 2 mmHg intervals and calibrated to show the pressure in the pressure bag due to the pressure transducer output. The mean pressure of each of the five test levels can then be calculated.

Fig. 6 : Cranio-Cervical Flexion Test Position and Apparatus



ARTICLES PUBLISHED WHICH REVIEW THE EFFICACY OF THE CCFT AND EXERCISES :

A prospective multi centre unblinded treatment and blinded outcome assessment for a treatment period of 6 weeks with follow-up at 3, 6 and 12 months was carried out (Jull 2002). Aim of this RCT was to determine the effectiveness of manipulative therapy and low load exercises for cervicogenic headache when used alone, in combination and in comparison with a control group in both the short and long term.

Methods :

The 200 participants, between 18 and 60 years of age, had either unilateral or predominant unilateral side-consistent headache with neck pain worsened by neck postures or movement, local tenderness on palpation of at least one upper cervical joint and at least one headache per week for a period of 2 months to 10 years. The subjects were excluded if they presented with bilateral symptoms, migraine type features, conditions contraindicated for manipulative therapy, if they were involved in litigation or workers' compensation or if they had received physiotherapy or chiropractic intervention during the previous 12 months. After screening for these inclusion and exclusion criteria they were further screened at the trial centres. Those eligible were then assessed by independent examiners and underwent a physical examination to establish eligibility. All participants had a radiograph of the cervical spine for precautionary reasons.

The manipulative therapy was that described by Maitland (Maitland 2000), including both mobilisation and manipulation techniques indicated by the assessment and at the practitioners discretion.

The therapeutic exercise therapy used was a programme of low-load endurance exercises to train muscle control (rather than strengthen the muscles) of the cervicoscapular area, including the craniocervical flexion exercises described previously specifically for the deep flexors, longus colli and capitis.

All participants continued their usual medication and a headache diary monitored intake before, during and after the treatment period.

Both forms of active treatment were allowed the same amount of time, number of sessions and were given by experienced physiotherapists.

The 200 subjects included in the study were randomised into 4 different groups :

1. manipulative therapy (no. = 51);
2. exercise therapy (no. = 52);
3. manipulative and exercise therapy combined (no. = 49);
4. control (no. = 48)

The control group received no form of physical treatment.

<u>The outcomes measures were changes</u> :

1. in headache frequency;
2. in intensity;
3. in duration;
4. in the Northwick Park Neck Pain Index;
5. in medication intake;
6. in patient satisfaction;
7. in pain on neck movement;
8. in upper cervical joint tenderness;
9. in the craniocervical flexion muscle test;
10. in the assessment of head posture using a photograph.

The physical tests and the measurements were taken at baseline, the week immediately after the end of the treatment, at 3, 6 and 12 months after conclusion of the intervention.

<u>Results</u> :

The following table shows the subject distribution, the numbers at follow up for each group and the number of the subjects that completed the trial.

Table 3 : Numbers of subjects in each group including numbers at follow up intervals and on completion.

Followed up at	Manipulation	Exercise	Manipulation + Ex	Control	Completed
Week 7	49	51	49	46	195
Month 3	49	51	49	46	195
Month 6	48	51	48	46	193
Month 12	48	51	48	46	193
Completed	48	51	48	46	193

At baseline there were no differences in either the headache or the demographic characteristics between the four groups. The drop out at follow-up was 3.5%. Immediately after treatment and at the 12 month follow-up both the manipulative group and the exercise group had a significant reduction in frequency and intensity of their headache and neck pain ($P<0.05$). The combined therapy was effective on headache duration, whereas the exercise treatment was no greater than the control group at completion of the treatment and at 12 months. The combined therapy group was not significantly superior to the single therapies however 10% more patients gained relief with the combination therapy. The effect was maintained, effect sizes were at least moderate and clinically relevant. In the treatment groups 76% obtained at least a 50% reduction in headache frequency, 35% gained total relief, as shown in table 4.

Table 4 : Proportion of subjects gaining reduction in headache frequency immediately after treatment (week 7)

Treatment group	50% reduction	100% reduction
MT & ExT	0.81	0.42
MT	0.71	0.33
ExT	0.76	0.31
Control	0.29	0.04
MT = Manipulative Therapy ExT = Exercise Therapy		

Medication intake was reduced in all intervention groups when comparing baseline with the 12 month follow up : by 100% for the manual therapy and exercise groups, by 93% in the combined group. The control group by contrast, increased intake by 33% therefore showing a significant difference ($P < 0.05$). Pain on palpation was also significantly different in the intervention groups immediately after treatment ($P<0.05$). The forward head posture did not change over the trial period.

Conclusion :

Manipulative therapy and exercise can reduce cervicogenic headache symptoms and the effects are also maintained. However there was no statistically significant evidence that the combined therapies are superior to the single treatment interventions. Reduction in headache frequency was also clinically relevant. All the treatments were effective on the physical outcomes except for the head posture. The manipulative therapy group failed to improve performance of the CCFT, indicating that there is not spontaneous recovery of the muscle action after relief of symptoms. 10% more participants in the combined therapy group obtained either good or excellent results indicating that this is the most effective treatment for cervicogenic headache.

In a study the relationship between cranio-cervical flexion range of motion and pressure change during the cranio-cervical flexion test was examined (Falla 2003b).The amount of cranio-cervical flexion (CCF) or sagittal angular displacement was measured in the five different positions of range of motion in the cranio-cervical flexion test (CCFT). The aim of the investigation was to quantify the angle of cranio-cervical flexion in 5 different stages of this head nod, with a specific gradual increase in the range of motion (ROM). Also the aim was to establish if a relationship exists between the ROM of cranio-cervical flexion and the pressure changes during the CCFT. It was hypothesised that favourable results of the study would not only increase the understanding of the test but also improve its practical application. A digital imaging method was used to measure this ROM in 20 healthy volunteers. The method used to measure the amount of movement was also examined to assess its reliability in both intra- and inter-rater assessment. The subjects were 12 male and 8 female aged between 18 and 44 with no present or past history of cervical or upper thoracic pain. Further exclusion criteria were limited ROM or tightness in the extensor muscles and if they were unable to perform the CCFT correctly.

The instrument used to measure the pressure was a Pressure Biofeedback Unit (PBU) consisting of an inflatable air-filled pressure sensor placed behind the subject's neck as described above. The PBU was inflated to a baseline pressure of 20 mmHg, filling the gap between the resting surface and the subject's neck, and the test was performed with the head nodding movement from 20 mmHg to 30 mmHg. As a previous study (Jull 1993) had demonstrated the linear relationship between the output and load on the pressure sensor in the lumbar spine, the present study was carried out in order to measure and record similar results in the cervical spine using a pressure transducer connected to the PBU. Electrical signals from the transducer were amplified and relayed to a visual feedback device and to an integrated amplifier, an analogue to digital converter and a storage system. The visual feedback device consisted of an electronic voltmeter with 2 mmHg increments marked from 20 to 30 mmHg. It was also calibrated to display the pressure in the PBU by basing it on the output of the pressure transducer. Sampling frequency for pressure measures was 1000Hz.

A digital camera and custom designed analytical software were used to measure the head nodding displacement during the CCFT. This method has been demonstrated to provide highly accurate results (Yang 2001). In order to standardise the process a constant distance and camera zoom were used, as well as standard anatomical references for the position of the markers.

The subjects were positioned in crook lying with a padded head support, which consisted of the force measuring device. The subjects' cranio-cervical and cervical spine were placed in a mid-position with the forehead and chin in a horizontal line and the tragus of the ear in line with the neck longitudinally so that it lay in parallel with the plinth.

After practicing the CCFT a photograph was taken in the starting position and in the 5 subsequent positions which were maintained for 10 seconds, but an interval of 15 seconds in the starting position was given between each contraction. Each subject was tested in one session but the procedure was repeated 3 times with a rest of 5 minutes between each test.

The intra and inter-tester repeatability of the digital imaging method for the assessment of the absolute angles of sagittal head displacement during each stage of the CCFT were measured. Four testers processed the photographs of each subject's first trial and was repeated by each tester three times randomly to assess the intra-tester reliability.

Results :

Both the intra-rater and inter-rater reliability of the digital imaging method in assessing the absolute cranio-cervical flexion ROM angles were found to be very high using the intraclass correlation coefficient (0.994 and 0.988-0.998 respectively). This indicates that consistent measurements of the head angle are possible despite the fact that these angles are very small.

A repeated measures analysis of variance (ANOVA) showed a significantly greater amount of cranio-cervical flexion ROM to obtain each stage of the CCFT. The relationship between these two was also demonstrated to be predominantly linear. Thus it would seem that if performed correctly an increasing amount of cranio-cervical flexion is required for the five stages of the test indicating that the deep neck flexors increase their contractile effort. The linear increments of each stage of the test implies that a progressive increase of the ROM during the CCFT should be observed by the clinician, whereas if it appears that the spine remains static or the ROM decreases it would imply that the movement pattern is not correct. In fact cranio-cervical flexion is often incorrectly substituted by neck retraction and should be discouraged. Due to the excellent levels of reliability found in this study, support for both the suitability of this technique when assessing cranio-cervical flexion range of motion, as well as the effectiveness of the exercise regime are confirmed.

The purpose of another study was to determine the amount of muscle activity in the deep cervical flexor muscles (DCF) using electromyography (Falla 2003c). It evaluated the signals of the DCF, but also sternocleidomastoid (SCM) and anterior scalene (AS) muscles during the cranio-cervical flexion test (CCFT). The authors retain that the most important muscles in the control system of the head and neck are the DCF muscles due to their morphological design which provides support to the cervical lordosis and to the cervical joints. Muscle activity of these deep muscles is required to stabilise the joints in the mid range postures, which are commonly used in working positions. Although these stabilising muscles have been studied using other techniques such as imaging, computer modelling or histological analyses, there have been few attempts of studying these muscles using EMG. This is mainly due to the difficulty of getting a direct measurement, as the longus colli and longus capitis muscles are difficult to access. Indwelling fine wire electrodes had been used previously but had only been used in subjects without any known pathology or impairment. This technique is not readily applied as it is considered inappropriate due to the fact that it is highly invasive and due to the proximity of a number of delicate structures, as well as being difficult to perform.

Thus the authors devised a method whereby a direct measurement of the DCF muscles was obtainable. The apparatus consists of electrode contacts attached to a suction catheter which was placed on the oropharyngeal wall through a nasopharyngeal tube. Posterior to the oropharyngeal wall lie the deep neck flexor muscles, providing the proximity necessary to record the contractions, without inserting intramuscular recorders.

This technique was used to record the role of the DCF muscles whilst performing the CCFT. The test is as described in detail previously, using the same 5 stages of increasing ROM. The authors believed that during the test the muscles would demonstrate an increasing effort, thus an increasing EMG amplitude would be recorded. This was the aim of the study, as well as assessing the reliability of the EMG measurements from the DCF muscles. It was thought that a reliable direct measurement of these muscles, would enable further research to assess the impairment in the muscles, which is thought to be present in people with neck pain.

Subjects :

10 volunteers between the ages of 21 and 53, with no history of neck disorders of both orthopaedic and neurological origin and no neck pain at the time of the study, gave informed consent. They were excluded if they had contraindications and/or precautions for the local anaesthetic used and also for the nasopharyngeal suction method used.

Method :

The custom made apparatus used bipolar electrodes which were inserted through the nose using a suction catheter to position them on the posterior oropharyngeal wall. The catheter was positioned and fixed to the mucosa by a suction pressure of 30 mmHg, at the level of the uvula, which corresponds to the C2-3 intervertebral disc level, where the greatest cross-sectional area of the longus colli muscle lies. Measurements were taken on the left side of the DCF muscles.

Measurements were also made of the sternal head of the sternocleidomastoid and anterior scalene muscles using bipolar surface electrodes positioned on both sides. The electrodes were carefully positioned after the necessary cleaning and skin preparation.

The 1-second maximum root mean square (1sRMS) was calculated using a custom-designed software programme which enabled measurement of the EMG signal amplitude. A voluntary contraction of cranio-cervical flexion (CCF) and cervical flexion was to reflect the action of the deep and superficial neck flexors separately. A standard supine position was used and the 1sRMS values were obtained and normalised by a percentage value of the reference voluntary contraction of both groups of muscles.

The CCF test with its 5 incremental stages of cranio-cervical flexion was performed on an air-filled pressure sensor positioned at the sub occipital area to guide the subject with visual feedback. The gentle nodding action was increased by 2 mmHg at each of the 5 incremental stages, starting at 22 mmHg and finishing at 30 mmHg. The measurements were made by connecting the pressure bag and pump to a pressure transducer. The signals were relayed to a device which amplified, converted and stored the information received from the pressure transducer. The visual feedback device consisted of a voltmeter which showed the pressure calibrations and enabled the 5 incremental stages to be read. The pressure traces were reviewed to ensure that each subject obtained the target and that the pressure was maintained for the duration of the recording.

A lateral photograph taken with a digital camera was used to obtain the measurement of the range of CCF at each stage of the test. Custom designed analytical software was also used for the angle measurements, a method which has shown to have a high level of reliability (Yang 2001).

Procedure :

The standardised starting position was used as described previously and the pressure biofeedback unit was positioned at the suboccipital area of the subjects' neck. The baseline pressure was 20 mmHg. Instruction on how to carry out the CCF test was given, then practiced by the subjects and checked for correct performance. The digital camera was placed at a standard distance and the markers fixed. Surface electrodes were positioned on the SCM and AS muscles and the electrode introduced under local anaesthetic and placed in such a way to ensure correct positioning in relationship to the fibres of the DCF muscles. Suction was then applied to maintain the electrode in contact with the mucosa.

Each subject carried out the combined movement of CCF and also cervical flexion so that the head just cleared the plinth and was maintained for 10 seconds. It was repeated twice, with a 30 second rest between the two tests, and the movement with the highest score was used for the reference 1sRMS value. The subjects then performed the 5 stages of the CCF test from 22 to 30 mmHg maintaining each position for 10 seconds. A rest of 30 seconds between each contraction was given when the head and neck position was checked.

Reliability :

The reliability of the test and the positioning of the EMG electrodes and their measurements had been established through previous work (Falla 2002 and 2003b).

Analysis :

Increasing CCF ROM should demonstrate increasing EMG amplitude of the DCF muscles with the increasing effort required. Therefore it was determined whether there was a relationship between the amplitude of the muscle activity and the 5 stages of the CCF test. An analysis was also conducted to see if there were differences between normalised 1sRMS values for each muscle at the different stages of the test and in the EMG amplitude at each stage.

The range of CCF was calculated and the ROM expressed as a percentage of the full range. The relationship between the range of upper cervical flexion and normalised 1sRMS from each of the 3 muscles was calculated.

Results :

The results showed a positive linear relationship between the normalised 1sRMS and the incremental stages of the CCF test. The AS and SCM muscles also showed a linear relationship between the normalised 1sRMS and test level. Increases in normalised 1sRMS of the DCF muscles were identified among the 5 stages of the CCF test and differences in the normalised 1sRMS for both the AS and SCM muscles over the stages of the test were also found from the 24 mmHg to the 30 mmHg stages.

Table 5 : Ranges of the normalized root-mean-square values for the deep cervical flexors, sternocleidomastoid and anterior scalene muscles at each pressure level of the cranio-cervical flexion test

Muscle	**22 mmHg Range**	**24 mmHg Range**	**26 mmHg Range**	**28 mmHg Range**	**30 mmHg Range**
Deep Cervical Flexors	19.76-60.88	30.31-63.89	32.28-73.24	37.09-82.22	41.87-98.77
Sternocleidomastoid	3.76-36.66	5.56-39.18	8.57-59.49	10.78-69.02	14.69-92.53
Anterior Scalene	5.24-37.09	5.52-39.78	6.29-58.49	13.67-64.15	13.74-74.16

The range increased with each incremental stage of CCF and so a positive relationship between the increasing angle of CCF and increasing EMG amplitude in both the deep and superficial neck flexors was demonstrated. The intraclass correlation coefficient results and those of normalised 1sRMS values obtained from the DCF muscles showed low values of the within-subject normalised SEM for the normalised 1sRMS values of the DCF muscle, proving the high reliability of these variables (Table 6).

Table 6 : Reliablility of normalised 1-second Root-mean-square values for the left deep cervical flexor muscles during the 5 stages of the CCFT

Stage of CCF Test (mmHg)	Variance due to subjects	Variance due to days	Variance due to trials	Within-subject n-SEM	Between-subject n-SEM
22	21.8	12.3	65.9	10.3	8.3
24	14.1	54.8	31.1	8.9	7.2
26	39.3	28.3	32.4	8.8	9.8
28	63.1	14.9	22.0	7.0	11.1
30	59.8	22.6	17.6	6.7	10.1

Discussion :

Although the DCF muscles have been investigated in various ways there has never been a direct attempt to measure their activity due to the difficulty of an effective and safe method of doing so. The method described in this study enabled the authors to carry out a direct measuring system of the activity of the DCF muscles with limited risks by recording EMG signals during the CCF test. A strong positive linear relationship was found between the normalised 1sRMS for the DCF, SCM and AS muscles and the progressive stages of the CCF test, although the number of subjects was small. In fact an increase of EMG activity was revealed at each stage of the test showing a relationship with the increased ROM of the anatomical action of these muscles. An increase in the normalised 1sRMS of the DCF muscles was also identified during the test. The superficial flexors (SCM and AS) only demonstrated an increase of EMG activity during the first 2 stages of the test (22 mmHg and 24 mmHg) with no change in magnitude but continued during the further stages of the test. Thus showing that the DCF test assesses both the deep and superficial flexor muscles of the neck.

The study also demonstrated a progressive increase in ROM of CCF during each stage of the test which correlates with increase in EMG amplitude for the 3 muscles examined, especially for the DCF muscles. However there is a possibility that the method used was not specific for the muscles being tested and the authors recognise the possibility of some cross talk from other muscles, although think it unlikely. The use of the suction technique reduces the risk of poor results due to movement of the electrode, was well tolerated and caused no side effects in all subjects.

Reliability :

The values of the normalised 1sRMS during the 5 stages of the test demonstrated reliability. In fact the low values obtained for the between- and within-subject variability for the 1sRMS values of the DCF muscles showed high repeatable precision. Furthermore, as there was little variation in the normalised 1sRMS across subjects and trials, it might imply that the method used may not be able to determine different muscle properties in uniform groups (non symptomatic subjects). Further research is required to determine the use of the method between symptomatic and non symptomatic subjects.

Conclusion :

The method described shows a way to measure EMG activity in the DCF muscles but further research using the same method is indicated to establish the possibility of cross talk from other muscles in the area. However it is a promising technique which should enable further examination of the DCF muscles and help understand the impairment shown in CCF in patients with neck pain of different origins.

The aim of a study on impairment in the cervical flexors in patients with neck pain of insidious onset or following whiplash, was to examine neck flexor synergy when carrying out the cranio-cervical flexion test (Jull 2004). The study also aimed to examine whether there was a difference in the nature of the physical impairment in symptomatic whiplash (WAD) patients in comparison with those with pain of insidious origin.

Other studies have examined the change in cervical flexor muscle function in patients with neck disorders of both whiplash and insidious origins as opposed to asymptomatic subjects (Aker, Cote, Grauer). Furthermore an imbalance between the neck flexors and extensors showed that the former became weaker in comparison with the latter, especially in subjects with WAD (Vernon 1992).

The results of previous studies have also shown that subjects with cervicogenic headache (Jull 1999) and those with WAD (Jull 2000) are less able to carry out the test successfully as compared to healthy subjects, implying a dysfunction of these muscles in these particular patient categories. It has also been shown through the use of electromyography that in WAD patients (Jull 2000) and in chronic neck pain patients (Sterling 2001) there was increased activity in the superficial neck flexor sternocleidomastoid during the CCFT, which could indicate poor activation of longus colli and reduced segmental stability.

This study examined the comparison of performance of the CCFT between patients with neck pain both from WAD and insidious origin as there had not been a previous study comparing these two patient groups.

<u>Subjects</u> :

There were seventy-five volunteers ranging between 18 and 66 years of age and they were divided into three groups of 25 subjects each. Group 1 were the control subjects, Group 2 had insidious onset neck pain and Group 3 were those with WAD. Inclusion criteria for Group 1 was no present or history of musculoskeletal pain or injury in the neck or upper limb. Group 2 subjects were included as long as the cause of their symptoms was not traumatic from a motor vehicle accident. Group 3 were attending a Whiplash Research Unit. Exclusion criteria for Groups 2 and 3 were history of neck surgery, previous disease of the neck or throat, disorders of neurological or rheumatic origin. The length of history of neck pain and visual analogue scale (VAS) of the average pain intensity was also recorded for Groups 2 and 3.

Cranio-Cervical Flexion Test :

The subjects carried out cranio-cervical flexion as described above in the supine position but each position was held for only 5 seconds with a rest of 10 seconds between each increased target position. A pressure sensor was connected to a pressure transducer and a recording device so that the mean pressure over the 5 seconds of holding time could be calculated in order to determine if each subject obtained the prescribed level of pressure. This enabled the differences between the mean pressure obtained and the nominated target pressure for each stage of the test to be calculated for each group.

Myoelectric signals were also collected from the Sternocleidomastoid (SCM) muscles using electrodes positioned along the muscle bellies and devices used to calculate the maximum root mean squared (RMS) value which were normalised for each subject and the data for both the right and left muscles were averaged for analysis.

Each subject not only carried out the CCFT but was first required to perform a head lift by tucking in the chin and lifting the head to just clear the bed whilst a 10 second recording was made for the normalising procedure.

Results :

There were no obvious differences between the different groups concerning their demographic details and VAS scores, whereas the insidious origin of neck pain group had a considerable longer history of symptoms in comparison with the WAD group. There were significant differences for the SCM normalised RMS value between the groups *($P=0.001$)* and stages of the test *($P=0.001$)*. Also a strong linear relationship between SCM normalised RMS values and stages of the CCFT, although the relationship levelled off at the highest pressure target in the whiplash group. Both the symptomatic groups had significantly higher SCM normalised RMS values than the control group at each level of the CCFT *(all $P<0.05$)*. There were no significant differences between the neck pain and whiplash groups at each stage of the test, except for the 22 mmHg stage *($P=0.02$)*.

Although dysfunction in the neck flexor muscles has been found to be present in both insidious neck pain and whiplash it was unclear if there was a difference between the groups which could be important in the treatment of the different categories. This study did not reveal a significant difference between the symptomatic groups for the impairment of the SCM and could not explain the slower recovery of the WAD group often seen in comparison with insidious onset of neck pain.

It is hypothesised that due to the increased action of the superficial flexor muscle (SCM) that it was recruited to stabilise the neck as the demand for further contraction of the deep flexor longus capitis increased with the different levels of cranio-cervical flexion. This would indicate an altered pattern of coordination between the two muscle groups in patients with neck pain, and the higher activity may be due to the poor active contractile capacity of the two deep muscles. However this study was unable to show this due to the technique used as longus colli and capitis were too deep to register their activity effectively.

The different results between the pressure target and that attained by the groups in this study showed that the control group was able to perform and control the head nodding accurately. The two symptomatic groups on the other hand were unable to carry out the task with such accuracy in each stage of the test. This again would imply that longus colli had poorer contractive control of flattening of the cervical curve. This was particularly apparent in the last three levels of the CCFT. The WAD group had the most difficulty at the 30 mmHg level and indicated that they were unable to achieve the necessary contractile capacity. These results show that neck pain patients of both traumatic and insidious onset, have difficulty in attaining the graded pressure targets and they also demonstrate increased normalised RMS values in the SCM, implying an impairment in neck flexor synergy. However the difference in time of onset of the symptoms does not appear to be important. Furthermore the altered patterns in muscle coordination in patients with both causes of neck pain are evident in the CCFT and that the physical impairment is similar in the two groups and does not account for the slower response to improvement in the rehabilitation of whiplash patients.

A further study on the motor function of patients with acute whiplash-associated disorders used the CCFT (Sterling 2004). However although this study used the CCFT it only assessed the function of the superficial and not the deep cervical flexors for which the test was principally designed. The CCFT was only a component of the assessment of motor function in the study, and also examined the sensory function and psychological distress in these subjects. It also compared their levels of pain and disability, which are important factors in this patient category. Patients with chronic whiplash associated disorders (WAD) are known to have high levels of dysfunction and psychological distress but not much is known about these components in acute WAD patients. It has been shown that higher levels of pain and disability are indications for poor outcome in these patients therefore it is important to establish further components of the disorders to establish the effective treatment for a better prognosis.

The motor function was assessed using the cervical range of movement, joint position error and the CCFT, as described previously but only the superficial neck flexors (Sternocleidomastoid right and left) using surface electrode EMG.

80 whiplash patients (Quebec Task Force WAD II and III) were included in the study within 1 month of injury. There were 20 healthy asymptomatic control subjects.

Results :

Although 3 subgroups were identified through analysis of the Neck Disability Index : mild, moderate and severe pain and disability, only the moderate and severe groups showed reduced joint position error and sensory function changes.

All the WAD patients showed reduced ROM and increased EMG levels (all $P < 0.01$) However interestingly the measures of psychological distress did not have an impact on between group differences in motor or sensory tests.

In a similar study the same author looked at altered patterns of muscle recruitment in WAD patients one month after injury. The CCFT was used but again it examined the increased activity in the superficial flexor muscles. The altered patterns in the recruitment of the superficial cervical flexors persisted to the 6 month follow up even in those patients who reported full recovery. This would imply that there is no spontaneous recovery to normal motor function, and this dysfunction could be one of the factors contributing to symptom recurrence.

In a study which examined the complexity of muscle impairment of the cervical flexor muscles in patients with chronic neck pain using electromyography, deficits in the motor control of the deep and superficial cervical flexor muscles in these subjects was identified (Falla 2004a). In fact a delay in onset of neck muscle contraction with movement of the upper limb was also demonstrated. This deficit consisted in an altered pattern of muscle activation where the deep muscles showed reduced activity in a low load cognitive task and an increase of the superficial muscles in both cognitive tasks and functional activities.

The application of surface EMG has been developed to obtain the application to both the superficial and deep cervical flexors with a direct measurement and consequently improved results.

The methodology was developed and applied to neck pain patients to investigate the cervical flexor muscle function in 3 areas of EMG assessment :

1. myoelectric manifestations of cervical muscle fatigue;
2. analysis of cervical flexor muscle activation patterns;
3. analysis of cervical motor control.

This paper presents these results which demonstrate the complexity of cervical muscle impairment in patients with neck pain and thus also gives indication to the optimal rehabilitation in this patient category .

Fatigue in cervical muscles :

EMG has been technologically developed to provide a more sophisticated method of measuring the fatigue in the cervical muscles of neck pain patients. The fatigability of Sternocleidomastoid (SCM) and Anterior Scalene (AS) muscles during sustained cervical flexion contractions was examined at both 25% and 50% of the maximum voluntary contractions (MCV) of chronic neck pain patients and a control group (Falla 2003a). The neck pain group demonstrated greater myoelectric manifestations of muscle fatigue in these two muscles at both levels, showing reduced endurance at both moderate (50% MCV) but also low load (25% MCV) sustained contractions. An increase of the mean frequency was also found at the beginning of the contraction for both muscles in the symptomatic group. The results suggested a predominance of type-II fibres in the neck pain patients which is in agreement with biopsy studies where slow-twitch type-I fibres have been shown to transform into fast-twitch type-IIB fibres in subjects with neck pain (Uhlig 1995). This could be due to modification of the recruited motor unit pool in which there is an increase of the type II fibres with respect to the type I fibres. Consequently in a further study the specificity of this abnormal muscle function was assessed (Falla 2004e). Differences in the fatigability of the SCM and AS muscles on the painful and non painful sides in patients with unilateral neck pain were examined using EMG and revealed, indicating that therapeutic exercise should address this difference when treating chronic neck pain patients. However the duration of symptoms does not seem to be relevant for the extent of the muscle fatigability which would suggest that it occurs early with the onset of pain and does not worsen with time (Falla 2004f).

The deep cervical flexor (DCF) muscles (longus colli, longus capitis, rectus capitis anterior and rectus capitis lateralis) are both histologically and morphologically designed to give support to the cervical lordosis and the cervical joints, hence the research into the deficits in these muscles in patients with neck pain.

The CCFT was performed by patients with and without chronic neck pain whist using a new EMG technique capable of obtaining a direct recording of DCF muscle activity. Results showed reduced activation of the DCF muscles in all stages of the test, especially in the later stages for the neck pain group. A reduced range of cranio-cervical flexion was also found in all stages of the test in this group. These results confirmed that there was a disturbance in neck flexor synergy, where an impairment of the deep muscles caused a compensatory increase in the superficial muscle activity.

Neuromuscular efficiency :

Increased EMG activity of the superficial neck flexors can be considered an inefficient neuromuscular activation pattern. Investigating the neuromuscular efficiency (NME) of the superficial muscles during the CCFT showed less NME in the SCM and AS muscles in the neck pain group. Greater muscle activity was shown to produce the same force or the same amount of electrical activity produced less force (Falla 2004b). This could be due to:

1. increased excitability of the motorneurone pool;
2. modification of neural activation patterns accommodating for weakness or inhibition of another muscle;
3. a combination of these two mechanisms.

Muscular activation during functional tasks :

The same investigation was carried out in the SNF muscles during functional tasks in neck pain patients. The task was a repetitive unilateral task where the subjects were required to mark three targets which were positioned on a desk in front of them, using the right hand whilst the left hand remained still, resting on the desk. A previous study (Nederhand 2000) had already shown increased activity of trapezius during this task and reduced relaxation on completion of the task in neck pain patients compared with controls. An altered pattern of muscle activation was found in both idiopathic neck pain and whiplash patients, with increased EMG amplitude for the superficial neck flexor muscles bilaterally, both during and on completion of the task. This could perhaps be due to an altered motor strategy to decrease activation of painful muscles.

During postural disturbances :

Neck muscles are usually co-activated within 50 ms of onset of deltoid activity during rapid arm movements. These responses are considered to be pre-planned by the nervous system and are called “feed forward” adjustments. Delayed onset of the timing in DCF and SCF muscles in people with neck pain in comparison with a control group was confirmed. The most significant deviation shown was in the DCF muscles during rapid shoulder flexion, although all of the neck muscles demonstrated some differences in onset time between groups. Therefore a significant deficit in automatic feed forward control of the cervical spine was found. As these muscles are fundamental for the cervical lordosis and the cervical joints it would imply that consequently a change in the feed forward response might leave the cervical spine susceptible to injury (Falla 2004d).

Results and implications for rehabilitation :

These studies have thus shown that patients with chronic neck pain have:

1. impairment in the deep cervical flexors;
2. deficit in muscle co-ordination;
3. insufficiency in pre-programmed activation;
4. inefficient neuromuscular activation;
5. great fatigability of the superficial cervical muscles.

Therefore there is a need for specificity in prescribing therapeutic exercises for neck pain patients. Deficits in the motor system early in onset of neck pain (Sterling 2003) does not resolve automatically with reduced symptoms or resolution of the problem. Advanced understanding of impairments of the deep and superficial neck flexors with neck pain patients provides the foundations to develop specific exercises for these conditions and indications for the rehabilitation of this patient category.

Another study demonstrated reduced EMG activity in neck pain patients.

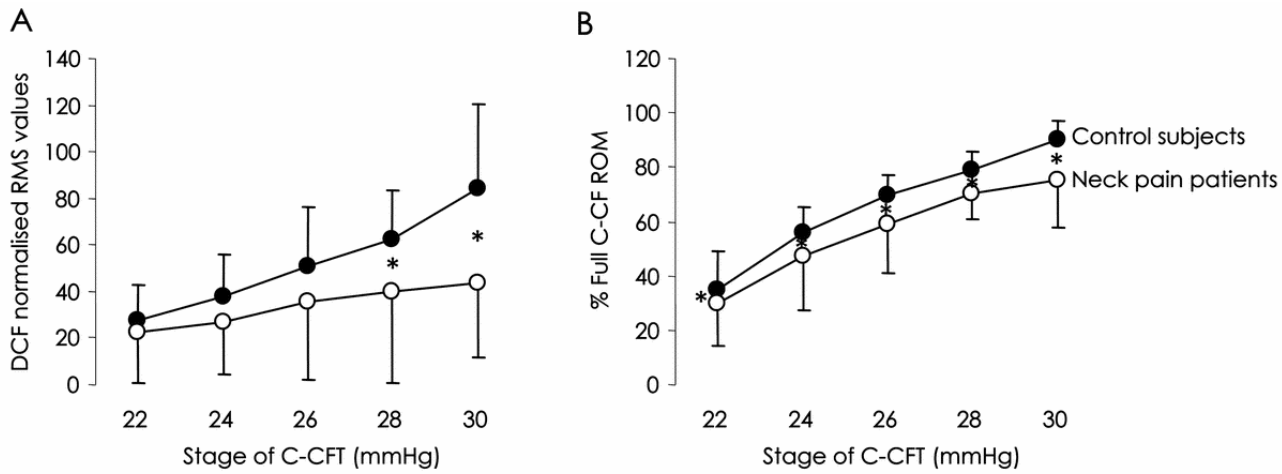
The purpose of this study was to compare the deep and superficial cervical flexor muscle activity during the CCFT as in the previous studies, but to establish the difference between a control group and in patients with chronic neck pain (Falla 2004c).

Subjects :

Ten patients with a history of chronic neck pain of more than 1 year, between the age of 19 and 46 years, were compared with ten control subjects. Three of the patients had whiplash associated disorders whereas the remaining seven had neck pain of

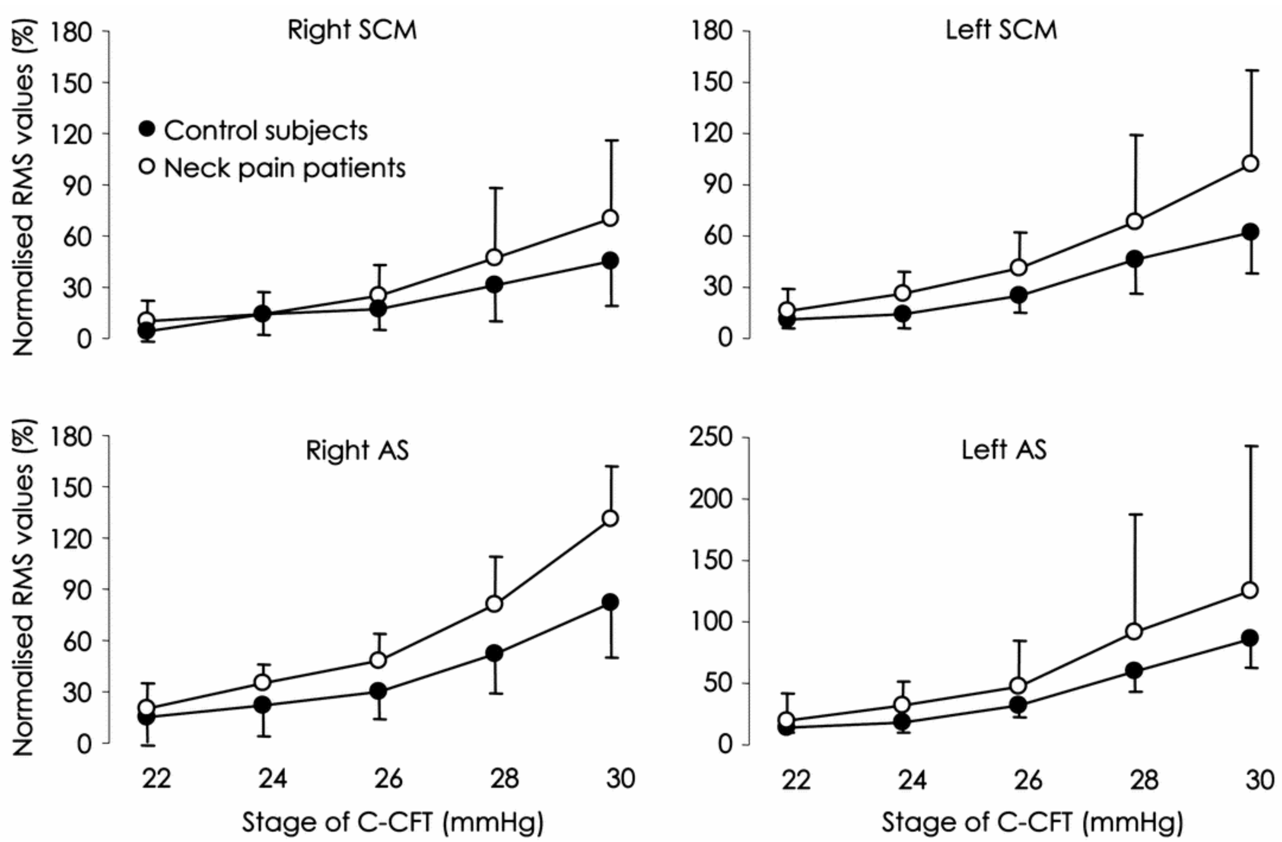
idiopathic origin. All ten patients complained of headache, three had arm pain and six also reported associated lumbar or thoracic symptoms. The exclusion criteria was previous surgery, neurological symptoms, involvement in a neck exercise programme in the previous 12 months or under treatment at the time of the study. The ten asymptomatic patients were between the age of 21 and 36 years with no neck pain or history of orthopaedic or neurological disorders affecting the cervical spine.
All subjects were examined to confirm the presence or absence of cervical spine dysfunction or neck pain before proceeding to the study. The patient group completed the neck pain disability index and indicated the VAS for average intensity of pain.
Electromyography :
The apparatus used was the same as described previously with the electrode and suction catheter being inserted via the nose to the oropharyngeal wall for optimal location to register the muscle activity. Surface electrodes were used to measure the EMG activity of sternocleidomastoid and the anterior scalene muscles and a ground reference positioned over C7 spinous process.
Procedure :
Both the position of the patients and subjects was that used in the previous studies and the feedback was obtained using the same pressure sensor and transducer to record the pressure increase during the CCFT as described above. The same normalising procedure for the EMG amplitude was also used, as was the standardised measuring procedure, shown to have a high level of reliability (Yang 2001). The inter-rater and intra-rater reliability of the method used and described above, has been found to be excellent (Falla 2003b).
Results : Analysis of the data and statistics gave the following results, as shown in Fig. 6) :

Fig. 6 : Group data for deep cervical flexor muscle EMG activity. A: normalised RMS values (mean and standard deviation), B: percentage of full cranio-cervical flexion test, * indicates significant difference between control group and neck pain patients



1. a linear increase of the pressure in deep cervical flexor EMG amplitude in the control group;
2. a linear increase of less pressure in the patient group indicating a smaller increase during the stages of the test (*P=0.002*);
3. control subjects demonstrated a trend for greater normalised 1-second RMS values during the test, especially at the higher stages of 28 and 30 mmHG (*P<0.05);*
4. both groups demonstrated a non linear, quadratic correlation in the relative range and the different stages of the test, with the control group obtaining a significant greater ROM (*P<0.05*);
5. the patient group showed a trend of increased EMG activity in the superficial neck flexors in each stage of the test compared with the control group (Fig. 7).

Fig. 7 : Group data for superficial neck flexor muscle activity. Normalised RMS values for the right and left sternocleidomastoid and anterior scalene muscles for each stage of the CCFT. Although not statistically significant, patients with neck pain consistently demonstrate greater RMS values for the superficial cervical flexor muscles across all stages of the test.



Therefore this study supports the hypothesis that :

A) decreased performance of the CCFT is related to impaired performance of the deep flexor muscles;

B) the patient subjects in this study show modified activity in these muscles;

C) the patient subjects in this study show a trend of increased activity in the superficial neck flexors.

Other considerations :

- Consistent with the results of previous studies;

- Cross talk from the superficial muscles is of minimal concern;
- The technique is shown to be accurate;
- However a small number of subjects reduce the strength of the results;
- The direct recordings from the deep muscles gives support to the hypotheses forwarded following studies on patients with idiopathic neck pain, WAD, acute and chronic neck pain (Jull 1999, 2000, 2002, Sterling 2003);
- Consistent with the results from studies on the lumbar spine (Hodges 1996, 1999, Sihvonen 1997).

Conclusion :

Although testing and retraining of the cervical spine stabilising muscles is widely used in patients with different neck pain conditions, efficacy of this specific exercise approach has only been established in patients with cervicogenic headache (Jull 2002). This study shows data supporting the hypothesis that poor performance of the test is due to impairment in the deep cervical flexors. Therefore investigation of the changes in the deep cervical flexors during performance of the rehabilitation protocol is needed in various types of neck pain syndromes.

Lower EMG amplitudes in the deep muscles were present with higher measurements in the superficial neck muscles, implying that neck pain patients use a different strategy to carry out the CCFT. However due to the limited number of subjects in the study, the differences in the superficial group of muscles was not consistently statically significant. Further studies are required to establish the reason for neck pain patients failing to obtain the pressure target in the stages of increased ROM during the CCFT.

The object of this RCT with single-blind outcome assessments was to evaluate the efficacy of a neck exercise programme in patients with chronic neck pain (Chiu 2004). The intervention used was both a dynamic strengthening programme together with the retraining of the deep cervical muscles for stabilisation of the neck (Jull 1999).

Subjects :

The subjects were Chinese and randomly allocated to either the exercise group (n.= 67) or the non exercise or control group (n.= 78).

The inclusion criteria were neck pain present for over 3 months, patients between 20 and 70 years of age, who could read Chinese. If previous trauma, an inflammatory disease, malignancy, congenital deformities, concurrent treatment, neurological deficit, lack of skin sensation, acute neck pain with reduced range of movement, manipulation or neck rehabilitation in the previous 6 months or injury at work were present, they were excluded. Computer-generated randomisation was used according to the minimisation method ensuring the smallest difference between the two groups. The control group received neck care advice and infrared radiation, whereas the exercise group also received the exercise programme for 6 weeks.

The outcome measures :

The outcome measures used were subjective pain and disability, as well as isometric neck strength at baseline, 6 weeks and 6 months. The disability score was obtained using the Chinese version of the Northwick Park Neck Pain Questionnaire and a verbal numerical pain scale between 0 and 10 (0=no pain, 10=worst pain), measurement of the peak isometric muscle strength in various directions of neck movement, as well as medication use, sick leave and patient satisfaction. A blinded independent assessor examined the subjects at baseline and at the follow up assessments.

Intervention :

The patients in the exercise group began with 10 minutes of activation of the deep neck muscles in order to improve control over active stabilisation. The supine position was used and the patient carried out the exercise with the use of the pressure sensor to monitor the action from 20 mmHg to an increase of the pressure without pushing the neck into lordosis. The position was maintained for 10 seconds and repeated for 10 minutes with a 15 second rest between each contraction, or until the patient was tired or unable to control the position, as revealed by the pressure sensor.

The dynamic component of the programme consisted of 15 repetitions of active flexion and extension using a Multi Cervical Rehabilitation Unit (MCRU) with the resistance initially at 20% of the peak isometric strength for warm up, and then set for training using a variable resistance to allow 8-12 repetitions, repeated 3 times within pain tolerance. Two weekly training sessions were carried out for a period of 6 weeks.

Infrared radiation was given to both groups using a standardised method, for 20 minutes to obtain superficial heating, twice a week for 6 weeks and was used as the control intervention.

Analysis :

Intention-to-treat statistical analysis was used to establish the difference between the two groups before and after intervention.

Results :

The dropout of the randomised 145 patients was similar in the two groups (Intervention group = 19, Control group = 17) for the same reasons : lack of time, dissatisfied with treatment, worsening of symptoms or other. No differences were noted between the intervention groups and the withdrawals in the neck disability scores, pain intensity or muscle strength. The baseline characteristics and mean values were also similar between the two intervention groups. No statistically significant differences were found prior to intervention between the two groups for the neck disability score ($P = 0.86$), pain intensity ($P = 0.28$) and isometric strength ($P = 0.10\text{-}0.98$).

Table 7 : Baseline characteristics of patients : age, gender, height, weight, pain history, education and exertion for the RCT

	Control	Exercise	*P**
No.	78	67	
Age (yr)			
Mean/SD	44.3/9.8	43.3/9.7	0.52
Range	21-64	23-59	
Gender (%)			
Male	33.3	28.4	0.30
Female	66.7	71.6	0.69
Height (cm)			
Mean/SD	159.6/8.9	159.2/11.6	0.85
Range	123-180	120-185	
Weight (kg)			
Mean/SD	59.1/9.1	59.3/11.1	0.91
Range	37.7-80	40-98	
Pain history (%)			
3-6 months	17.9	18.2	0.68
>6-12 months	16.5	25.8	0.35
>12 months	66.6	56.0	0.11
Education (%)			
Primary	28.,2	23.8	0.33
Secondary	57.7	55.2	0.38
Tertiary	14.1	21.0	0.55
Exertion (%)			
Static work	16.7	26.9	0.37
Minimal	44.9	41.8	0.38
Moderate	26.9	19.9	0.48
Heavy	6.4	7.4	1.00
N/A	5.1	4.0	1.00
Verbal numerical pain scale #			
Mean/SD	4.3/2.1	4.6/1.9	0.28
Disability score §			
Mean/SD	1.4/0.5	1.4/0.6	0.86
Strength (in 6 directions)			
Mean/SD	7.2-11.5/4.0-5.8	7.5-11.5/4.2-6.1	0.10-0.98

* *P* values of comparison of baseline characteristics

\# Verbal numerical pain scale: 0 (no pain) to 10 (worst pain)

§ Disability score was measured by the Chinese version of the Northwick Park Neck Pain Questionaire: 0(no pain) to 4 (worst pain)

At the 6 week follow up both groups had a significant difference in the disability score but the exercise group was significantly better than that of the control group (*P = 0.03*), as was the subjective pain score (*P = 0.01*) and isometric muscle strength (*P =0.57-0.00*). There was a significant reduction in the absence from work due to neck pain at 6 months but the difference between groups was not significant. There was also a reduction in self reported medication use between baseline and 6 month follow up, but the difference between groups was not significant either. However at the 6 week and 6 month follow up the patient's satisfaction between groups were statistically significant (*P = 0.04 and P = 0.02* respectively).

The results found were similar to those in other similar studies, however are only typical of patients with chronic pain (over 3 months) and due to the study design it is not possible to determine the effective difference between the two forms of exercise used in the intervention group. Thus it can be summarised that after 6 weeks training the exercise group were significantly improved in disability scores, subjective pain intensity, treatment satisfaction and isometric muscle strength than the control group. However only the subjective report of pain and patient satisfaction were statistically significant at 6 months, thus showing that the effect of exercise is less favourable in the long term in this study.

BRIEF SUMMARY OF THE STUDIES DISCUSSED :

Thus the above studies demonstrate that :

1. manipulative therapy and exercise reduces cervicogenic headache symptoms maintaining the effects over time. However the combined therapies were not statistically significantly superior to the single treatment interventions. Reduction in headache frequency was clinically relevant. All the treatments were effective on the physical outcomes except for the protruded head posture. The manipulative therapy group failed to improve performance of the CCFT, indicating that there is not spontaneous recovery of the muscle action after relief of symptoms. 10% more participants in the combined therapy group did obtain either good or excellent results indicating that this is the most effective treatment for cervicogenic headache.
2. if performed correctly an increasing amount of cranio-cervical flexion is required for the five stages of the test indicating that the deep neck flexors increase their contractile effort. The linear increments of each stage of the test implies that a progressive increase of the ROM during the CCFT should be observed by the clinician, whereas if it appears that the spine remains static or the ROM decreases it would imply that the movement pattern is not correct. In fact cranio-cervical flexion is often incorrectly substituted by neck retraction and should be discouraged. The excellent levels of reliability found in this study give support for both the suitability of this technique when assessing cranio-cervical flexion range of motion, as well as the effectiveness of the exercise regime.
3. it is possible to measure EMG activity in the DCF muscles effectively but further research using the same method is indicated to establish the possibility of cross talk from other muscles in the area. However it is a promising technique which should enable further examination of the DCF muscles and help understand the impairment shown in CCF in patients with neck pain of different origins.

4. neck pain patients of both traumatic and insidious onset, have difficulty in attaining the graded pressure targets and they also demonstrate increased normalised RMS values in the SCM, implying an impairment in neck flexor synergy. However the difference in time of onset of the symptoms does not appear to be important. Furthermore the altered patterns in muscle coordination in patients with both causes of neck pain are evident in the CCFT and that the physical impairment is similar in the two groups and does not account for the slower response to improvement in the rehabilitation of whiplash patients.
5. patients with chronic neck pain have:
    1. impairment in the deep cervical flexors;
    2. deficit in muscle co-ordination;
    3. insufficiency in pre-programmed activation;
    4. inefficient neuromuscular activation;
    5. great fatigability of the superficial cervical muscles.

    The complex and multifaceted nature of cervical muscle impairment in neck pain patients has been demonstrated which consequently has significant indications for the rehabilitation of this patient category.
6. lower EMG amplitudes in the deep muscles were present with higher measurements in the superficial neck muscles, implying that neck pain patients use a different strategy to carry out the CCFT. However due to the limited number of subjects in the study, the differences in the superficial group of muscles was not consistently statically significant. This study does however indicate that the hypothesis of poor performance of the CCF test is due to impairment in the deep cervical flexors. Therefore investigation of the changes in these muscles when performing the rehabilitation protocol is required in patients with neck pain syndromes.
7. after 6 weeks of deep neck flexor exercises and dynamic isometric training the exercise group were significantly improved in disability scores, subjective pain intensity, treatment satisfaction and isometric muscle strength than the control

group. However only the subjective report of pain and patient satisfaction were statistically significant at 6 months, thus showing that the effect of exercise is less favourable in the long term in this study.

CONCLUSION :

A number of exercise programmes for muscle deficits in the cervical spine have been developed based on research findings. The protocol examined in this paper can be summarised as follows :

Motor control and improvement of muscle control within the neck flexor synergy (Jull 2004) using low load exercises to train co-ordination between the layers of neck flexor muscles. CCF performance and holding of progressive inner range movement with minimal activation of the superficial neck flexors. “This exercise approach is based on biomechanical evidence of the functional interplay of the deep and superficial neck muscles and on physiological and clinical evidence of impairments in the muscles in neck pain patients”. This approach has been used with CCF training in association with shoulder girdle movements in patients with cervicogenic headache patients in a RCT of physiotherapy management (Jull 2002). The results showed significant reduction in the frequency of headache and neck pain both in the short and long term.

This exercise regime has shown favourable results in the rehabilitation of the neck flexor programmes. However there is a lack of good clinical studies regarding efficacy.

Although based on sound theory, the mechanism of efficacy is unclear. Further research in the field is required to understand the different physiological factors with the exercise regime and find the intervention to demonstrate the most effective treatment. In fact critical reviews and meta-analyses call for further randomised controlled trials on the cervical spine (Aker 1996, Kjellmann 1999, Panel 2001).

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