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Original Article

The effect of therapeutic exercise on activation of the deep cervical flexor muscles in people with chronic neck pain

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ABSTRACT

Deep cervical flexor muscle (DCF) activation is impaired with neck pain. This study investigated the effects of low load cranio-cervical flexion (C-CF) and neck flexor strengthening exercises on spatial and temporal characteristics of DCF activation during a neck movement task and a task challenging the neck's postural stability. Forty-six chronic neck pain subjects were randomly assigned to an exercise group and undertook a 6-week training program. Electromyographic (EMG) activity was recorded from the DCF, sternocleidomastoid (SCM) and anterior scalene (AS) muscles pre and post intervention during the cranio-cervical flexion test (CCFT) and during perturbations induced by rapid, unilateral shoulder flexion and extension. C-CF training increased DCF EMG amplitude and decreased SCM and AS EMG amplitude across all stages of the CCFT (all $P < 0.05$). No change occurred in DCF EMG amplitude following strength training. There was no significant between group difference in pre-post intervention change in relative latency of DCF but a greater proportion of the C-CF group shortened the relative latency between the activation of the deltoid and the DCF during rapid arm movement compared to the strength group ($P < 0.05$). Specific low load C-CF exercise changes spatial and temporal characteristics of DCF activation which may partially explain its efficacy in rehabilitation.

1. Introduction

There is increasing evidence of impaired cervical flexor muscle function in neck pain disorders. Although earlier studies focused on, and demonstrated, a reduction in flexor strength and endurance (Watson and Trott, 1993; Barton and Hayes, 1996), recent research has provided evidence of more specific deficits. Studies of the coordination of the deep and superficial cervical flexor muscles in a low load cranio-cervical flexion (C-CF) task have revealed increased electromyographic (EMG) amplitude of the large superficial sternocleidomastoid (SCM) (Jull et al., 2004) and anterior scalene (AS) muscles in patients with neck pain (Falla et al., 2004b). This was associated with reduced activation of the deep cervical flexors (DCFs), longus capitis and longus colli, and reduced range of C-CF motion to perform the task (Falla et al., 2004b). Furthermore a delay in activation of both the deep and superficial cervical flexor muscles has been demonstrated during rapid arm movements, indicating a change in the automatic feedforward control of the cervical spine (Falla et al., 2004a).

Two contrasting exercise programs have been used to address impaired cervical flexor muscle function: general strengthening exercises (e.g. head lift exercise) (Berg et al., 1994; Bronfort et al., 2001); and a low load program designed to focus more specifically on motor control aspects to train the coordination between the layers of neck flexor muscles and the quality of C-CF movement (Jull et al., 2008). Clinical trials of both exercise regimes have demonstrated outcomes of reduced neck pain and headache (Bronfort et al., 2001; Jull et al., 2002). Although the low load exercise regime improved performance in the cranio-cervical flexion test (CCFT), this was judged clinically by the subject's ability to successfully complete higher stages of the test (Jull et al., 2002). It is unknown whether the coordination of the deep and superficial cervical flexor muscles was modified or restored by the exercise. Nor is it known if such specific task retraining is necessary or whether a general exercise, such as conventional strengthening exercises, would achieve the same effect. Finally, it is unknown if improvements following exercise with either regime translate to improvements in automatic function of the cervical muscles. Changes in activation of deep trunk muscles in an untrained task, following motor training

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in patients with low back pain, suggest that such transfer could be expected (Tsao and Hodges, 2007, 2008).

This study compared the physiological effects of low load C-CF exercise and neck flexor strengthening to evaluate effects on deep and superficial cervical muscle activity during the CCFT and on their automatic activation during rapid, unilateral arm movements in patients with non-severe chronic neck pain. We hypothesised that specific training would be more efficient than general strengthening in addressing deep and superficial muscle control in the CCFT and in automatic function when the neck is perturbed during rapid arm movements.

2. Methods

2.1. Subjects

Participants were 46 female subjects with chronic neck pain greater than 3 months duration. Sample size was based on the difference in EMG amplitude of the SCM between patients with neck pain and controls in the CCFT (Sterling et al., 2003). Forty-two patients (21 per group) were required to detect a 70% (0.195) difference in EMG amplitude between patients with neck pain and controls with a SD of 0.223 at 80% power, and 95% confidence. The sample was increased to 46 to allow for a 10% dropout rate.

Subjects were recruited by advertisements in the local press. Two particular inclusion criteria were; (i) non-severe neck symptoms (Neck Disability Index score <15/50) to avoid exacerbation of pain with the strengthening exercises; (ii) poor performance in the CCFT – unable to control more than the second stage of the test (Jull, 2000) to ensure that subjects had the muscle impairment for which the training was required. Subjects were excluded if they previously had cervical spine surgery, neurological signs in the upper limb or participated in a neck exercise program in the past 12 months. Ethical approval for the study was granted by the Institutional Medical Research Ethics Committee. Written consent was provided before participation.

2.2. Exercise interventions

Subjects were randomized into two exercise groups, low load or higher load strength training, by drawing a number in a sealed envelope from a box. Exercise regimes were of 6-weeks duration and were commenced within one week of the initial assessment. All subjects received personal instruction and supervision by one of 10 experienced physiotherapists once per week. No exercise sessions were longer than 30 min. Subjects were asked not to seek other interventions for neck pain although usual medication was not withheld. Subjects received an exercise diary and were requested to practice their respective regime twice per day (10–20 min) for the duration of the trial, without provoking neck pain and with attention to performance of smooth uniplanar movements.

2.2.1. C-CF training. The low load training of the cranio-cervical flexor muscles followed an established protocol (Jull et al., 2002; Jull et al., 2008). This exercise targets the deep flexor muscles of the upper cervical region (longus capitis and longus colli), rather than the superficial flexor muscles (SCM and AS). The SCM has a large flexor moment for the cervical region but does not contribute to flexor moments at the cranio-cervical region (Vasavada et al., 1998) and the AS muscles have no attachment to the cranium. In the first phase of training the physiotherapist taught the subject to perform a slow and controlled C-CF action in the supine position. The subject concentrated on feeling the back of the head slide in cephalad and caudad directions on the supporting surface to ensure a sagittal rotation rather than a retraction movement. Once the correct C-CF motion was achieved, subjects began the second phase of training in which they were trained to hold progressively increasing ranges of C-CF using feedback from an air-filled pressure sensor (Stabilizer™, Chattanooga Group Inc. USA) placed behind the neck. The feedback dial displayed the amount of pressure change as the cervical lordosis progressively flattened during C-CF. The subject initially performed C-CF to sequentially reach 5 pressure targets in 2 mmHg increments from a baseline of 20 mmHg to the final level of 30 mmHg. The physiotherapist identified the target level that the subject could hold steadily for 5 s without resorting to retraction, without dominant use of the superficial neck flexor muscles, and without a quick, jerky C-CF movement. Contribution from the superficial muscles was monitored by the physiotherapist using palpation. Training commenced at the target level that the subject could achieve with a correct C-CF movement and without dominant use of the superficial muscles. They then trained to be able to sustain progressively greater ranges of C-CF using feedback from the pressure sensor. For each target level, the contraction duration was increased to 10 s, and the subject trained to perform 10 repetitions with brief rest periods between each contraction ($\sim$3–5 s). Once a stage was achieved, the exercise was progressed to train at the next target level up to the final target of 30 mmHg.

2.2.2. Strength training. The strength training consisted of a progressive resistance exercise program in supine with the head supported. Subjects slowly lifted the head and neck through as full a range of motion (ROM) as possible without causing discomfort or reproducing symptoms. It was a two-stage program of two weeks and then four weeks duration as recommended by McArdle et al. (1996) for initiating a weight training program in untrained individuals. In stage one, subjects performed 12–15 repetitions with a weight that they could lift 12 times at the first session and progressed to 15 repetitions. They maintained this stage for the remainder of the two week period. In stage two, subjects performed 3 sets of 10 repetitions, with the first set using a 50% 10 repetition maximum (RM) load, the second set a 75% 10 RM load and the third set a full 10 RM load. All repetitions were performed over a 1 s period with no rest between repetitions and with a 1 min rest interval between sets. If head weight was insufficient to provide a 10 RM load, weights were applied to the subject's forehead in 0.5 kg increments. If the subject could not perform the head lift or the head lift caused discomfort, the load on the neck flexors was reduced by decreasing the vertical component of the head weight vector (the upper body was inclined up from horizontal).

2.3. Outcome measures

Primary outcome measures were EMG amplitude of the DCF, SCM and AS muscles and ROM during the five stages of the CCFT, and the relative latencies between onset of DCF, SCM and AS EMG and that of deltoid during rapid unilateral arm movements. The latter measure had added importance as unlike the CCFT, it was a measure and task that was unrelated to the training protocols of either group. Secondary outcome measures were patient self reports of pain and disability and perceived benefit of exercise. All measures were taken at baseline and in week 7 immediately after treatment except for the perceived benefit of exercise which was obtained only following the intervention period. The researcher was blinded to subject group for the outcome assessments.

2.3.1. Electromyography

Myoelectric signals were recorded from the DCF muscles unilaterally on the side of greatest pain. The apparatus consisted of bipolar silver wire electrode contacts (2 mm $\times$ 0.6 mm, interelectrode distance: 10 mm) attached to a suction catheter (size 10 FG), with a heat sealed distal end, which was inserted via the nose to the posterior oropharyngeal wall. The electrode location was confirmed by inspection through the mouth ~1 cm lateral to the midline at the level of the uvula (Falla et al., 2003a). The electrode contacts were fixed to the mucosal wall with a suction pressure of 30 mmHg via a portal between the two contacts. Before insertion, the nose and pharynx were anaesthetised with three metered doses of 2% Xylocaine® spray (lidocaine, Astra Pharmaceuticals, Sweden) administered via the nostril and to the posterior oropharyngeal wall, via the mouth.

Surface EMG signals were recorded from the sternal head of SCM and the AS bilaterally and the anterior and posterior deltoid unilaterally (on the side that DCF EMG was acquired) using Ag/AgCl electrodes (Grass Telefactor, Astro-Med Inc.) following skin preparation and guidelines for electrode placement (Hermens et al., 1999; Falla et al., 2002). The ground electrode was placed on the upper thoracic spine. EMG data were amplified (Gain = 1000), band-pass filtered between 20 Hz–1 kHz and sampled at 2 kHz. Data were sampled with Spike software using a micro1401 data acquisition system (Cambridge Electronic Design, Cambridge, UK) and converted into a format suitable for signal processing with Matlab (MathWorks, Inc. MA, USA).

2.3.2. Measures of pain, disability and perceived benefit

At baseline and post intervention, subjects completed the Neck Disability Index (NDI) (Vernon and Silvano, 1991) (score/50). The average intensity of neck pain was measured on a 10 cm Numerical Rating Scale (NRS) anchored with "no pain" and "the worst possible pain imaginable". Subjects rated perceived benefit of the exercise program on a NRS anchored with "0%" and "100%".

2.4. Experimental procedure

2.4.1. CCFT. Subjects were comfortably positioned in supine, crook lying with head position standardised in a mid-position (Falla et al., 2003a). The pressure sensor was placed sub-occipitally behind the subject's neck and inflated to a 20 mmHg baseline pressure. Subjects received visual feedback of pressure. They were instructed by the researcher in the C-CF action and practiced targeting the five test levels (progressive increments: 2 mmHg) between 22 and 30 mmHg in two practice trials before the electrodes were applied. Before experimental trials, EMG data were collected for 10 s during a standardised manoeuvre for normalisation purposes. The task involved cervical and C-CF to lift and hold the head just clear of the bed (reference voluntary contraction). Subjects then performed the five incremental stages (22–30 mmHg) of the CCFT to the best of their abilities, maintaining the pressure steady on each target for 10 s. Data collection commenced when the subject reached the pressure target. A 30 s rest was allowed between stages. C-CF ROM was recorded for each test stage using a digital imaging method as previously described (Falla et al., 2003b).

2.4.2. Arm movement task. Subjects performed five repetitions of rapid unilateral shoulder flexion and extension to approximately 45° in each direction, always starting with the arm resting beside the body (shoulder in neutral rotation and elbow in full extension) whilst standing with feet placed shoulder width apart (Hodges and Richardson, 1997). Visual commands to move were provided by light emitting diodes fixed to an adjustable board positioned at eye level. The voltage drop produced by the onset of the stimulus to move was recorded with the EMG signals. Directions of arm movement were randomized between subjects. The time between stimuli varied and was controlled by the investigator. Subjects were instructed to move "as fast as possible" with the emphasis on speed not distance. Subjects performed 2–3 practice repetitions in both directions to check signal quality and to ensure consistent speed and distance of arm movement between repetitions.

2.5. Data analysis

2.5.1. CCFT. To obtain a measure of EMG signal amplitude, maximum root mean square (RMS) was calculated using a 1 s sliding window. For normalisation, EMG amplitude for each CCFT stage was expressed as a percentage of the 1 s maximum RMS values obtained during the reference voluntary contraction. A mixed design analysis of variance (ANOVA) was used to evaluate changes in RMS values post intervention with group (C-CF training, strength training) as the between subjects variable and time (pre, post intervention), muscle (DCF, left SCM, right SCM, left AS, right AS) and stage of the test (five stages of 2 mmHg) as the within subject variables. The ROM obtained at each stage of the CCFT (i.e. change in angle from the start position) was expressed as a percentage of the full range of C-CF. Mixed design ANOVA was used to evaluate changes in ROM with group as the between subjects variable and time and stage of the test as the within subject variables. Any significant differences were investigated with post-hoc Student-Newman-Keuls (SNK) pair-wise comparisons.

2.5.2. Arm movement task. EMG data were rectified and displayed using interactive software and inspected visually to identify the EMG onset for each trace (Hodges and Richardson, 1997; Falla et al., 2004a). The onset was defined as the earliest increase in EMG activity above the baseline level of activity. Recordings were enlarged to a resolution of 0.5 ms and were displayed individually without reference to the muscle or other temporal landmarks to exclude observer bias. Neck muscle EMG onsets were expressed relative to the onset of deltoid EMG, i.e. the relative latency (onset of the deltoid EMG subtracted from the onset of neck muscle EMG, expressed in ms). Any neck muscle EMG onsets that were more than 150 ms before or 500 ms after the onset of deltoid EMG were discarded from analysis as it is unlikely to be related to the perturbation resulting from movement of the arm. A mixed design ANOVA was used to evaluate pre-post intervention change in the relative latencies with group (C-CF training, strength training) as the between subjects variable and muscle (DCF, left SCM, right SCM, left AS, right AS) and direction (flexion, extension) as within subject variables. Significant differences were investigated with post-hoc Student-Newman-Keuls (SNK) pair-wise comparisons. Chi-squared analyses were performed to compare the distribution of subjects showing earlier or later relative latencies of the DCF muscles compared to pre-intervention baseline values. Data were categorized based on a change in the timing of the DCF (<-40 – >40 ms in 10 ms increments).

Paired t-tests were conducted to determine if NDI and NRS were significantly different pre to post intervention for both groups. Independent t-tests were conducted to compare for group differences. Statistical analyses were performed using SPSS 10.0 for Windows. A value of $P < 0.05$ was used to indicate statistical significance.

3. Results

No subjects were lost to follow up assessment. Table 1 presents subject descriptive data. Baseline characteristics, pain and disability levels, EMG amplitude, ROM for the CCFT and relative latencies during the arm movement task were not different between groups (all: $P > 0.05$). All participants in the strength group and all but three in the C-CF group received all treatments. Procedural difficulties with insertion of the nasopharyngeal electrode resulted in a reduced number of subjects for the DCF EMG data during the CCFT

Table 1
Baseline characteristics of the C-CF and strengthening exercise groups (Mean and standard deviation).

	C-CF training ($n = 23$)	Strength training ($n = 23$)	P
Age (years)	39.6 ± 12.2	37.1 ± 10.3	0.45
Length of History (years)	10.1 ± 10.6	9.2 ± 6.6	0.73
Onset (insidious, trauma) % insidious	91.3	91.3	0.99
Neck Pain Intensity (NRS 0–10)	4.5 ± 1.6	4.2 ± 2.1	0.61
Neck Disability Index (50)	11.0 ± 2.7	9.6 ± 3.1	0.10

(C-CF training: $n = 20$; strength training: $n = 20$) and arm movement task (C-CF training: $n = 18$; strength training: $n = 20$).

3.1. CCFT

A significant interaction was observed between group and time for values of EMG amplitude ($F = 13.8$, $P < 0.001$). Post hoc analysis demonstrated that a significant change in EMG amplitude was only identified for the C-CF group (SNK: $P < 0.0001$). Accordingly, a significant interaction occurred between group, time, muscle and stage of the CCFT for the values of EMG amplitude ($F = 1.6$; $P < 0.05$). Post intervention, the DCF EMG amplitude was increased for the C-CF training group across all stages of the CCFT (SNK: all $P < 0.05$; Fig. 1). In contrast, there was no difference in DCF EMG amplitude in the strength-training group (SNK: all $P > 0.05$; Fig. 1). In the C-CF group, the EMG amplitude for the left and right SCM and AS decreased across all CCFT stages, except for the lowest level (22 mmHg) (SNK all $P < 0.05$; Figs. 2 and 3 respectively). There was no significant reduction in EMG amplitude of the superficial flexors for the strength-training group except for the left SCM at 28 mmHg test stage (SNK $P < 0.05$; Fig. 2), for the left and right AS at 30 mmHg (SNK $P < 0.05$; Fig. 3). No differences in the full range of C-CF were observed after the intervention for either group (change in full range of C-CF group: 1.2 ± 1.0°; strength group: 0.4 ± 1.0°). Range of C-CF motion used during the CCFT depended on the interaction between group, time and stage ($F = 2.6$; $P < 0.05$). The relative range of C-CF was increased across all CCFT stages for the C-CF group post intervention (SNK: all $P < 0.00001$; Fig. 4). In contrast, the strength-training group only demonstrated an increase in ROM at the 22 mmHg and 28 mmHg stages (SNK: $P < 0.05$; Fig. 4).

3.2. Arm movement task

The analysis revealed that changes in the relative latencies of DCF, SCM and AS were not dependent on time or group. Nevertheless, visual inspection of the data suggested a tendency for earlier onsets of the DCF muscles in both directions of arm movement for the C-CF training group post intervention (Figs. 5 and 6). Calculation of frequencies indicated an earlier onset of DCF EMG in 83.5% and 89% of subjects during arm flexion and extension respectively for the C-CF group compared with 55% in each direction for the strength-training group. When the onset data were categorized based on the change in timing of the DCF (<−40 – >40 ms in 10 ms increments) and the distribution of data directly compared across the two training groups, the subsequent analysis showed that the distribution of changes in relative latencies across

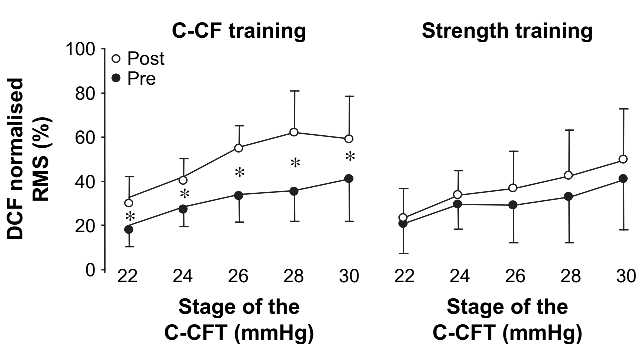

Fig. 1. Normalised RMS values (mean and standard deviation) for the DCF muscles for each stage of the CCFT. Data are presented for the C-CF retraining group and strength-training group both pre and post intervention. *indicates significant difference between pre and post intervention data ($P < 0.05$).

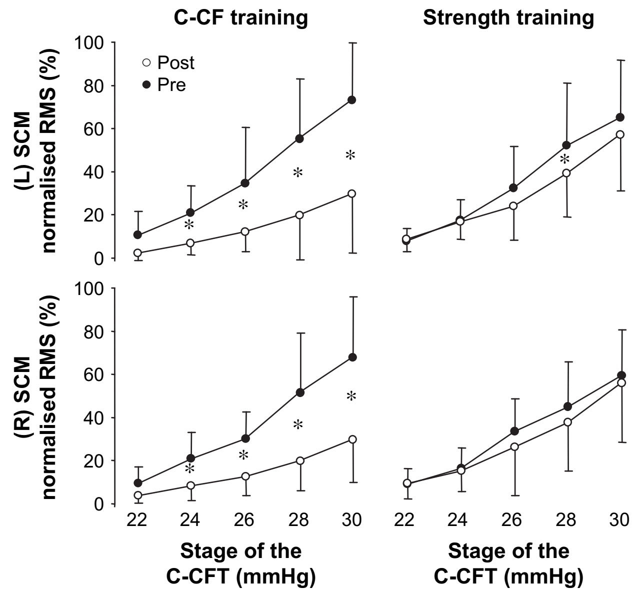

Fig. 2. Normalised RMS values (mean and standard deviation) for the left and right SCM muscles for each stage of the CCFT. Data are presented for the C-CF training group and strength-training group both pre and post intervention. *indicates significant difference between pre and post intervention data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

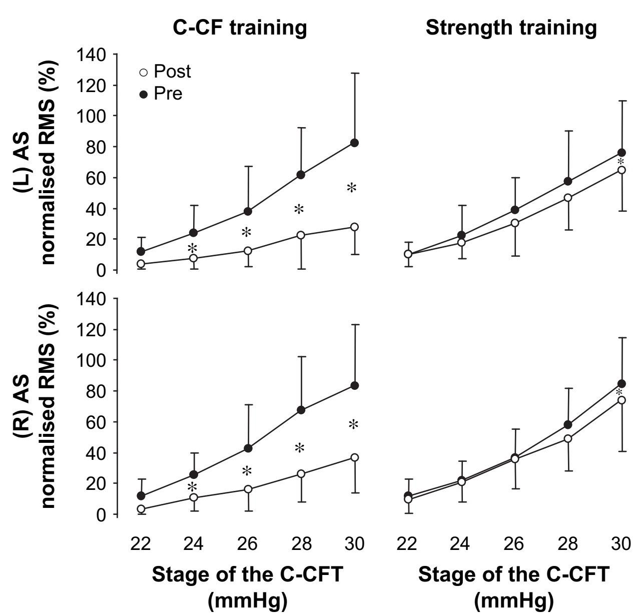

Fig. 3. Normalised RMS values (mean and standard deviation) for the left and right AS muscles for each stage of the CCFT. Data are presented for the C-CF training group and strength-training group both pre and post intervention. *indicates significant difference between pre and post intervention data ($P < 0.05$).

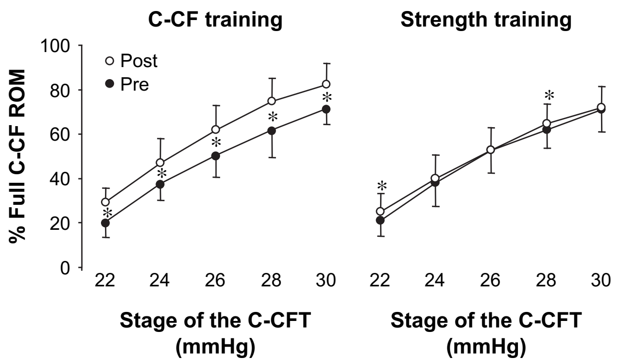

Fig. 4. Percentage of full C-CF ROM (mean and standard deviation) for each stage of the CCFT are presented for the C-CF training group and strength-training group both pre and post intervention. *indicates significant difference between pre and post intervention data ($P < 0.05$).

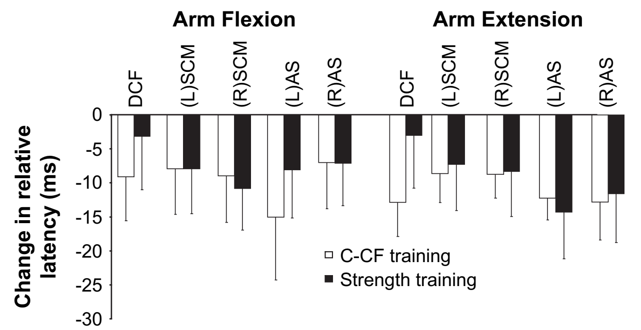

Fig. 6. Pre-post intervention change in relative latency of the DCF, left (L) and right (R) SCM and AS are shown for the C-CF training group and strength-training group for both arm movement directions.

subjects was different between the two training groups (flexion: $\chi^2 = 22.55$, $P < 0.01$; extension: $\chi^2 = 37.45$, $P < 0.01$; Fig. 7).

3.3. Measures of pain, disability and perceived benefit

Both exercise groups demonstrated a significant reduction in average pain intensity (NRS) (C-CF training, $P < 0.001$; strength training $P < 0.05$), and NDI score (C-CF training, $P < 0.001$; strength training, $P < 0.001$) but there were no between group differences (both $P > 0.05$) (Table 2). Perceived benefit of the exercises was also similar between groups.

4. Discussion

Specific deficits in DCF muscle activation have been identified in patients with neck pain compared to asymptomatic individuals (Jull et al., 2004; Falla et al., 2004b). This study showed that activation of the DCF was increased at each of the five levels of the CCFT and activity of the SCM and AS muscles reduced following C-CF training. The interaction between the deep and superficial flexors during the test changed so that it closely mirrored that measured previously in asymptomatic subjects (Falla et al., 2004b). There was an increase in the angle of C-CF used in each test stage, which suggests a more accurate performance of C-CF rather than an aberrant pattern inclusive of a retraction action (Falla et al., 2004b) and parallels improvement in activation of the DCF. The strength training produced no substantive change in the activation of the deep and superficial flexors, thus did not address the altered neuromuscular strategy in the CCFT that has been measured regularly in patients with neck pain disorders (Jull et al., 2004; Falla et al., 2004b).

This result may not be surprising as the C-CF training exercise and the outcome task were similar and there is considerable evidence that task specific improvements can be achieved with training (Weir et al., 1995; Young et al., 2001). Nevertheless of note clinically, improvement in DCF activation capacity was achieved with a recumbent, low load exercise. Cagnie et al. (2008) in a recent MRI study of three cervical flexor exercise tasks showed that T2 changes in the longus capitis and the longus colli in the C-CF exercise were 42% and 19% respectively of that achieved in the high load head lift exercise of C-CF with cervical flexion. Thus the evidence suggests that the low load C-CF exercise can train the DCF effectively, even in the early stages of rehabilitation when pain or pathology might preclude high load exercise.

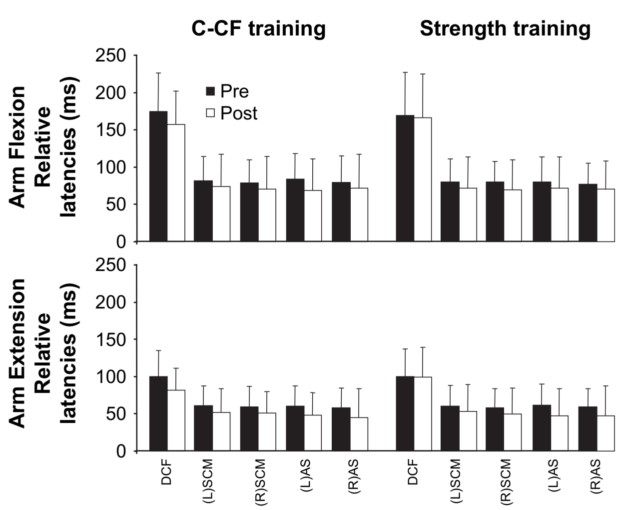

Fig. 5. Mean and standard deviation of the relative latencies of the DCF, left (L) and right (R) SCM and AS are presented for the C-CF training group and strength-training group both pre and post intervention for both arm movement directions.

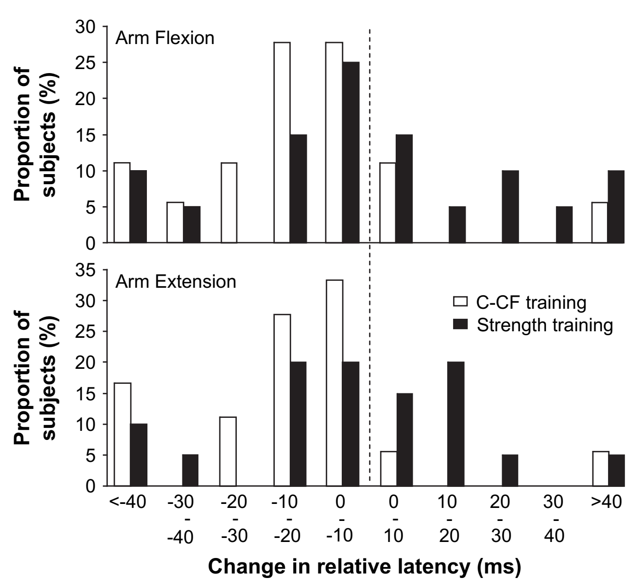

Fig. 7. Proportion of subjects showing a change in relative latency of the DCF muscles during unilateral arm movements for the C-CF training group and strength-training group.

Table 2
The change from baseline for the C-CF and strengthening exercise group in measures of pain and disability following exercise as well as the perceived benefit of exercise.

	C-CF training ($n=23$)	Strength training ($n=23$)	P[a]
Neck Pain Intensity (NRS 0–10)	-1.7 ± 2.0	-1.0 ± 3.3	0.35
Neck Disability Index (50)	-5.0 ± 4.2	-3.5 ± 2.3	0.15
Perceived benefit of exercise (%)	60.4 ± 24.7	54.6 ± 27.3	0.44

[a] Results of the between group analysis.

Coordination between the deep and superficial flexors is considered necessary for safe progression of exercise in patients with neck pain. There is evidence that both the cranio-cervical (Watson and Trott, 1993; O'Leary et al., 2007) and cervical flexors (Barton and Hayes, 1996) have reduced strength and endurance in neck pain, thus warranting rehabilitation. It is unknown if the degree of impaired strength differs between the deep and the superficial flexors. However, it is known that SCM and AS together provide 83% of the cervical flexion capacity while the longus capitis and longus colli provide only 17% (Vasavada et al., 1998). Thus if the coordination between the superficial and deep flexors is not corrected in the first instance, work of the superficial muscles might mask or substitute for any impaired performance of the DCF muscles in any premature progression to higher load exercise.

Previous research in patients with neck pain revealed delays in activation of both the DCF and superficial SCM and AS in response to postural perturbations, indicating a defect in the automatic feedforward control of the cervical spine (Falla et al., 2004a). Similar delays were recorded in this neck pain group with greatest delays identified for DCF EMG onset (Fig. 5). We proposed that the specific C-CF training exercise which focused on repeated activation of the DCF in a motor relearning model might redress this delay and do so more efficiently than the strengthening exercise, akin to the deep abdominal muscles using a similar training protocol (Tsao and Hodges, 2007, 2008). Although there were no significant differences in pre-post intervention change in relative latency of DCF muscle between the two training groups, consistent with our hypothesis, a greater proportion of subjects showed earlier onsets of their DCF post intervention following C-CF training compared to strength training. Although earlier onset of DCF activity was identified during rapid arm movement, the relative latencies did not reach values consistent with data from a pain-free population (Falla et al., 2004a) and cannot be termed feedforward postural adjustments as the EMG onsets did not occur earlier than 50 ms after the onset of deltoid EMG. Further research is necessary to investigate whether increased training duration would induce greater changes. Studies have shown that patients achieve a progressive gain in EMG onset with continued training (Tsao and Hodges, 2008).

Both exercise groups gained similar pain relief with the exercise training and considered the exercises beneficial. The subjects, by design, had relatively mild neck pain syndromes and the study was not designed to evaluate the difference in efficacy of the two interventions. Nevertheless these results reflect the pain relieving effects gained in previous trials of these exercise techniques (Bronfort et al., 2001; Jull et al., 2002).

5. Conclusion

As hypothesised, specific low load C-CF training but not strength training enhanced the pattern of deep and superficial muscle activity in the CCFT. In addition, a greater proportion of patients showed improved temporal characteristics of DCF muscle activation following cranio-C-CF training compared to strength training. These observations may partially explain the efficacy of this exercise in rehabilitation of individuals with chronic neck pain.

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