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Original article

Impairment in the cervical flexors: a comparison of whiplash and insidious onset neck pain patients

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Abstract

There has been little investigation into whether or not differences exist in the nature of physical impairment associated with neck pain of whiplash and insidious origin. This study examined the neck flexor synergy during performance of the cranio-cervical flexion test, a test targeting the action of the deep neck flexors.

Seventy-five volunteer subjects participated in this study and were equally divided between Group 1, asymptomatic control subjects, Group 2, subjects with insidious onset neck pain and Group 3, subjects with neck pain following a whiplash injury. The cranio-cervical flexion test was performed in five progressive stages of increasing cranio-cervical flexion range. Subjects' performance was guided by feedback from a pressure sensor inserted behind the neck which monitored the slight flattening of the cervical lordosis which occurs with the contraction of longus colli. Myoelectric signals (EMG) were detected from the muscles during performance of the test.

The results indicated that both the insidious onset neck pain and whiplash groups had higher measures of EMG signal amplitude (normalized root mean square) in the sternocleidomastoid during each stage of the test compared to the control subjects (all $P<0.05$) and had significantly greater shortfalls from the pressure targets in the test stages ($P<0.05$). No significant differences were evident between the neck pain groups in either parameter indicating that this physical impairment in the neck flexor synergy is common to neck pain of both whiplash and insidious origin.

Keywords: Neck flexors; Whiplash; Neck pain

1. Introduction

Neck pain is a common condition causing substantial personal and financial costs (Côté et al., 1998; Holmstrom et al., 1992). Broadly, onset may be insidious or may follow trauma. Pain is often persistent or recurrent in nature. Neck pain of traumatic origin following a motor vehicle crash (whiplash) often poses a particular challenge in management. There are several influences that may impact on the perception of neck pain and disability in persons with whiplash associated disorders (WAD) compared to those with an insidious onset of neck pain. These include the magnitude of the injury, psychological responses to injury and pain, social factors and litigation (Côté et al., 2001; Radanov and Sturzenegger, 1996). There has been little investigation into whether or not differences exist in the nature of physical impairment associated with neck pain of whiplash and insidious origins which may contribute to the greater difficulty often encountered in the rehabilitation of patients with WAD.

Changes in cervical flexor muscle function have been investigated in neck disorders of both whiplash and insidious origins. Vernon et al. (1992) in an initial comparative study of neck isometric strength and flexor/extensor strength ratios, found that subjects with both WAD and insidious onset neck pain had lesser strength than asymptomatic subjects. There was a progressive anterior-to-posterior muscle imbalance in the neck pain subjects, with the cervical flexors becoming relatively weaker as compared to the extensors. This was more apparent in subjects with WAD, suggesting that there could be a difference in the degree of impairment between these subject groups.

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Cervical flexor muscle function has also been examined using the cranio-cervical flexion test (C-CFT) (Jull, 2000). The cranio-cervical movement aims to assess the anatomical action of longus capitis in synergy with longus colli, rather than that of the superficial flexors, sternocleidomastoid (SCM) and anterior scalene muscles, which flex the neck but not the head. The longus colli muscle has a unique role in the support of the cervical segments and curve (Mayoux-Benhamou et al., 1994). In the C-CFT, the subject performs five increments of increasingly inner range cranio-cervical flexion in a supine lying position (Falla et al., 2003a; Jull, 2000). Patients are guided to the test level by feedback from a pressure unit (Stabilizer, Chattanooga, USA) which is placed behind the neck to monitor the progressive flattening of the cervical lordosis which results from the contraction of longus colli (Mayoux-Benhamou et al., 1994, 1997). Performance in the test has been examined in subjects with WAD (Jull, 2000) and cervicogenic headache (Jull et al., 1999). The results of these studies indicated that patients were less able to achieve and hold the progressive positions of the test as compared to the respective control subjects. These results inferred dysfunction in the deep neck flexors, as no direct measure of these muscles could be made. In the study of subjects with WAD (Jull, 2000) and in a study of patients with chronic neck pain (Sterling et al., 2001), amplitudes of muscle signals (electromyography, EMG) were measured in the sternocleidomastoid (SCM) during the test, following Cholewicki et al.'s (1997) hypothesis that increased activity of the superficial muscles could be a measurable compensation for poor segmental stability, or in this case of the C-CFT, poorer activation of the longus colli. It was shown that both neck pain patient groups had higher amplitudes of muscle signals in the SCM.

There has not been a direct comparison of performance in the C-CFT between patients with neck pain from whiplash and insidious origin. This study was undertaken to make this comparison. A clinically applicable version of the C-CFT was used.

2. Methods

2.1. Subjects

Seventy-five volunteer subjects between the ages of 18–66 years were enrolled in the study. They comprised three groups, each of 25 subjects. Control subjects (Group 1) and insidious onset neck pain subjects (Group 2) were volunteers from the general and university communities who responded to advertising. The control subjects were eligible for the study provided they had no current or past history of musculoskeletal pain or injury in the neck or upper limb. Insidious onset neck pain subjects were eligible provided that their condition had not been caused by trauma from a motor vehicle crash. Subjects with WAD (Group 3) were those attending for assessment at a Whiplash Research Unit. Subjects for Groups 2 and 3 were not considered if they had a history of neck surgery, previous diseases affecting the neck or throat, and rheumatic or neurological disorders. Ethical clearance for the study was obtained from the Medical Ethics Committee, The University of Queensland, and all subjects gave informed consent to participate in the study.

2.2. Instrumentation and measurements

For Groups 2 and 3, data were collected regarding the length of history of neck pain and subjects rated their average pain intensity on a visual analogue scale (VAS), anchored with 'no pain' and 'the worst pain imaginable'.

2.2.1. Cranio-cervical flexion test

The subjects were positioned in a supine lying position. The pressure sensor was inserted between the testing surface and the back of the neck and was preinflated to a baseline of 20 mmHg (Fig. 1). Subjects were asked to perform progressive repetitions of cranio-cervical flexion to increase the pressure by 2 mmHg incremental targets from 22 mmHg to a maximum of 30 mmHg. Each target pressure was held for 5 s with a 10 s rest between each task. The pressure sensor was connected to a pressure transducer (RS components) and electrical signals from the pressure transducer were amplified and relayed to a visual feedback device and to an Amlab data acquisition system (Associated Measurements Pty Ltd, Australia). The visual feedback device consisted of an electronic voltmeter, marked in 2 mmHg increments from 20 to 30 mmHg, and calibrated to

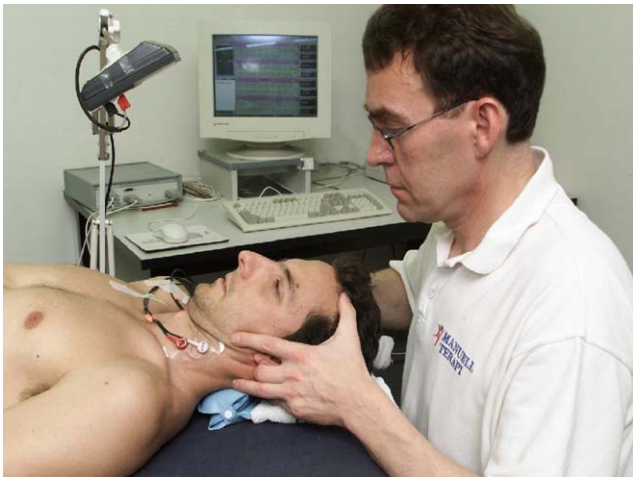

Fig. 1. The cranio-cervical flexion test demonstrating the visual feedback with the pressure sensor and measurement with surface EMG.

display the pressure in the pressure bag, based on the pressure transducer output. Sampling frequency for pressure measures was 1000 Hz. The mean pressure that each subject achieved over the 5 s holding time of the five test levels was calculated to determine whether subjects had reached each prescribed level of the test. The differences between the mean pressure achieved and the nominated target pressure for each stage were calculated for each group.

Myoelectric signals were collected from the SCM muscles using Ag–AgCl electrodes (Conmed, USA) in a bipolar configuration. Electrodes were positioned along the lower one-third of the muscle bellies of the SCM (Falla et al., 2002). Signals were amplified (Amlab), and passed through a 20–500 Hz bandwidth filter. They were sampled at 1000 Hz. EMG data (amplitude of the signal) were analysed off-line (Matlab). The maximum root mean squared (RMS) value was identified for each trace using a 1 s sliding window, incremented in 100 ms steps. RMS values were normalized for each subject, by dividing the 1 s maximum RMS from each level of the cranio-cervical flexion test by the 1 s maximum RMS during a standardized head lift. The normalized RMS data for the left and right SCMs were averaged for analysis.

2.3. Procedure

Subjects received written and verbal information about test procedures and informed consent was obtained. Demographic details were obtained from all subjects and the neck pain subjects rated their pain on the VAS.

Subjects were positioned in supine lying with the head and neck in a mid position such that the face line was horizontal and an imaginary horizontal line bisected the neck longitudinally. If necessary, layers of towel were placed under the head to gain the position. Subjects were fully familiarized with the C-CFT by the researcher who was skilled in the clinical test procedure. They participated in a practice session with the pressure biofeedback during which time the researcher corrected performance.

EMG electrodes were applied over the lower one-third of the SCM following skin preparation involving mild abrasion with fine sandpaper and cleaning with an isopropyl alcohol swab. The subject was first required to perform a head lift by tucking their chin in and lifting the head to just clear the bed. A 10 s recording was made for later normalization procedures. The pressure bag was placed behind the subject's cervical spine and inflated until a stable pressure of 20 mmHg was achieved. The researcher instructed the subject to perform the C-CFT to target 22 mmHg and hold the position steady. A research assistant operated the computer system. A 10 s recording was made for each stage to capture the 5 s holding time. Subjects then rested for 10 s. With a similar procedure, the subject sequentially targeted the other four levels of the test to the maximum of 30 mmHg.

2.4. Statistical analysis

The analysis of the SCM RMS values required a log transformation to remove the skewness in the original measure. A saturated design model was fitted initially and non-significant terms were removed. A mixed model ANOVA was used to investigate within and between group differences in the normalized RMS values for the SCM muscles for the factors of age, gender and stages of the C-CFT. Boxplots of the pressure data indicated possible differences in the means for the shortfall in pressures from the designated pressure levels of the C-CFT across groups and pressure levels. Variances between measurements within groups indicated that models needed to include terms for this heteroscedacity. The linear effects model used to model target pressure error included specific variance functions modelling variance as a power of the pressure level covariate.

3. Results

The demographic details for each subject group as well as the length of history and VAS scores for the neck pain groups are presented in Table 1. The only obvious difference between the groups was the length of history of the insidious onset neck pain group compared to the whiplash group. The results of primary analyses for SCM normalized RMS values revealed significant differences between groups ($P = 0.001$) and stages of the test ($P = 0.001$). There were no significant effects for gender ($P = 0.51$) or age ($P = 0.62$). The analysis revealed a strong positive linear relationship between SCM normalized RMS values and stage of the C-CFT, but the relationship levelled off for the whiplash group at the highest pressure target (Fig. 2). Both the neck pain and whiplash groups had significantly higher SCM normalized RMS values than the control group at each stage of the C-CFT (all $P<0.05$). However there were no significant differences in SCM normalized RMS

Table 1
Characteristics of the subject groups

	Controls ($n = 25$)	Neck pain ($n = 25$)	Whiplash ($n = 25$)
Gender (females %)	60	80	68
Age (years, mean ± SD)	39.3 ± 14.0	40.3 ± 9.2	36.3 ± 10.2
Length of history (years)	—	8.5 ± 6.0	1.8 ± 1.1
Average pain (VAS 0–10)	—	6.3 ± 1.5	6.2 ± 2.3

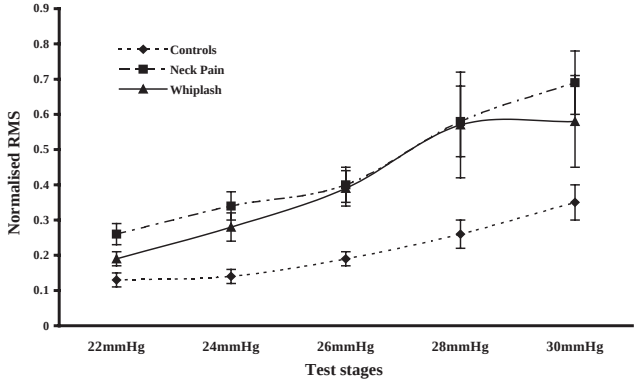

Fig. 2. The means (se) for the normalized RMS values for sternocleidomastoid in each stage of the cranio-cervical flexion test for control, insidious onset neck pain and whiplash groups.

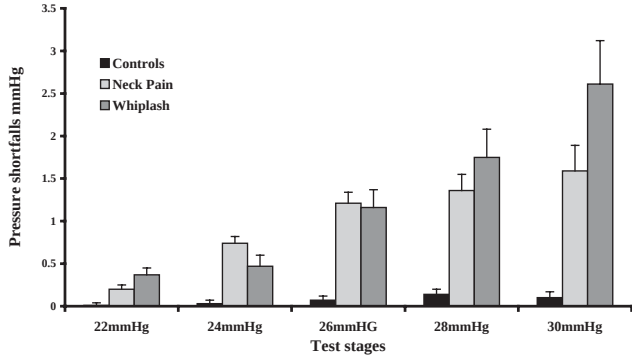

Fig. 3. The means (se) for the shortfall in pressure from the target pressures for each stage of the cranio-cervical flexion test for control, insidious onset neck pain and whiplash groups.

values between the neck pain and whiplash groups with the exception of the 22 mmHg stage ($P = 0.02$). The analysis was repeated for the insidious onset neck pain and whiplash groups using length of history of neck pain as a covariate and results remained unchanged.

The differences between the target pressure and the mean pressure achieved for each stage of the test for each group are presented in Fig. 3. Within the test stages, the mean shortfalls in pressure for the neck pain and whiplash groups were not significantly different at any stage of the test ($P > 0.05$), but those of both groups were significantly greater than the control group ($P < 0.002$). The exception was at the 22 mmHg target where the mean for the neck pain group was not significantly different from the control group ($P = 0.11$).

4. Discussion

Dysfunction in the neck flexor muscles has been found to be associated with neck pain of both whiplash and insidious origins (Jull et al., 1999, 2000; Sterling et al., 2001; Vernon et al., 1992; Watson and Trott, 1993). However there has been little investigation into whether or not differences exist between the groups which might impact on the rehabilitation process.

The results of this study revealed a strong linear relationship between the magnitude of the SCM normalized RMS values and each progressive stage of the test for all groups but there were higher levels of SCM normalized RMS values in the neck pain and whiplash groups in all stages of the C-CFT compared to the asymptomatic control group. This is in accord with the findings of previous studies of subjects with WAD and insidious onset neck pain (Jull, 2000; Sterling et al., 2001). No significant differences were evident between the neck pain and WAD groups indicating that this physical impairment or altered pattern of muscle co-ordination is common to neck pain of both whiplash and insidious origin and would not seem to be a reason why patients with chronic WAD often are more challenging to treat than patients with insidious origin neck pain.

Cranio-cervical flexion is the action of longus capitis in synergy with longus colli. The presence of progressively increasing SCM normalized RMS values in each test stage in all subject groups suggests that these muscles were recruited to further stabilize the neck as the contractile demand of the longus capitis increased in the inner ranges of cranio-cervical flexion. The presence of higher SCM normalized RMS values in the neck pain groups infers that altered patterns of co-ordination may be present between the deep and superficial flexor muscles in patients with neck pain, and this higher activity may be a measurable compensation (Cholewicki et al., 1997) for poorer active contractile capacity of the longus colli and capitis muscles. The clinical version of the C-CFT used in this study has the deficit of no direct measure of the activity of longus capitis and colli. The muscles are deep and not accessible for use of conventional surface EMG. Falla et al. (2003b) used a novel surface EMG electrode in a laboratory version of the C-CFT. A bipolar surface electrode was inbuilt into a nasopharageal suction catheter and the electrode was inserted via the nasal passage and suctioned onto the back of the throat adjacent to the uvula, over the longus capitis and colli. In their study on asymptomatic subjects, they demonstrated a stronger linear relationship between the amplitude of the deep neck flexor muscle signal and the increasing incremental stages of the test, which confirms anatomical predictions for the test. In a further study of 10 neck pain and 10 control subjects, Falla et al. (2003c) again demonstrated a strong linear relationship between the EMG amplitude of the deep neck flexor muscles and the incremental stages of the C-CFT for both control and neck pain subjects. However, the amplitude of deep neck flexor

EMG was less in the neck pain group than for the control group and the difference was significant for the higher levels of the test. Although not significant, there was a strong trend for greater EMG activity in the SCM and anterior scalene muscles in the neck pain group. These findings lend support to the contention that the higher levels of SCM normalized RMS values measured in all stages of the C-CFT in our study of neck pain patients as compared to the control subjects may reflect a compensation strategy for poorer contractile capacity of the deep cervical flexors. Further study on larger sample sizes to better understand the compensation strategies in the C-CFT as well as their sensitivity and specificity to neck pain patients is warranted.

The pressure unit, which is inserted behind the neck in the C-CFT, monitors the slight flattening of the cervical spine accompanying the contraction of the longus colli (Mayoux-Benhamou et al., 1994). The results of the differences between the pressure target and that attained by the subjects in this study revealed that the control group could quite accurately perform and control the cranio-cervical flexion action to the designated pressures of each task (Fig. 3). In contrast, both neck pain groups demonstrated larger pressure shortfalls at all stages of the C-CFT. This again would infer poorer active contractile capacity of the longus colli to flatten the cervical curve, particularly in the latter three stages of the test. At the 30 mmHg stage of the test, the WAD group had a particularly large shortfall indicating that many of the subjects could not perform this stage of the test. This was associated with a levelling off of the EMG normalized RMS values in the WAD group at the test stage. Thus the results of the study show that the neck pain groups of both insidious and whiplash origin have difficulty attaining the pressure targets of the test and in association they both exhibit higher normalized RMS values in the SCM, indicating similar impairment in the neck flexor synergy.

The neck pain groups were of similar age and gender and reported similar levels of pain associated with their condition, although the insidious onset neck pain group had a longer history of their condition than the whiplash group. These differences in length of history did not impact on results. Similar findings of the lack of effect of length of history were reported by Nederhand et al. (2002) in their study of muscle activation patterns of upper trapezius in patients with WAD (mean length of history 1.7 ± 1.3 years) and patients with chronic non-specific neck pain (6.7 ± 5.6 years). These authors concluded that cervical muscle dysfunction was apparently not related to a specific traumatic injury as was also found in this study. Thus these changes in muscle function appear not to be time dependent beyond a certain point and the common factor may be the presence of pain.

5. Conclusion

This study has determined that altered patterns muscle co-ordination within the neck flexor synergy are present in patients with neck pain of whiplash and insidious origin as evident in the C-CFT. It appears that this physical impairment between the two groups is similar and of itself would not account for the greater difficulty often encountered in the rehabilitation of patients following whiplash.

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References

Cholewicki J, Panjabi MM, Khachatryan A. Stabilizing function of the trunk flexor-extensor muscles around a neutral spine. Spine 1997;22:2207–12.

Côté P, Cassidy JD, Carrol L. The Saskatchewan health and back pain survey: the prevalence of neck pain and related disability in Saskatchewan adults. Spine 1998;23:1689–98.

Côté P, Cassidy D, Carroll L, Frank J, Bombardier C. A systematic review of the prognosis of acute whiplash and a new conceptual framework to synthesize the literature. Spine 2001;26:E445.

Falla D, Dall'Alba P, Rianoldi A, Merletti R, Jull G. Location of innervation zones of sternocleidomastoid and scalene muscles—a basis for clinical and research electromyography applications. Clinical Neurophysiology 2002;113:57–63.

Falla D, Campbell C, Fagan A, Thompson D, Jull G. An investigation of the relationship between upper cervical flexion range of motion and pressure change during the cranio-cervical flexion test. Manual Therapy 2003a;8:92–6.

Falla D, Jull G, Dall'Alba P, Rianoldi A, Merletti R. An electromyographic analysis of the deep cervical flexor muscles in performance of cranio-cervical flexion. Physical Therapy 2003b; accepted for publication.

Falla D, Jull G, Hodges P. Neck pain patients demonstrate reduced EMG activity of the deep cervical flexor muscles during performance of cranio-cervical flexion. 2003c; submitted for publication.

Holmstrom EB, Lindell J, Moritz U. Low back and neck/shoulder pain in construction workers: Occupational workload and psychosocial risk factors: Part 2 relationship to neck and shoulder pain. Spine 1992;17:672–7.

Jull GA. Deep cervical neck flexor dysfunction in whiplash. Journal of Musculoskeletal Pain 2000;8:143–54.

Jull G, Barrett C, Magee R, Ho P. Further characterisation of muscle dysfunction in cervical headache. Cephalalgia 1999;19:179–85.

Mayoux-Benhamou MA, Revel M, Vallee C, Roudier R, Barbet JP, Bargy F. Longus colli has a postural function on cervical curvature. Surgical Radiologic Anatomy 1994;16:367–71.

Mayoux-Benhamou MA, Revel M, Vallee C. Selective electromyography of dorsal neck muscles in humans. Experimental Brain Research 1997;113:353–60.

Nederhand MJ, Hermens HJ, Ijzerman MJ, Turk DC, Zivold G. Cervical muscle dysfunction in chronic whiplash-associated disorder grade 2: the relevance of the trauma. Spine 2002;27:1056–61.

Radanov B, Sturzenegger M. Predicting recovery from common whiplash. European Neurology 1996;36:48–51.

Sterling M, Jull G, Wright A. Cervical mobilisation: Concurrent effects on pain, motor function and sympathetic nervous system activity. Manual Therapy 2001;6:72–81.

Vernon HT, Aker P, Aramenko M, Battershill D, Alepin A, Penner T. Evaluation of neck muscle strength with a modified sphygmomanometer dynamometer: reliability and validity. The Journal of Manipulative and Physiological Therapeutics 1992;15:343–9.

Watson DH, Trott PH. Cervical headache: an investigation of natural head posture and upper cervical flexor muscle performance. Cephalalgia 1993;13:272–84.