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ORIGINAL REPORT

SHORT- AND LONG-TERM EFFECTS OF EXERCISE ON NECK MUSCLE FUNCTION IN CERVICAL RADICULOPATHY: A RANDOMIZED CLINICAL TRIAL

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Objective: **To compare short- and long-term changes in neck muscle endurance, electromyography measures of neck muscle activation and fatigue and ratings of fatigue and pain after neck-specific training or physical activity in people with cervical radiculopathy.**

Design: **Randomized clinical trial.**

Subjects/patients: **Seventy-five patients with cervical radiculopathy.**

Methods: **Patients underwent neck-specific training in combination with a cognitive behavioural approach or prescribed physical activity over a period of 14 weeks. Immediately after the intervention and 12 months later, surface electromyography was recorded from neck flexor and extensor muscles during neck endurance tests. Time to task failure, amplitude and median frequency of the electromyography signal, and subjective fatigue and pain ratings were analysed in 50 patients who completed at least one follow-up.**

Results: **A significant increase in neck flexor endurance time was observed for both groups at 14 weeks compared with baseline and this was maintained at the 12-month follow-up ($p<0.005$). No change was identified for the slope of the median frequency. For the neck-specific training group, splenius capitis was less active during neck flexion at both follow-ups ($p<0.01$), indicating reduced muscle co-activation.**

Conclusion: **Both specific and general exercise increased neck flexor endurance, but neck-specific training only reduced co-activation of antagonist muscles during sustained neck flexion.**

Key words: cervical radiculopathy; electromyography; endurance; fatigue; pain; training.

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INTRODUCTION

Distinct modifications of the surface electromyography (EMG) signal can be identified during sustained voluntary muscle contractions. The analysis of myoelectric manifestations of fatigue provides important information about physiological changes developing in the muscle (1). The most frequently monitored surface EMG variables during the assessment of myoelectric manifestations of fatigue are spectral variables, such as the mean or median frequency (MDF), amplitude variables, such as the average rectified value (ARV) or root mean square. The typical pattern observed during sustained contractions is a decrease in spectral variables with time and an initial increase in signal amplitude prior to the onset of mechanical fatigue (1).

Cervical radiculopathy (CR) is often described as neck pain with radiating pain into one or both arms and the symptoms are related to dysfunctional cervical spinal nerve root(s), and neurological symptoms, such as numbness, muscle weakness and inhibited reflexes in the arms, are usually present. Incidence rates for CR indicated an overall rate of 83.2 per 100,000 in the general population (63.5 for women and 107.3 for men) (2).

During sub-maximal isometric endurance tests for the neck extensor and flexor muscles, a greater negative slope of the MDF of the surface EMG signals, and thus greater myoelectric manifestations of muscle fatigue, was identified in patients with CR compared with asymptomatic subjects (3). Similar results have been reported for the neck flexor muscles in women with chronic neck pain during sustained neck flexion contractions (4). Moreover, clinical outcome measures have identified reduced function of the neck muscles in patients with CR, including reduced strength and endurance (5, 6).

Evidence for the benefit of active exercises in the treatment of patients with CR is sparse (7). A small study compared surgery plus 3 months of structured physiotherapy (neck-specific exercises in combination with a cognitive behavioural approach) with

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the same structured physiotherapy programme only in people with CR and showed no differences at a 2-year follow-up (6, 8). However, no studies have investigated the physiological effects of exercise in patients with CR. This study evaluated the effects of specific vs general exercise on neck muscle function including endurance, myoelectric manifestations of fatigue, co-activation and ratings of fatigue and pain, 14 weeks and 12 months following a programme of neck-specific training or physical activity in patients with CR. It was hypothesized that patients who participated in neck-specific training would show a greater improvement in neck muscle function compared with those who had participated in general physical activity.

METHODS

Participants

Participants were patients with CR verified by magnetic resonance imaging and clinical examination including the Spurling sign test. They were recruited from a neurosurgery clinic for selection for surgery and were a sub-sample recruited for a randomized clinical trial (ClinicalTrials.gov identifier: NCT01831271) (9) (Fig. 1). For the full randomized clinical trial, pain measured on a VAS scale was the primary outcome variable and a power analysis revealed that a sample size of 56 was required in each group. The subjects reported in the current study are only those who were additionally tested with EMG.

All participants displayed signs of a neurological condition characterized by loss of neurological function, i.e. sensory loss, motor weakness, and/or impaired reflexes in the arm and hand. Patients with earlier luxation or fracture of the cervical spine, myelopathy, malignancy or spinal tumour, spinal infection or previous surgery in the cervical column were excluded. Seventy-five patients (39 women and 36 men) completed the baseline tests, which included EMG measurements (Table I). Data from 50 patients (26 women, age 46 years, standard deviation (SD) 8.8 years, and 24 men, age 49 years, SD 11.8 years) who completed at least 1 test occasion including EMG measurements other than the baseline session were analysed. The study was approved by the regional ethics committee (No. 2009/1756-31/4) and all patients signed an informed consent following a detailed explanation of the study. This study is registered in ClinicalTrials.gov identifier: NCT01831271.

Exercise interventions

After baseline assessments, the patients were randomized to either: (*i*) active physical rehabilitation with a neck-specific exercise programme in combination with a cognitive behavioural approach (neck training), or (*ii*) prescribed self-mediated physical activity (physical activity). The intervention period was 14 weeks and participants were encouraged to continue to be active after this period. The randomization was performed according to a random-generated computer list by a person not involved in the testing or treatment of subjects and group allocation was concealed until after baseline measurement.

Blinding of the patients, the test leader and the treating physiotherapists participating in the study was not possible because it would have been obvious to the patient which type of intervention they received. The test leader was the contact person for the patients enrolled and the patients thereby disclosed their group assignment.

The neck training programme consisted of a standardized programme with structured progression, which aimed to improve physical function with a focus on sensorimotor function, neck muscle endurance and pain reduction (10, 11). The patients were requested to train 3 times a week with assistance from a physiotherapist. This group also received education about pain physiology, the consequences of stress, exercise, relaxation techniques, coping strategies and ergonomic advice. The physical activity programme included tailored physical activity and motivational interviews performed by the physiotherapists. The main goal was to increase general physical activity levels. A more comprehensive description of the interventions has been described elsewhere (9).

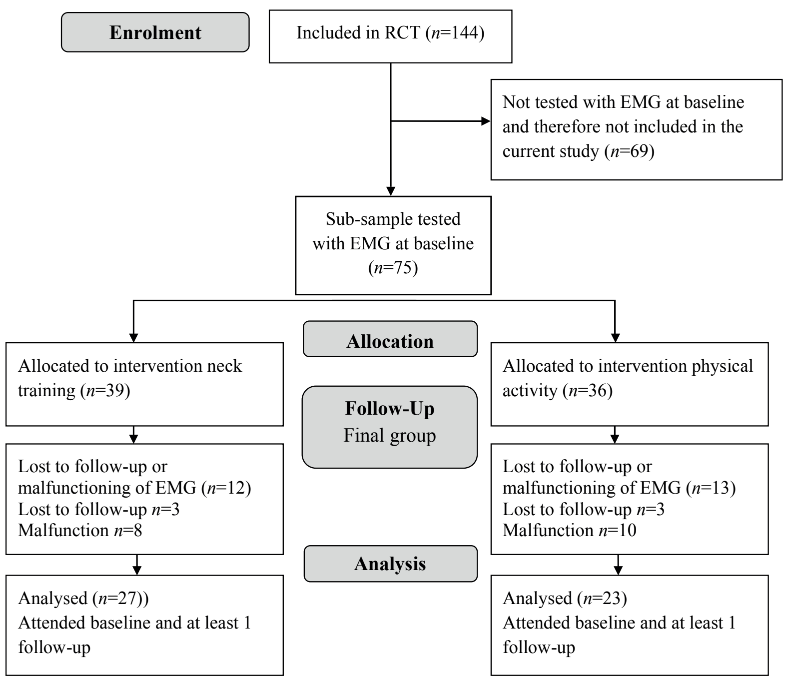

Fig. 1. CONSORT (Consolidated Standards Of Reporting Trials) flow diagram of the patients included in the study. RCT: randomized controlled trial; EMG: electromyography.

Isometric neck muscle endurance test

Two submaximal isometric endurance tests, with established reliability, were used to evaluate neck muscle endurance (Fig. 2) (5). To test neck extensor endurance, the patients were positioned in prone with their head resting in a neutral position on the plinth, arms along the side of the body, and legs straight. A load of 2 kg for women and 4 kg for men was applied in a standardized way attached to a rope on the head above the ear (5). After 5 min of rest the neck flexor endurance test was performed and the patient was positioned in supine without external weight on the head. The test instruction was to “nod the chin slightly and lift the head” (i.e. craniocervical flexion followed by neck flexion). The 2 endurance tests were always performed in the same order, since the neck flexion test was considered more demanding. Each task was performed until the patient could no longer maintain the position due to volitional exhaustion, i.e. was not able to keep the head in the required neck position (controlled by the investigator) or chose to interrupt the test indicative of the time to task failure. The endurance time (in s) was noted. The patients were allowed a short “pre-test” to become accustomed to the test procedure. The endurance tests, which included EMG measurements, were conducted at baseline before the exercise period, at the end of the 14-week training period and again after 12 months.

Table I. *Characteristics of patients, showing mean (standard deviation; SD) for sex, age, weight (kg), height (m), body mass index (BMI) and for pain duration (months) median and 25th–75th percentile for all patients included (*n = 75*), the final group of patients (*n = 50*) divided in the neck training group (*n = 27*) and the physical activity group (*n = 23*)*

Patients	Sex	Age Mean (SD)	Weight Mean (SD)	Height Mean (SD)	BMI Mean (SD)	Pain duration Median (25th–75th)
All	All	49 (11.2)	75 (13.5)	1.71 (0.1)	25 (6.4)	7 (4–24)
(*n*=75)	Men=36	50 (13.2)	84 (10.4)	1.77 (0.8)	25 (7.0)	12 (6–36)
	Women=39	47 (9.0)	68 (11.6)	1.65 (0.7)	24 (5.9)	6 (4–14)
Final group	All	48 (10.2)	74 (13.9)	1.70 (0.1)	24 (7.0)	6 (4–20)
(*n*=50)	Men=23	49 (11.9)	82 (10.5)	1.77 (0.8)	24 (7.9)	9 (4–39)
	Women=27	46 (8.4)	67 (12.5)	1.64 (7.3)	23 (6.3)	6 (4–14)
Neck-specific group	All	47 (10.9)	75 (14.4)	1.71 (0.1)	23 (7.7)	6 (4–17)
(*n*=27)	Men=12	48 (13.7)	83 (12.3)	1.79 (0.8)	24 (8.0)	7 (4–27)
	Women=15	45 (8.5)	68 (12.3)	1.65 (0.7)	23 (7.7)	6 (4–13)
Physical activity group	All	49 (9.4)	73 (13.6)	1.70 (0.1)	24 (6.3)	10 (4–32)
(*n*=23)	Men=11	51 (10.3)	81 (8.4)	1.76 (0.8)	24 (7.9)	15 (5–51)
	Women=12	48 (8.6)	66 (13.4)	1.64 (0.8)	24 (4.2)	7 (4–18)

EMG

Surface EMG was recorded from selected neck muscles using circular, bipolar, Ag/AgCl self-adhesive surface electrodes (AMBU-Blue Sensor, N-00-S, Medicotest A/S, Denmark). After cleaning the skin with alcohol, the electrodes were placed over the splenius capitis (SCap), upper trapezius (UT), middle trapezius (MT), and sternocleidomastoid muscles (SCM), bilaterally following established guidelines (12, 13) while the patient was sitting. Inter-electrode distances were ~20 mm, with a reference electrode over the right clavicle.

Single differential EMG signals were transmitted telemetrically (Myoresearch XP 1.06.68, Noraxon, USA). The raw EMG signals were recorded at a sampling rate of 1000 Hz and band-pass filtered (10–500 Hz).

The rate of change of the MDF was computed off-line with numerical algorithms using non-overlapping 1-s signal epochs across the sustained contractions (14). To have a comparable task across measurement sessions, only the first 30 s of sustained flexion and 60 s of sustained extension were included. To compare the rate of change of the MDF and allow comparison between groups and changes over time, the time course of the MDF was then normalized with respect to the intercept to produce the MDF slope.

The ARV was determined for 10% epochs of the 30 s sustained flexion and 60 s sustained extension contractions. To normalize the data and allow comparison between groups and changes over time, the ARV was normalized with respect to that in the first 10% epoch: the percentage change in ARV was then determined across the sustained contractions (10–100%). The data were analysed with a custom Matlab script (Matlab 2012a, The MathWorks Inc., Natick, MA, USA).

For each muscle the EMG data were expressed as ipsilateral or contralateral to the side of pain (or greatest pain), since greater myoelectric manifestations of fatigue ipsilateral to the side of pain have been shown (15).

Fatigue and pain ratings

The patients rated their neck pain intensity on a 100-mm visual analogue scale (VAS) before and after each endurance test. Perceived fatigue in the neck muscles was rated on Borg CR-10 scales (16) before and after each endurance test. During the extensor endurance test, perceived fatigue was obtained every 15 s and every minute during the 5-min recovery time before commencing the flexor endurance test. Fatigue was not assessed during the flexor endurance test, due to the inherent difficulty in speaking while performing this task.

Statistical analysis

For the current study, the EMG variables and endurance time were the primary outcome variables, whereas pain and fatigue ratings before and after each endurance test were secondary outcomes.

Mean and SD or median and interquartile range was used to describe patients' demographic characteristics.

A repeated-measure analysis of variance (ANOVA) with time (baseline, 14 weeks and 12 months) as within-subject factors, and the intervention group allocation (neck training or physical activity) as between-subject factors was used to evaluate endurance time. A Bonferroni *post-hoc* test was then applied. A 4-way repeated measures ANOVA was used to evaluate changes in the slope of the MDF for the extensor muscles during the extension contraction, with group (neck training and physical activity), muscle (SCap, UT, MT), side (ipsilateral, contralateral) and time (baseline, 14 weeks, 12 months) as factors. In addition, a 3-way repeated measures ANOVA was used to evaluate changes in the slope of the MDF for the SCM muscle during the flexion contrac-

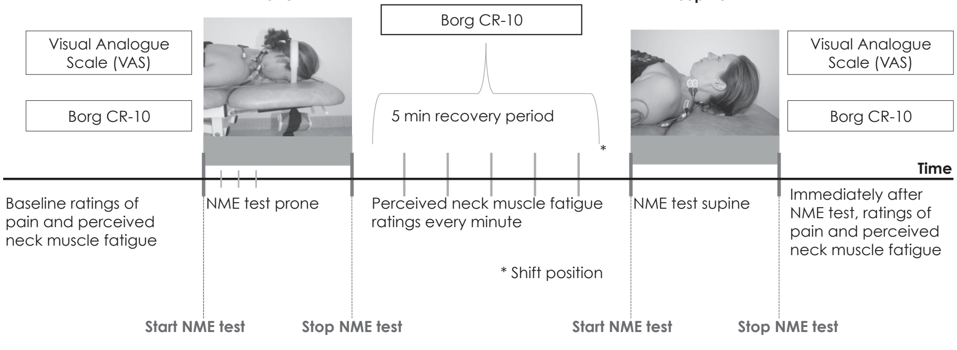

Fig. 2. Test procedure for the sub-maximal isometric neck muscle endurance tests (NME) in prone (extensor) and supine (flexor) positions.

tion with group (neck training and physical activity), side (ipsilateral, contralateral) and time (baseline, 14 weeks, 12 months) as factors.

The EMG ARV of the SCM and SCap muscles was expressed as a percentage change relative to the initial epoch. It was assessed for both flexion and extension contractions with a 3-way repeated measures ANOVA with group (neck training and physical activity), time (baseline, 14 weeks, 12 months) and stage (10–100% of the contraction time) as factors. Significant differences revealed by ANOVA were followed by post-hoc Student-Newman-Keuls pair-wise comparisons.

Present neck pain intensity, rated with VAS, and self-perceived fatigue, rated with the Borg CR-10 scale (ranging from 0–10), were treated as ordinal scales and non-parametric Friedman's ANOVA and Wilcoxon's test as *post-hoc* test were used.

Table II. *Descriptive statistics for endurance time, Borg ratings and visual analogue scale (VAS) ratings during the submaximal neck muscle endurance test (NME) at baseline, after 14 weeks and 12 months for all patients included (*n = 75*), the final group of patients (*n = 50*) divided in the neck training group (*n = 27*) and the physical activity group (*n = 23*). Mean and standard deviation (SD) for test times extension and flexion. Median and 25th –75th percentile for Borg and VAS ratings*

	All patients		Final group		Neck training		Physical activity	
	n		*n*		*n*		*n*	
Test time Extension (s), mean (SD)								
Baseline	74	201 (149)	50	199 (159)	27	191 (170)	23	208 (150)
14 weeks	52	216 (172)	50	223 (171)	27	213 (156)	23	234 (190)
1 year	45	209 (147)	43	215 (146)	24	200 (154)	19	234 (138)
Test time Flexion (s), mean (SD)								
Baseline	74	59 (40)	50	60 (41)	27	70 (48)	23	48 (28)
14 weeks	51	74 (57)	50	76 (56)	27	86 (60)	23	63 (51)
1 year	45	76 (52)	43	78 (52)	24	86 (58)	19	68 (41)
Fatigue rating Start (Borg CR-10), median (25th–75th)								
Baseline	74	0.4 (0–2)	50	0.5 (0–2)	27	0.5 (0–2)	23	0.3 (0–3)
14 weeks	52	0.5 (0–2)	50	0.5 (0–2)	27	0.5 (0–2)	23	0.5 (0–2)
1 year	42	0 (0–2)	41	0 (0–1.8)	22	0 (0–1)	19	0 (0–3.0)
Fatigue rating after 30 s Ext (Borg CR-10), median (25th–75th)								
Baseline	65	2 (0.5–4.5)	43	2 (0.3–4)	24	3 (0.6–4)	19	1 (0.3–3)
14 weeks	45	2 (0.3–3)	44	2 (0.3–3)	25	2 (0.3–3)	19	2 (0.3–3)
1 year	39	1 (0.3–3)	38	0.8 (0.3–3)	21	1 (0.3–3)	17	0.5 (0.2–3)
Fatigue rating after 45 s Ext (Borg CR-10), median (25th–75th)								
Baseline	63	2.5 (0.5–5)	41	2 (0.5–4)	23	3 (0.5–4)	18	1.5 (0.3–2.9)
14 weeks	44	2.5 (0.5–4)	43	2.5 (0.5–4)	25	2.5 (0.8–4.5)	18	2.5 (0.5–3.3)
1 year	37	1 (0.3–3)	36	1 (0.3–3)	20	1 (0.3–4)	16	1 (0.1–3)
Fatigue rating after 60 s Ext (Borg CR-10), median (25th–75th)								
Baseline	61	3 (1–5)	39	3 (1–5)	21	3 (1–5)	18	2.5 (1–4.5)
14 weeks	41	3 (0.8–4.5)	41	3 (0.8–4.5)	24	2.5 (1–5)	17	3 (0.5–4)
1 year	36	1.5 (0.4–3.8)	35	1.5 (0.3–4)	19	2 (0.5–4)	16	1.5 (0.3–4)
Fatigue rating Extension stop (Borg CR-10)[a], median (25th–75th)								
Baseline	74	7 (5.8–9)	50	7 (5–9)	27	7 (5–9)	23	8 (4–9)
14 weeks	52	8 (5–10)	50	8 (5–10)	27	8 (5–9)	23	7 (4–10)
1 year	42	5 (3.8–8)	41	5 (3.5–8)	23	5 (3–8)	18	7 (4–8)
Fatigue rating End, (Borg CR-10), median (25th–75th)								
Baseline	74	2 (0.2–3)	50	2 (0.5–3)	27	3 (1–3)	23	2 (0.3–3)
14 weeks	50	1.5 (0.3–3.3)	49	1.5 (0.3–3)	27	1 (0.3–3)	22	1.5 (0.2–3)
1 year	42	1.8 (0.5–4)	41	1.5 (0.4–3.5)	22	1 (0.5–4)	19	2 (0.3–3)
Present neck pain intensity, Start VAS (mm), median (25th–75th)								
Baseline	74	30 (5–45)	50	30 (5–41)	27	30 (5–45)	23	30 (5–40)
14 weeks	52	20 (0–40)	50	20 (0–40)	27	20 (0–40)	23	20 (0–40)
1 year	42	5 (0–30)	41	1 (0–30)	22	3 (0–31)	19	1 (0–20)
Present neck pain intensity End, VAS (mm), median (25th–75th)								
Baseline	74	40 (10–50)	50	40 (10–50)	27	40 (10–50)	23	40 (5–50)
14 weeks	50	20 (0–60)	49	20 (0–60)	27	20 (0–50)	22	30 (0–64)
1 year	41	3 (0–40)	41	2 (0–38)	22	4 (0–40)	19	1 (0–30)

[a]Fatigue rating at the end of the NME test in prone position.

Table III. *Repeated measures analysis of variance (ANOVA), Bonferroni post-hoc test, mean and standard deviation (SD) for endurance time (s) at baseline, 14 weeks and 1 year after intervention, for those who were tested at 3 occasions (*n *= 43), divided in the neck training group (*n*= 24) and the physical activity group (*n *= 19)*

	Baseline Mean (SD)	14 weeks Mean (SD)	12 months Mean (SD)	ANOVA *p* occasion	*p* group	*p* occasion X group	*Post hoc* Baseline–14 weeks	*Post hoc* Baseline–12 months	Post *hoc* 14 weeks–12 months
Endurance All	211 (166)	232 (179)	215 (146)	0.480	0.544	0.957			
Etensor Neck training	202 (177)	220 (161)	200 (154)						
Physical activity	222 (156)	248 (203)	234 (138)						
Endurance All	64 (43)	80 (59)	78 (52)	0.005	0.113	0.814	0.814	0.026	1.000
Flexor Neck training	74 (49)	91 (61)	86 (58)						
Physical activity	50 (29)	66 (55)	68 (41)						

All statistical analyses were conducted using the Statistical packages for the social sciences for Windows software (SPSS release 22) and $p < 0.05$ was considered statistically significant.

RESULTS

Patient characteristics and general outcome

Of the 75 patients included, 50 patients attended baseline and at least 1 follow-up session (Fig. 1). One patient was excluded from analysis of endurance time and EMG at baseline due to pain that resulted in too short endurance time. There were no significant differences in age, sex or initial pain intensity between those who only completed the baseline tests and those who also completed the follow-up tests (Table I). No adverse events were recorded.

Table II shows descriptive statistics for endurance time, perceived fatigue ratings and pain during the endurance tests at baseline, after 14 weeks and 12 months for all patients included ($n = 75$), and the final group of patients with EMG recordings ($n = 50$) divided into the neck training group ($n = 27$) and the physical activity group ($n = 23$).

Endurance time

Extensor endurance time did not change following either intervention ($p = 0.480$) and no differences were observed between groups ($p = 0.544$) (Table III). Furthermore, there was no interaction effect between time and group ($p = 0.957$). However, neck flexor endurance time significantly increased for both groups ($p < 0.005$), but with no difference between groups ($p = 0.113$). No interaction was seen between time and group for neck flexor endurance ($p = 0.814$). *Post hoc* analyses revealed a significant increase in neck flexor endurance time at 14 weeks compared with baseline and this was maintained at the 12-month follow-up.

EMG

Fig. 3 illustrates the slope of the MDF of the SCM muscle at each time-point for each group during the sustained flexion contraction. Fig. 4 illustrates the slope of the MDF of the SCap, UT and MT muscles at each time-point for each group during the sustained extension contraction. Despite trends, no significant change in the MDF was noted for any muscle following the interventions for either group (all $p > 0.05$).

Fig. 5 illustrates the percentage change (relative to the initial 10%) in EMG amplitude (ARV) across the sustained flexion contraction for both the SCM (agonist) and SCap (antagonist) muscles for both groups. The percentage change in SCM ARV increased over the duration of the contraction regardless of group or time ($F = 53.36$, $p < 0.00001$), but did not differ between groups and was not affected by either intervention. The percentage change in SCap ARV also increased during the flexion contraction ($F = 43.96$, $p < 0.00001$). However, an

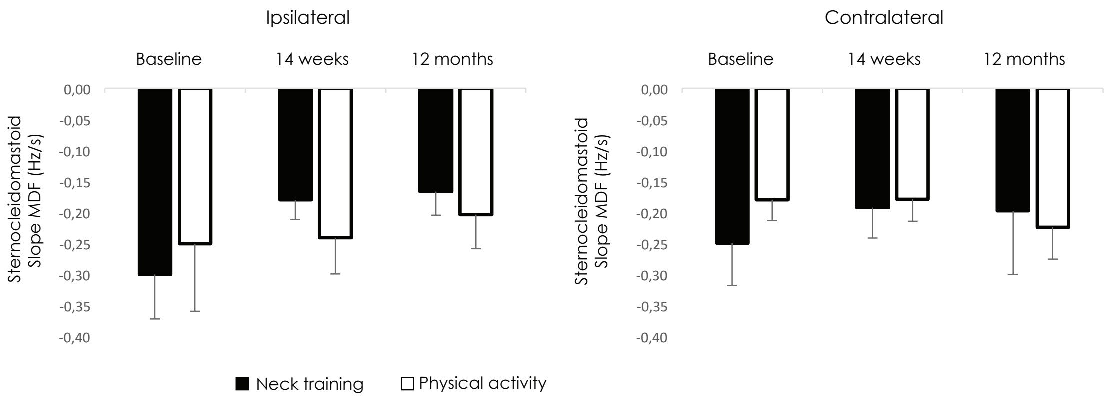

Fig. 3. Median frequency (MDF) slope recorded from the sternocleidomastoid muscle ipsilateral and contralateral to the side of greatest pain at each time-point for each group during sustained neck flexion.

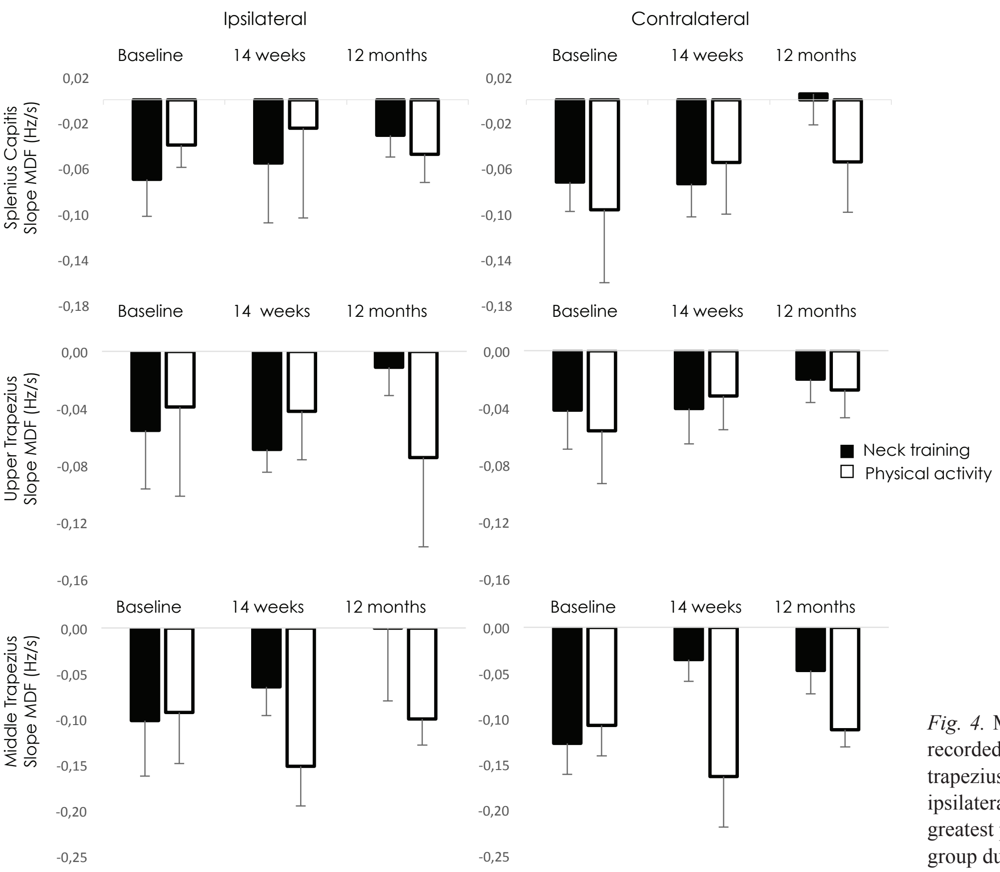

Fig. 4. Median frequency (MDF) slope recorded from the splenius capitis, upper trapezius, and middle trapezius muscles ipsilateral and contralateral to the side of greatest pain at each time-point for each group during sustained neck extension.

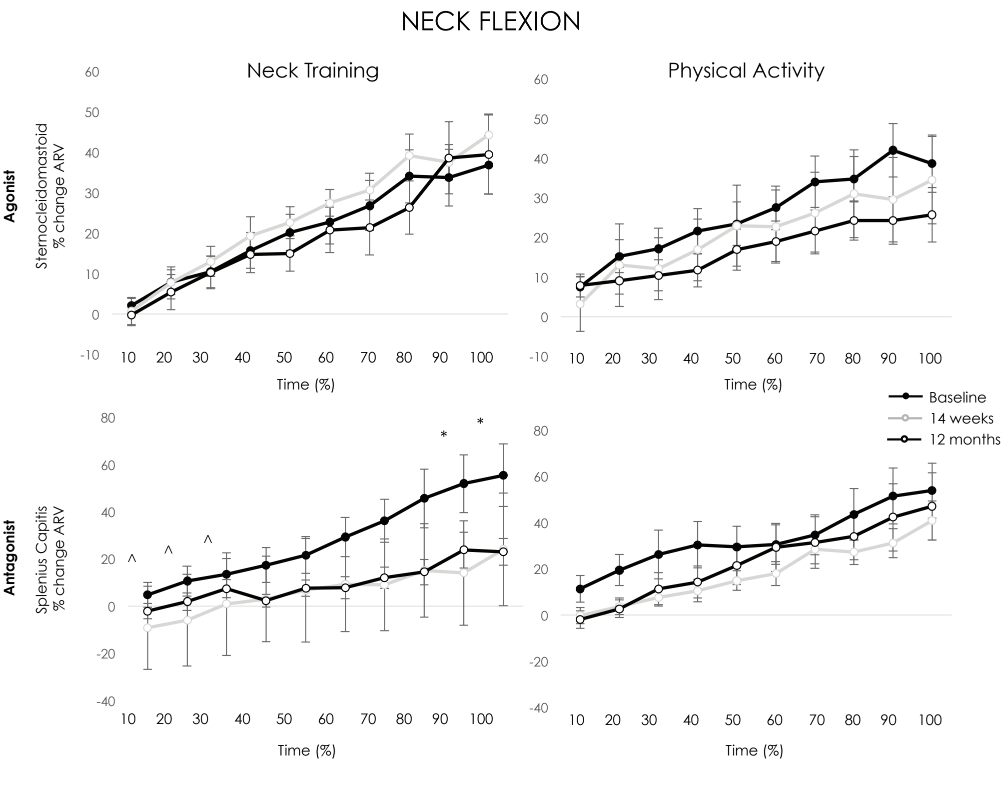

Fig. 5. Percentage change in electromyography (EMG) amplitude (average rectified values; ARV) across the sustained neck flexion contraction for both the sternocleidomastoid muscle (agonist) and splenius capitis (antagonist) recorded at each time-point for both intervention groups.

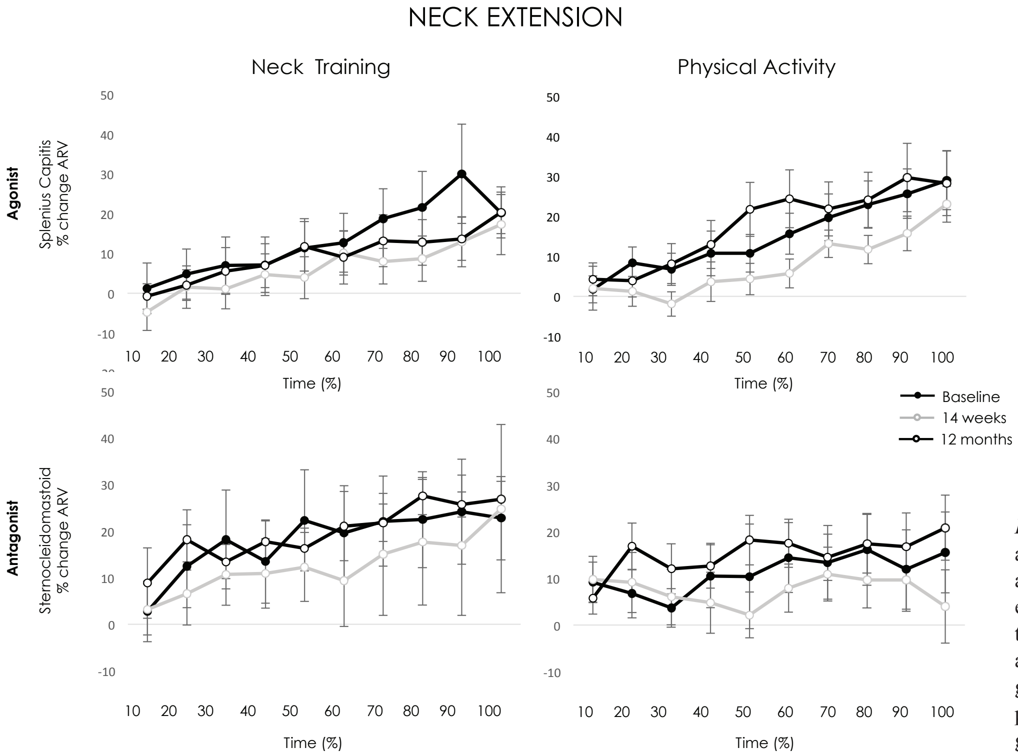

Fig. 6. Percentage change in average rectified values (ARV) across the sustained neck extension contraction for both the splenius capitis (agonist) and sternocleidomastoid (antagonist) recorded at each time-point for both intervention groups.

interaction was found between group, time and stage ($F=2.59$, $p<0.001$). For the neck training group, there was a significant reduction in the percentage change in SCap ARV towards the end of the contraction (90–100% of the endurance time) from baseline to 14 weeks. Moreover, for the neck training group there was a significant reduction in the percentage change in SCap ARV towards the beginning of the contraction (10–30% of the endurance time) from baseline to 12 months. This finding indicates a reduction in the degree of co-activation of the antagonist muscle during the flexion contraction following the neck-specific training programme. No difference was observed between the ARV values recorded from SCap during the flexion contraction between 14 weeks and 12 months. No change was observed for the prescribed physical activity group.

Fig. 6 illustrates the percentage change (relative to the initial 10%) in ARV across the sustained extension contraction for both

Table IV. *Friedman's analysis of variance (ANOVA), Wilcoxon's test as post-hoc test and median and 25th–75th percentile of fatigue ratings (Borg CR-10 scale) at 30 s, 45 s, 60 s and at end of the neck muscle endurance (NME) test in prone, and neck pain (VAS) at baseline, 14 weeks and 1 year after intervention, and neck pain rated before and after the NME in prone and after supine position, for those who were tested at 3 occasions (*n *= 43)*

	Baseline	14 weeks after	1 year after intervention	Friedman ANOVA	Wilcoxon Baseline – 14 weeks after	Wilcoxon Baseline – 1 year after	Wilcoxon 14 weeks – 1 year after
Fatigue, Start *n*=41	0.3 (0–2)	0.5 (0–2)	0 (0–2)	0.165			
Fatigue, 30 s *n*=30	1 (0.3–3)	0.5 (0–2)	0.5 (0–2.5)	0.264			
Fatigue, 45 s *n*=28	2 (0.4–3)	1 (0.3–3)	0.5 (0.3–2)	0.209			
Fatigue, 60 s *n*=26	2 (0.5–4)	1.5 (0.5–3)	1 (0.3–2)	0.134			
Fatigue, Stop[a] *n*=41	7 (5–9)	8 (4–9)	5 (3.5–8)	0.002	0.459	0.006	0.016
Fatigue, End *n*=40	2 (0.3–3)	1.5 (0.3–4)	2 (0.5–4)	0.808			
Neck pain, Start *n*=41	30 (5–45)	20 (0–40)	10 (0–30)	0.000	0.273	0.000	0.014
Neck pain, End *n*=41	40 (11–60)	20 (0–60)	2 (0–39)	0.000	0.127	0.000	0.005

[a]Fatigue stop: fatigue rating at the end of the NME test in prone position.

SCap (agonist) and SCM (antagonist) muscles for both groups. The percentage change in both SCap ($F=22.17$, $p<0.00001$) and SCM ($F=3.50$, $p<0.001$) ARV increased over the duration of the contraction regardless of group or time, but did not differ between groups and was not affected by either intervention.

Fatigue ratings and pain

Despite a tendency for reduced fatigue scores over time for each fixed time-point, the change was not significant except for the fatigue rating at the end of the extension test. This was significantly lower at 12 months than at baseline and at 14 weeks (Table IV). The patients rated significantly lower neck pain intensity at both the start and end of the endurance tests after 12 months compared with baseline and 12 months compared with the 14-week follow-up (Table IV). The patients interrupted the endurance tests (extension/flexion) at baseline due to fatigue (21/27) or pain (17/13) or both (9/3) or other reasons (3/7). Similar results were shown at the 14-week follow-up: fatigue (26/30) or pain (8/13) or both (10/3) or other reason (3/3). At 12 months, the reasons were: fatigue (24/34) or pain (11/6) or both (5/1) or other reasons (10/9).

DISCUSSION

Fourteen weeks of either neck-specific training or general physical activity lead to increased neck flexor endurance immediately after training and at a 12-month follow-up. Changes in endurance were not reflected in changes in myoelectric manifestations of fatigue of the neck muscles. However, for the neck training group only, there was a significant reduction in the activation of the SCap during the neck flexion task at 14 weeks and at 12 months, indicating a reduction in neck muscle co-activation.

Overall neck pain intensity decreased significantly at the 12-month follow-up compared with baseline and 14 weeks for both groups. Physical activity with different forms of exercises may reduce pain and improve function for patients with neck pain disorders (17–19) and therefore the present interventions might have contributed to this recovery. However, we cannot associate the improvement entirely with the interventions since no control group was included.

Neck flexor endurance improved at 14 weeks compared with before the intervention period for both groups, but did not further improve at the 12-month follow-up. On the contrary the fatigue ratings had not changed by 14 weeks, and significant changes were only noted at 12 months. This could indicate that the experience of fatigue takes longer to change, since the perception of fatigue is related to, e.g. psychosocial factors, such as fear-avoidance beliefs, anxiety and coping strategies and stress, depression, hopelessness, and job control, which can take longer to improve (20). The same pattern was observed for the pain intensity ratings. Clinically, the fatigue rating during an endurance test can provide valuable information. The improvement in fatigue ratings at the end of the neck extensor endurance test can be associated with reduced fatigue intensity and maybe increased self-confidence that allowed the patients to lift their head without fear of pain, hence providing improved muscle endurance. The observation that neck flexion, but not extension, endurance improved with training suggests that higher load training or more specific training of the neck extensor muscles is required to improve endurance time.

Although endurance time and perceived fatigue improved over time, there was no significant change in the MDF of the EMG signal. This suggests that the improvement was not due to peripheral adaptations occurring in the muscle, but, rather, central adaptations or changes in the willingness of the patient to perform the task (e.g. reduced fear of pain). However, there were trends present suggesting that the neck-specific training had some effect on reducing the MDF slope. Although speculative, perhaps a longer training duration or a higher volume of training may have induced a larger adaptation. For instance, a previous exercise study in people with chronic idiopathic neck pain (21) demonstrated a reduction in the slope of the mean spectral frequency measured from the neck flexor muscles following an endurance training programme that included an external load on the flexor muscles (weighted sand-bags applied to the forehead).

One feature observed in people with neck pain is increased antagonistic neck muscle activity (22, 23). Co-activation of the neck flexor and extensor muscles may be a protective strategy (24) and although increased co-activation may be beneficial in acute pain to protect sensitive cervical structures, it may have negative long-term consequences. These include reduced neck strength and eventual pain recurrence caused by increased load on the spine (25). Co-activation of agonist/antagonist muscles significantly increases spinal stiffness (26) and spinal compression is considered sufficient to induce lumbar spine injuries and, consequently, low-back pain (27). It may also be relevant in persistent neck pain disorders (28). The neck-specific training, but not the prescribed physical activity training, reduced the level of antagonist muscle activity during the sustained neck flexion contraction, both immediately following the intervention and at the 12-month follow-up. Although data from asymptomatic subjects were not available for comparison, the reduction in antagonist activity, and thus reduction in co-activation, probably reflects a more efficient neuromuscular strategy during the task.

A limitation to this study was the drop-out rate. This was high either due to lack of time of the subject to participate in the intervention or due to technical difficulties with the EMG recordings. Although significant results were found, the sample size was relatively small, and therefore the results must be interpreted with caution. However, the group of included patients could be considered as representative of a larger group of patients with CR. Further studies are needed to evaluate training effects over a longer term and evaluate whether training reduces the recurrence rate of neck pain. Further study is required into psychosocial factors and their interaction with measures of muscle behaviour and changes with intervention.

In conclusion, patients with CR showed both short- and long-term improvement in neck flexor endurance regardless of whether they participated in a programme of neck-specific exercise or general physical activity. Overall, perceived neck muscle fatigue during the endurance tasks and neck pain intensity were reduced at 12 months for both groups. Only patients in the neck training group displayed reduced antagonist co-activation muscles during sustained neck flexion, which implies that neck-specific training may be more relevant for some patients who display more specific neuromuscular changes.

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