Neck Flexor Muscle Strength, Efficiency, and Relaxation Times in Normal Subjects and Subjects With Unilateral Neck Pain and Headache

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ABSTRACT. Barton PM, Hayes KC. Neck flexor muscle strength, efficiency, and relaxation times in normal subjects and subjects with unilateral neck pain and headache. Arch Phys Med Rehabil 1996;77:680-7.

Objective: To determine the test-retest reliability of a new method for measuring muscular strength, efficiency, and relaxation times of the neck flexor musculature of healthy adults, and to compare these neck flexor muscle properties in subjects who have unilateral neck pain and headache with those in controls.

Design: Subjects lay supine and isometrically flexed their necks against a force transducer attached to the back of a webbing and velcro helmet. Electromyograms (EMGs) were recorded from surface electrodes on the sternocleidomastoid (SCM) muscles. Two consecutive sessions of five contractions of varying levels of effort from minimal through moderate and maximal effort were analyzed.

Setting: Ambulatory referral center.

Participants: Volunteer control subjects ($n = 10$, 3 men and 7 women) were recruited from hospital and university personnel. Volunteer neck pain subjects ($n = 10$, 3 men and 7 women) were recruited from a physiatric chronic pain practice and a hospital outpatient physical therapy practice.

Results: In the controls, the intraclass correlation coefficients (ICCs) for the first two maximum neck flexion contractions were: peak force ICC = .81; peak force/body weight ICC = .75; average force ICC = .75; force relaxation time ICC = .73; SCM EMG relaxation times: right ICC = .60 and left ICC = .67. Comparing sessions 1 and 2 the intraclass correlations for SCM efficiencies were right ICC = .58 and left ICC = .97. The peak force in controls ($\bar{x} = 45.3 \pm 17.6$N) was reduced by 50% in the neck pain subjects ($\bar{x} = 22.4 \pm 13.1$N) ($p = .004$). Similarly, peak force/body weight in the neck pain subjects ($\bar{x} = 0.3 \pm 0.2$N/kg) was 46% of controls ($\bar{x} = 0.7 \pm 0.2$N/kg) ($p = .001$), and average force in the neck pain subjects ($\bar{x} = 12.1 \pm 7.5$N) was 43% of controls ($\bar{x} = 28.5 \pm 11.0$N) ($p = .001$). In two neck pain subjects, SCM EMG and force relaxation times were abnormally long in both the affected and the unaffected SCM muscles, exceeding the control values by greater than 3 standard deviations. The difference between the right SCM efficiency of the control subjects ($\bar{x} = 0.3 \pm 0.2$N/μV) and the affected SCM efficiency of the neck pain subjects ($\bar{x} = 0.1 \pm 0.1$ N/μV) approached the $p < .05$ criterion for significance ($p = .055$).

Conclusion: The technique was found to be highly reliable for the measurement of neck flexor peak force, peak force/body weight, average force, and force relaxation time, and moderately reliable for the quantitation of SCM EMG relaxation times and SCM efficiency. All force values were significantly lower in the neck pain population compared with the controls. In the neck pain population, force and SCM EMG relaxation times, as well as efficiencies, suggested abnormalities. Neck pain subjects showed no significant differences in SCM EMG relaxation time or SCM efficiency between affected and unaffected SCM muscles.

TRAUMA-RELATED neck pain and headache are increasingly prevalent and costly in terms of treatment costs, income support, and lost productivity.[1] Assessment and treatment of these conditions usually proves challenging. Traditional medicine has tended to focus on diagnosis rather than on management of the morbidity caused by these "benign muscle tension headaches." For those attempting to manage this problem, success has been hampered by a lack of adequate assessment tools coupled with a poor understanding of the cause and perpetuators of the condition. At best, clinical evaluation includes use of pain diagrams and scales, examination of posture, assessment of cervical range of motion with goniometers, manual assessment for segmental spinal motion, evaluation of muscle tenderness with palpation and algometry, and attempts to evaluate neck muscle strength.[2-12] At the present time, however, there are few normative values against which to compare a patient's status, and little information is available on how these values are associated with the underlying complaint of pain.

The functions of the neck muscles have been well studied electromyographically.[13-18] MacNab[19] found that in flexion-extension whiplash injuries from motor vehicle accidents, the sternocleidomastoid (SCM) and longus colli muscles sustain extensive injury. Evidence of neck flexor muscle dysfunction also comes from the electromyography (EMG) demonstration of hyperactivity in the SCM muscle of patients with temporomandibular joint problems[20] and the cervical myoelectric response to acute experimental SCM pain.[21]

We were prompted to study the role of the SCM as it relates to neck pain, but most particularly headache, by the pain referral patterns[22] documented by our patients and by the concurrent observation that many of these affected patients were unable to lift their head off the examining table when lying supine. It had been noted during biofeedback relaxation training that some patients were unable to relax the SCM muscles, suggesting that muscle pain may be perpetuated by sustained muscle contractions.

The present study measured the flexion force generated by the combined (bilateral) action of the SCM muscles as well as

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Submitted for publication February 3, 1995. Accepted in revised form November 30, 1995.

Supported by the Department of Physical Medicine and Rehabilitation, The University of Western Ontario, and Parkwood Hospital, London, Ontario, Canada.

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0003-9993/96/7707-3410$3.00/0

Table 1: Demographics of the Control and Neck Pain Subjects

Subjects	N	Age (yr)	Weight (kg)	Height (cm)
Controls				
Women	7	27.4 (9.6)	63.8 (7.6)	164.6 (4.0)
Men	3	27.3 (1.5)	74.0 (8.7)	180.0 (5.2)
All	10	27.4 (7.9)*	66.9 (8.9)	169.2 (8.5)
Neck Pain				
Women	7	41.0 (10.8)	67.4 (11.1)	163.8 (7.6)
Men	3	46.0 (17.1)	84.4 (5.7)	177.1 (4.5)
All	10	42.5 (12.2)	72.5 (12.5)	167.8 (9.2)

All values expressed as $\bar{x}$(SD).
*Significant difference between control subjects and neck pain subjects.

the EMG-net force relationships for each SCM muscle. The method was developed to be especially relevant to those patients with severe neck flexor weakness who could not easily lift their heads off the bed when lying supine and thus could not be assessed by other measures.

The specific objectives of the present study were:

1. To determine the test-retest reliability of a new method for quantitating neck flexor strength, muscular efficiency,[23,24] SCM EMG relaxation time, and force relaxation time in control subjects.
2. To test the hypothesis that there are reductions in the strength and muscular efficiency and prolongations of the SCM EMG relaxation time and force relaxation time of the affected SCM muscle in patients with unilateral chronic neck pain and headache compared with asymptomatic control subjects.
3. To compare the SCM EMG relaxation times and muscular efficiencies of affected and unaffected SCM muscles in the subjects with unilateral chronic neck pain and headache.

Use of the measure of muscular efficiency, ie, EMG-net force relationship,[23,24] was predicated on the assumption that it provides a useful index of conditioning that does not require maximal contraction and is independent of motivation. For this study muscular efficiency (E) was defined as $E = 1/m$, where m is the linear regression beta coefficient describing the slope of the line of best fit for the average EMG (AEMG) as a function of the average net force level (AForce).[24]

MATERIALS AND METHODS

Subjects

Controls. Healthy adult subjects ($n = 10$) were recruited from hospital and university personnel. Three men and 7 women volunteered for the study. They completed a questionnaire regarding symptoms of headache, neck, arm, or upper back pain and underwent a physical examination including neck range of motion and palpation of neck muscles for tenderness.[22] Candidates were excluded if they had a history of whiplash, other neck injury, recurrent (more than 1 per month) headache or neck pain, neurological or orthopedic injury that was considered likely to influence their neck strength, decreased or painful cervical range of motion, or extensive neck muscle tenderness. They returned 1 week later for testing. The physical characteristics of the subjects are shown in table 1. All subjects had normal cervical range of motion,[25-27] and there were no cases where the sternocleidomastoid muscles were tender.

Neck pain subjects. Candidates for the study were identified from the practice of a physiatrist specializing in the management of chronic pain and the physiotherapy practice of a hospital outpatient department in London, Ontario. They completed a medical questionnaire regarding symptoms of headache, neck, arm, or upper back pain. A physical examination was done that included neck range of motion with a standard goniometer[28] and palpation of neck muscles for tenderness.[22] Candidates were excluded if they experienced unilateral headache without neck pain. Ten symptomatic subjects, 3 men and 7 women, volunteered for the study. They had experienced unilateral neck pain and headache for longer than 3 months' duration and had unilateral tenderness to palpation of the SCM muscle on the same side as the neck pain. Six of these subjects had been injured in motor vehicle accidents and 4 had work-related injuries (2 had a sudden onset caused by a single injury, 2 had a repetitive-use injury with gradual onset).

The demographics of the neck pain subjects are shown in table 1. The neck pain subjects had a mean duration of symptoms of 39 ± 24 months. Their cervical spine range of motion was decreased, particularly in flexion, extension, right rotation, and left rotation, when compared with standard values in the literature.[25-27] Of the six neck muscles palpated bilaterally, they had 5 ± 1 tender muscles on the same side as their unilateral headache and neck pain, and 1 ± 1 tender muscles on the asymptomatic side (table 2).

All subjects (control and neck pain) gave informed consent, and the project was approved by the university's Review Board for Health Sciences Research Involving Human Subjects.

Measurement of Neck Flexion Force

Each subject reclined on a plinth, in a sagitally symmetrical supine position. The head was firmly strapped into a webbing and velcro harness. A spirit level was attached by velcro to the harness over the forehead and videotaped to ensure that during active isometric flexion of the neck there was no significant deviation of the head from the sagittal plane. The harness was attached in the region of the subject's occipital ridge to a force transducer that was rigidly fixed to the frame of the plinth below the hole in the plinth surface. Directly above the subject, affixed to the ceiling, was a signal light (fig 1).

The subject was instructed to start isometric neck flexion when a green light appeared and to stop immediately on a red light. Neck flexion force was measured by a Shaevitz force transducer[a] (range = 0 to 50lb), fed through an LVDT (Linear Variable Differential Transformer) signal amplifier and displayed on a storage oscilloscope. Force records were obtained for a total of 3,000msec: ~500msec before the green light (preburst or rest period), ~1,000msec until the red light flashed (burst or contraction period) and then another ~1,500 msec (post-burst or relaxation period) (fig 2).

Two consecutive sessions of force measurements were collected on one day with a 15-minute rest between sessions 1 and 2. Each session had five contraction trials at varying levels of effort, from minimal through moderate and maximal effort. This yielded 3 to 4 trials at maximum effort. No feedback was provided to the subjects about their performance. The sequence of force levels was randomized to minimize order effects within each session. Because the slope coefficient of the line describing the AEMG/AForce relationship was the variable of interest in later derivation of the efficiency, no attempt was made to standardize the levels of force between subjects.

Measurement of Integrated EMG

Electromyographic recordings of the sternal heads of both right and left SCMs were obtained from surface electrodes placed at the midpoint between the sternum and the mastoid, and reference surface electrodes placed at the medial tip of each clavicle. A ground electrode was placed on the sternum. The EMG signals were fed through a Disa/Dantec (Type 16C01) preamplifier and amplifier,[b] filtered from 10Hz to 1kHz, and displayed on a storage oscilloscope. Triggered EMG signals

Table 2: Duration of Symptoms, Cervical Spine Range of Motion, and Number of Tender Muscles on Each of the Affected and Unaffected Sides in the Neck Pain Subjects

Neck Pain Subjects	Duration (mo)	Cervical Range of Motion (degrees)						No. of Tender Muscles	
		Fl	Ex	RR	LR	RB	LB	A Side	U side
Women	37 (16)	33 (22)	44 (19)	48 (22)	52 (21)	33 (10)	31 (3)	5 (1)	1 (1)
Men	44 (43)	23 (12)	23 (10)	52 (10)	42 (10)	27 (10)	30 (10)	4 (2)	0 (1)
All	39 (24)	30 (19)	38 (19)	49 (19)	49 (18)	31 (10)	31 (6)	5 (1)	1 (1)

All values expressed as $\bar{x}$(SD).
Muscles assessed bilaterally: suboccipital, cervical paraspinal, scalene, sternocleidomastoid upper trapezius, levator scapulae.
Abbreviations: Fl, flexion; Ex, extension; RR, right rotation; LR, left rotation; RB, right bending; LB, left bending; A, affected; U, unaffected.

were collected concurrently with the force signal for a total of 3,000msec (figs 1 and 2).

Signal Collection and Processing

Force and EMG signals were sampled and collected at 2,000Hz and stored on videotape using a PCM VCR Recorder Adapter.[c] These signals were later analog-to-digital (A/D) converted at 1,000Hz with an MDAS 7000 A/D Converter[d] and stored for analysis. The EMG signals were calibrated, the average bias level was removed, and the waveforms were rectified. The force signals were calibrated and the bias removed to make the zero force level occur at the lowest force signal level. A customized interactive graphics software program was used to determine the onset and termination time for each of the EMG burst and the force deflections.

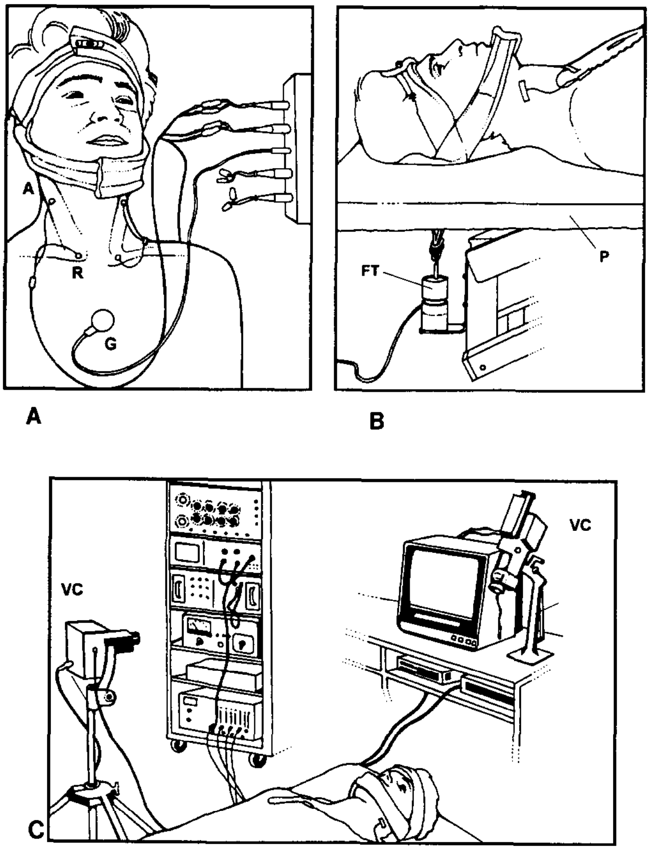

Fig 1. (A) The placement of the active (A, midpoint of sternal head of SCM), reference (R, medial tip of clavicle), and ground (G, sternum) electrodes, as well as the webbing and velcro harness for force measurement. (B) The attachment, through a hole in the plinth (P), of the harness to the force transducer (FT) below the plinth. (C) The overall equipment setup including video cameras (VC).

Data Analysis

AEMG and AForce. AEMG, the average time integral of the rectified EMG signal amplitude (mV), was measured for each of the right and left SCM muscles in control subjects and for the affected and unaffected SCM muscles in the neck pain subjects. AForce, the average time integral of the isometric bilateral neck flexion force (N), was calculated for each of the three periods: pre-burst, burst, and post-burst. The following equations were used:

$$\text{AEMG} = 1/T \int |\text{EMG}|\,dt \qquad \text{[Eqn 1]}$$

$$\text{AForce} = 1/T \int |F|\,dt \qquad \text{[Eqn 2]}$$

Efficiency (E). For each of the right and left SCM muscles in control subjects and for the affected and unaffected SCM muscles in the neck pain subjects, the relationship between AEMG and AForce was investigated for the burst period by calculating a line of best fit using linear regression. The slope coefficient, the variable of interest in deriving the efficiency, was derived from the regression analysis. All 10 trials in sessions 1 and 2 were included (see footnotes to tables 3 and 4).

For the force recordings, the average value of the pre-burst or post-burst level (whichever was less) was subtracted from the AForce burst level to remove any noise associated with the

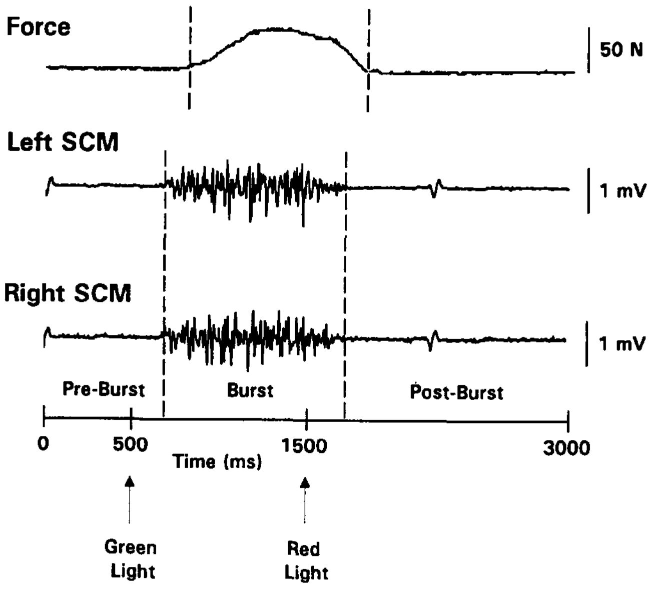

Fig 2. The data collection format for measurement of isometric neck flexion force and left and right SCM EMG recordings. The burst period began at ~500msec when the green light flashed and ended at ~1,500msec when the red light flashed.

force signal. The reciprocal of the slope (m) of the line of best fit for AEMG/AForce was used in the intraclass correlation determinations of reliability, in the comparison of side-to-side differences, and in comparisons between control and neck pain subjects.

$$m = AEMG/AForce \quad [Eqn\ 3]$$

$$E = 1/m = AForce/AEMG \quad [Eqn\ 4]$$

where m = linear regression beta coefficient describing the slope of the line of best fit for the plot of AEMG versus AForce. E = efficiency expressed as N/uV.

Peak force, peak force/body weight, and average force. In the reliability studies with the control subjects, the peak force, peak force/body weight, and average force were determined for each of the first two maximum isometric neck flexion contractions in the 10 trials. For the comparisons between control and neck pain subjects, the peak force (N), peak force/body weight (N/kg), and average force (N) were determined from the average of the 3 to 4 maximum isometric neck flexion contractions in the 10 trials.

EMG and force relaxation times. In the reliability studies with the control subjects, the force and EMG relaxation times were determined for each of the first two maximum neck flexion contractions. For the comparisons between control and neck pain subjects the force and EMG relaxation times were determined from the average of the 3 to 4 maximum isometric neck flexion contractions. Relaxation times were calculated using the equation below, where 1,500 is the time in milliseconds when the red light flashed to indicate the end of the contraction and the post-burst latency is the time when the force or EMG recordings returned to the pretest levels.

$$\text{Relaxation time (ms)} = (\text{post-burst latency} - 1{,}500)\text{msec}$$

Statistical Analysis

Standard descriptive statistics were used initially to characterize the data. Intraclass correlations (based on a random effects model analysis of variance [ANOVA]) were used to determine the reliability of measurement (Model 1.1 from Shrout and Fleiss[29]). This involved explicit partitioning of the "error free" variance between subjects and the "error" variance (within subjects across sessions). A *t* test for dependent (correlated) samples was used to test for any differences between left and right SCM relaxation times and efficiencies in control subjects and between affected and unaffected SCMs in neck pain subjects. A one-tailed *t* test for uncorrelated samples was used to test for a significant reduction in neck flexion force in neck pain subjects compared to controls. A one-tailed *t* test for uncorrelated samples was used to test for a significant decrease in efficiency for neck pain subjects compared to normal control subjects.

RESULTS

Figure 3A illustrates recordings from a control subject. The traces show the isometric neck flexion force and the EMG interference patterns from the left and right SCM muscles for 3 different levels of force production (minimum, intermediate, and maximum). Figure 3B shows the linear regression lines of best fit characterizing the relationships between the AEMG for the individual SCM muscles and the isometric neck flexion force (AForce). In Figure 3, a control subject, the linear model clearly provided a good fit to the data ($r = .98$ for the left SCM and $r = .96$ for the right SCM). In figure 4, a neck pain subject, there was also a good data fit ($r = .92$ for the affected SCM and $r = .89$ for the unaffected SCM).

Reliability

Descriptive data of the control group results are summarized in table 3 together with the variance estimates used to derive the intraclass correlation indices of reliability. The intraclass correlation coefficients (ICC) were high for the peak force (ICC = .81), peak force/body weight (ICC = .75), average force (ICC = .75), force relaxation time (ICC = .73) and for the left SCM efficiency (ICC = .97). The results yielded lower reliability indices for the right (ICC = .60) and left (ICC = .67) SCM EMG relaxation times as well as the right SCM efficiency (ICC = .58).

Neck Pain Subjects Versus Control Subjects

All force values were significantly lower in the neck pain subjects than in the controls (table 4). The peak force in controls ($\bar{x} = 45.3 \pm 17.6$N) was reduced by 50% in the patients ($\bar{x} = 22.4 \pm 13.1$N) ($p = .004$). Similarly, peak force/body weight in the neck pain subjects ($\bar{x} = 0.3 \pm 0.2$N/kg) was 46% of controls ($\bar{x} = 0.7 \pm 0.2$N/kg) ($p = .001$), and average force in the neck pain subjects ($\bar{x} = 12.1 \pm 7.5$N) was 43% of controls ($\bar{x} = 28.5 \pm 11.0$N) ($p = .001$). There were no significant differences between the right ($\bar{x} = 449.4 \pm 151.2$msec) and left ($\bar{x} = 469.3 \pm 175.3$ msec) SCM EMG relaxation times in the control subjects, indicating a fair degree of symmetry in response. The SCM EMG relaxation times for the majority of neck pain subjects were generally similar to the controls (within ±2 SD of the mean of the controls). In two neck pain subjects, however, SCM EMG relaxation times were abnormally long, exceeding the control values by greater than 3 standard deviations. These long relaxation times were evident in both the affected and the unaffected SCM muscles, even though pain was only acknowledged by the neck pain subjects to be unilateral.

The force relaxation times correlated highly with the SCM EMG relaxation times in the control subjects ($r = .97$, $p < .05$ for the right side and $r = .96$, $p < .05$ for the left side) and in the neck pain subjects ($r = .98$, $p < .05$ for both the affected and unaffected sides). The force values lagged the EMG values by approximately 60msec in the control subjects and by approximately 60msec on both the affected and unaffected sides of the neck pain subjects. Two neck pain subjects with abnormally long EMG relaxation times also had abnormally long (>3 SD) force relaxation times.

The values for the muscular efficiency for control and neck pain subjects are summarized in table 4 and illustrative sets of data appear in figures 3 and 4. In table 4, the difference between the right SCM efficiency of the control subjects ($\bar{x} = 0.3 \pm 0.2$N/μV) and the affected SCM efficiency of the neck pain subjects ($\bar{x} = 0.1 \pm 0.1$N/μV) approached statistical significance ($p = .055$).

DISCUSSION

The present study was designed to test the reliability of a new method for evaluating neck flexor function and then to determine if any differences existed between control subjects and subjects with unilateral neck pain and headache. The specific measures of interest were neck flexor muscle strength, muscular efficiency, SCM EMG relaxation time, and force relaxation time. These were used in an attempt to shed light on some of the factors that are thought to contribute to the perpetuation of symptoms in patients with chronic neck pain and headache. Previous studies have indicated that flexor and extensor muscle strength are reduced in patients with neck pain.[8,12,21]

Reliability

The intraclass correlation analyses of the test-retest reliability revealed that the reproducibility of values was good for peak force,

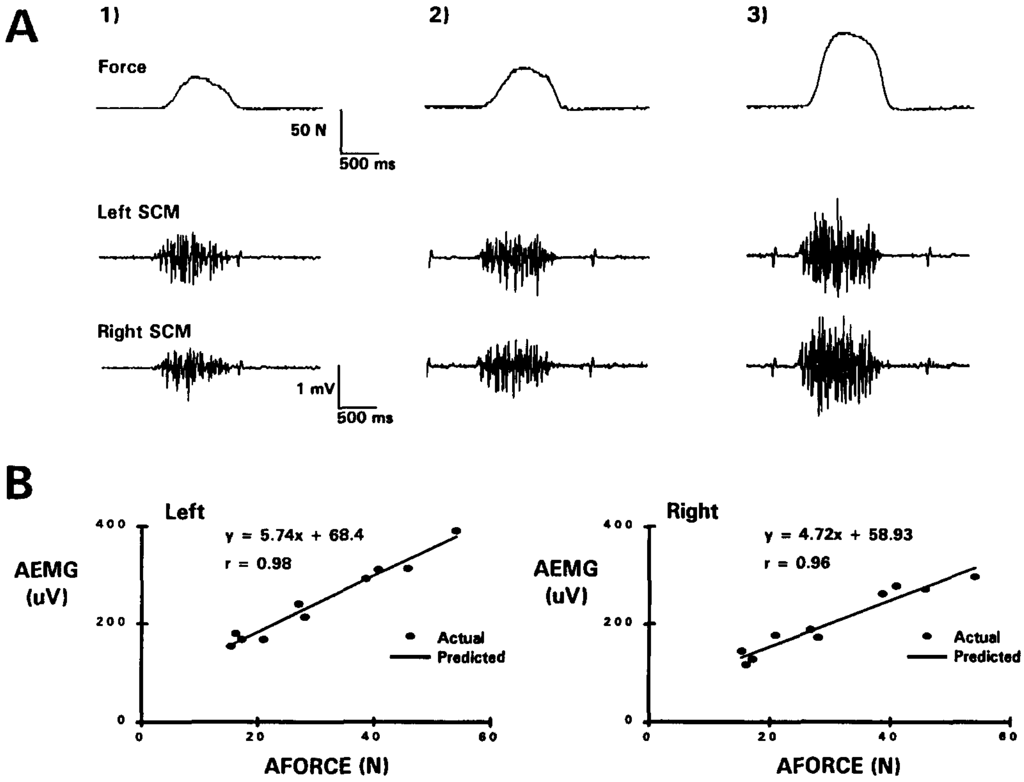

Fig 3. (A) The isometric neck flexion force and left and right SCM EMG recordings from one control subject for minimum (1), intermediate (2), and maximum (3) strength contractions. (B) The linear regression lines of best fit characterizing the relationships between AEMG and AForce for the left and right SCMs for the same subject. Efficiency of the left SCM is 1/m = 1/5.7 = .17N/μV; efficiency of the right SCM is 1/4.72 = .21N/μV.

peak force/body weight, average force, and force relaxation time. The reliability was moderate for SCM EMG relaxation time, and was generally poor for muscular efficiency. Incorporation of the electrophysiological indices clearly introduced additional variability that compromised the reliability of measures of muscular efficiency. Nevertheless, these results indicate that this approach to the measurement of neck flexor muscle force per se is sufficiently reliable to prove useful in the assessment of neck function if sufficient repeated measures are undertaken.

The present results confirm and extend previous reports showing that neck flexor strength can be reliably assessed[9,10] and show that indices of EMG and force relaxation in neck flexor musculature can also be obtained reliably. The electromyographic recordings were undertaken to establish normative

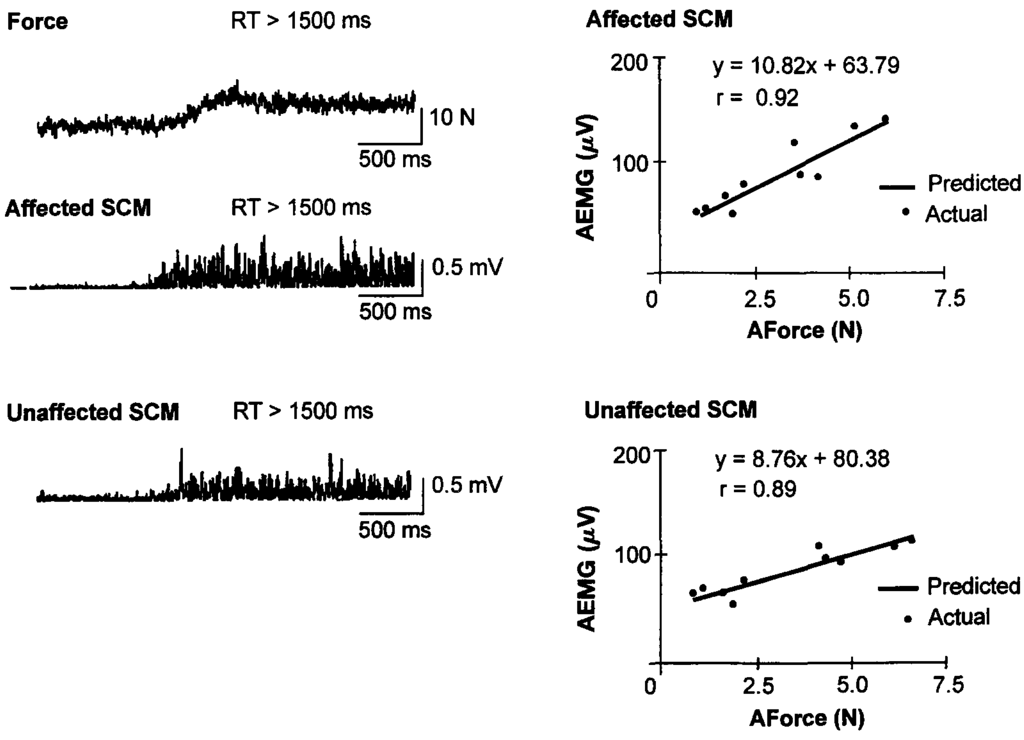

Fig 4. The raw force curves and rectified EMG data during maximum isometric neck flexion and the linear regression lines of best fit characterizing the relationships between AEMG and AForce for the affected and unaffected SCMs for a neck pain subject. This subject was unable to resume a relaxed state within the data collection time period, resulting in an extremely prolonged relaxation time (RT) of greater than 1,500msec. Efficiency of the affected SCM is 1/m = 1/10.82 = .09 N/μV; efficiency of the unaffected SCM is 1/m = 1/8.76 = .11 N/μV.

Table 3: Reliability—Control Subjects

	N	Peak Force (N)	Peak Force/Body Wt (N/kg)	Average Force (N)	Force Relaxation Time (msec)	SCM EMG Relaxation Time (msec)		Efficiency (N/μV)*	
						Right	Left	Right	Left
Maximum Contraction 1	10	45.0 (18.5)	0.7 (0.2)	28.3 (12.9)	537.8 (260.2)	465.1 (261.9)	471.3 (277.2)	0.3 (0.3)'	0.3 (0.3)'
Maximum Contraction 2	10	48.2 (16.4)	0.7 (0.2)	30.2 (11.6)	511.6 (170.8)	449.5 (154.7)	444.7 (184.9)	.22 (.20)'	0.3 (0.3)'
Reliability									
Subjects		246.1	0.0	111.0	34,766.9	27,414.9	36,706.0	.03	.09
Error		58.2	.01	37.8	13,127.0	17,935.0	17,985.6	.03	.002
Intraclass Correlation		.81	.75	.75	.73	0.6	.67	.58	.97
ICC Confidence Interval		0.5-0.9	0.4-0.9	0.4-0.9	0.4-0.9	0.2-0.9	0.3-0.9	0.1-0.9	0.9-1.0

Values for maximum contractions expressed as x̄(SD). Reliability values expressed as estimates of error-free between-subjects variance (Subjects) and within-subjects between-trials variance (Error).
* Each efficiency estimate derived from 5 contraction trials from either session 1 or session 2.
' Session 1 (trials 1 through 5).
' Session 2 (trials 6 through 10).

values for SCM muscle relaxation and to assist with determination of the normal extent of asymmetry of SCM contribution to the neck flexor muscle torque. In the control subjects, there were no significant differences between the right and left SCM EMG relaxation times in the group as a whole. There was a trend for the force relaxation times to be slightly longer than the SCM EMG relaxation times.

Control Subject–Neck Pain Subject Comparisons

Highland and colleagues[11] reported that in 70 patients with cervical sprains the combined arc of flexion and extension was 105° ± 16° before and 113° ± 12° after a neck extensor strengthening program. In our 10 neck pain subjects the flexion-extension arc was much less ($\bar{x}$ = 68° ± 34°). All axes of active cervical range of motion were reduced in our neck pain subjects compared with previously published normal populations.[25-27]

Our findings confirm those of Silverman and coworkers[9] and Vernon and colleagues[10] in that the patient populations had significantly less neck flexor strength than the control populations. In Silverman's study, the mean patient and control subject neck flexor strengths (peak force/body weight) were 1.16 ± .49N/kg and 1.71 ± .42N/kg, respectively, compared with 0.3 ± 0.2N/kg and 0.7 ± 0.2N/kg in our study. Patient neck flexor strength was 68% of the strength of the controls in Silverman's study, compared with 46% in our study. Silverman did not report absolute neck flexor strengths, making it difficult to clarify why there were 2- to 3-fold differences in the values for neck flexor force/body weight values even in the control subjects. The difference in values may have been due to Silverman's inclusion of more male subjects or due to differences in the method of testing. Vernon[10] studied neck flexion with a modified sphygmomanometer dynamometer and found that neck flexor strength in a population of patients with neck pain was 43% of that of a control population. When only the whiplash patients were considered, their neck flexor strength was only 26% of that of controls.

The mean age difference between control and neck pain subjects in the present study raised the question of whether the differences in strength could be attributable to an effect of age rather than the impairment. Pearson product moment correlations calculated for the control subjects' age with peak force $r = -.23$, average force $r = .17$, and peak force/body weight $r = -.14$ all indicated that any age-related decline in neck strength within the age range of 20 to 47 years was trivially small and nonsignificant ($p < .05$). This is in agreement with previous reports that have shown the principal decline in a large number of different muscle groups to be after the age of 60 years.[30] These observations support the argument that the age difference between control and neck pain subjects did not account for the difference in strength between the two groups, and the inference may be drawn that this was due to the underlying impairment.

There was some evidence from the group data to suggest that the SCM EMG and force relaxation times are prolonged in subjects with neck pain and headache. Further inspection found that this was primarily attributable to 2 neck pain subjects who had extremely long relaxation times of greater than 1,500msec (fig 4). This raises the possibility that one mechanism for the perpetuation of symptoms in some members of this population may be that affected muscles do not fully relax after contraction, resulting in an overuse phenomenon of the affected muscles.[20,31]

Efficiencies for the SCM muscles have never been reported. In this study there was an almost significant difference ($p = .055$) between the efficiencies of the right SCM in the control

Table 4: Neck Pain Subjects Versus Control Subjects

	N	Peak Force (N)	Peak Force/Body Wt (N/kg)	Average Force (N)	Force Relaxation Time (msec)	SCM EMG Relaxation Time (msec)		Efficiency (N/μV)	
						Right	Left	Right	Left
Control Subjects	10	45.3 (17.6)	0.7 (0.2)	28.5 (11)	528.9 (167.3)	449.4 (151.2)	469.3 (175.3)	0.3 (0.2)	0.3 (0.3)
						Affected	Unaffected	Affected	Unaffected
Neck Pain Subjects	10	22.4 (13.1)	0.3 (0.2)	12.1 (7.5)	796.7 (391.0)	736.7 (431.0)	742.6 (421.8)	0.1 (0.1)	0.2 (0.1)
t value		3.3	4.1	3.9	−2.0				
p value		.004	.001	.001	.069	.072	.083	.055	.171

All values for control and neck pain subjects expressed as x̄(SD).
Efficiency estimates were based on combining the ten contraction trials from Sessions 1 and 2, whereas all other measures were derived from the mean of all 3 to 4 maximum voluntary isometric contractions.

population and the affected SCM in the neck pain population. The inability to reach significance in these values is likely due to the small number of subjects.

In this project, we purposely chose to study a population with unilateral and ipsilateral neck pain, headache, and SCM tenderness, anticipating that there would be differences in SCM EMG relaxation times and efficiency between the affected and unaffected SCM muscles. There were no significant differences. In neck flexion the SCM muscles act in concert. When the contraction of a single SCM causes pain, not only is that SCM inhibited, but the contralateral SCM is also inhibited because of concurrent contralateral inhibition.[32-34] This could result in bilateral SCM weakness and atrophy despite unilateral symptoms.

The necessity for regaining and maintaining adequate range of motion of the neck is well recognized in the treatment of patients with soft tissue neck injuries. In addition, Travell and Simons[22] have stressed the need to clear trigger points which compromise muscle strength by achieving full muscle length through specific muscle stretches. However, the role of aggressive neck muscle strengthening programs is less clear. If weakness of any muscle group is found to be common in this population, it may underline the need to integrate specific neck muscle strengthening exercises into the overall treatment program. Rodriquez and associates[35] have explored the value of therapeutic exercise in the management of chronic neck pain. Similarly, there may be a role for teaching relaxation of specific hyperactive muscles. Middaugh and Kee[36] have explored the role of EMG monitoring and biofeedback in balancing the EMG activity of the right and left neck extensors, sternocleidomastoids, and trapezeii.

In conclusion:

1. Neck muscle strength may be measured reliably, but the assessments of muscular efficiency, SCM EMG relaxation time, and force relaxation time introduce additional sources of variance that necessitate more repeated measures to obtain good estimates of the values.
2. All measures of maximum neck flexor strength—peak force, peak force/body weight, and average force—were significantly less in the neck pain subjects than in the control subjects. There were no significant differences in muscular efficiency, SCM EMG relaxation time, or force relaxation time of the affected SCM muscle in subjects with unilateral chronic neck pain and headache compared with asymptomatic control subjects.
3. There were no significant differences in SCM EMG relaxation times or efficiencies between affected and unaffected SCM muscles in the neck pain population, thereby suggesting bilateral inhibition.

Acknowledgment: The authors acknowledge and thank Dalton Wolfe and Jane Hsieh for expert technical assistance, Dr. Gail Woodbury for statistical assistance, and Gwyn Nursall for graphics assistance.

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Suppliers

a. Shaevitz Engineering, US Route 130, Pennsauken, NJ 08110.
b. Dantec Electromedical and Scientific Equipment, Ltd., 140 Shorting Road, Scarborough, Ontario, Canada M1S 3S6.
c. Medical Systems Corporation, One Plaza Road, Greenvale, NY 11548.
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