Chronic Pain and Difficulty in Relaxing Postural Muscles in Patients with Fibromyalgia and Chronic Whiplash Associated Disorders

JESSICA ELERT, SALLY ASPEGREN KENDALL, BARBRO LARSSON, BJARNE MÅNSSON, and BJÖRN GERDLE

ABSTRACT. ***Objective***. To investigate if muscle tension according to the surface electromyogram (EMG) of the shoulder flexors is increased in consecutive patients with fibromyalgia (FM) or chronic whiplash associated disorders (WAD).

Methods. A total of 59 consecutive patients with FM (n = 36) or chronic WAD (n = 23) performed 100 maximal isokinetic contractions combined with surface electromyography of the trapezius and infraspinatus. A randomized group of pain-free female (n = 27) subjects served as control group. Peak torque initially (Pti) and absolute and relative peak torque at endurance level (PTe, PTer) were registered as output variables, together with the EMG level of unnecessary muscle tension, i.e., the signal amplitude ratio (SAR).

Results. The patient groups had a higher level of unnecessary tension initially and at the endurance level. The patients had lower absolute output (PTi and PTe), but the relative levels (PTer) did not differ comparing all 3 groups. Subjects with FM had significantly higher body mass index (BMI) than the other groups. BMI did not influence the SAR but correlated positively with PTi.

Conclusion. The results confirmed earlier findings that groups of patients with chronic pain have increased muscle tension and decreased output during dynamic activity compared to pain-free controls. However, the results indicated there is heterogeneity within groups of patients with the same chronic pain disorder and that not all patients with chronic pain have increased muscle tension. (J Rheumatol 2001;28:1361–8)

Key Indexing Terms:
FIBROMYALGIA MUSCLE PAIN STRENGTH WHIPLASH

In clinical practice patients with chronic neck and shoulder pain, increased muscle tension is often assumed and targeted for intervention. Reduction of muscle tension is assumed to lead to reduction of muscle pain. However, no increased tension according to surface electromyographic (EMG) recordings has been generally found at rest[1].

During repetitive dynamic work, cycles consisting of muscle activity and rest are found in a muscle working optimally. Isokinetic dynamometry can be used to investigate dynamic mechanical performance in humans in a highly standardized manner[2]. In studies of fatigue several groups have used a schedule consisting of 100–200 repetitive maximum contractions. Isokinetic dynamometry has often been combined with surface EMG from the relevant muscles. In studies of shoulder forward flexion performance of healthy female students we observed that some subjects had difficulty relaxing, as observed in EMG recordings between the maximal contractions[3,4]. Such an inability was associated with lower mechanical output throughout the isokinetic endurance test[3]. To quantify the relative activity during the supposed pauses of the contraction cycle we determined the ratio between the signal amplitude (root mean square, RMS) of the EMG of the passive part of the contraction cycle and the signal amplitude (RMS) of the active part. This ratio, the signal amplitude ratio (SAR), increased with angular velocity[4]. We have reported one-year reproducibility for SAR of the trapezius (r = 0.76) and infraspinatus (r = 0.47) and knee extensors (r = 0.44)[5,6]. In an epidemiological study of clinically healthy subjects randomly selected from the official census lists of a Swedish town (n = 55) we found no significant sex differences in SAR of the shoulder forward flexors[7]. In small studies of patients with fibromyalgia (FM) and chronic whiplash associated disorders (WAD) we have reported increased SAR of the muscles of the shoulder forward flexors[8,9]. These results indicated that the SAR might be used to monitor a relatively insufficient working pattern in healthy subjects and in patients with chronic pain. However, the number of subjects

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with FM (n = 9) and chronic WAD (n = 22) was very small and researchers working with other methods were not able to reproduce our results. We concluded that more studies were needed to establish whether SAR is increased in patients with FM and chronic WAD.

We investigated if it was possible to reproduce the finding that the SAR of the shoulder flexors is significantly increased in consecutive patients with FM or chronic WAD.

MATERIALS AND METHODS

Subjects. The 2 female patient groups were recruited consecutively among patients referred to the Pain and Rehabilitation Centre, University Hospital, Linköping.

Chronic WAD. The group of subjects with chronic WAD consisted of 23 female patients, referred due to chronic WAD (the majority had chronic pain as a prominent symptom). The criteria for inclusion in the WAD group were whiplash trauma more than 3 and less than 24 months previously and chronic WAD. Patients with clinically diagnosed brain injury were excluded.

Fibromyalgia. The 36 female patients of this group were diagnosed according to the 1990 American College of Rheumatology criteria[10]. Those with concomitant inflammatory or other serious medical condition were excluded. The duration of widespread pain was 5.9 ± 4.1 years (median 5.0, range 1–15) and they had had their FM diagnosis for 3.0 ± 3.6 years (median 1.0, range 1–15).

Healthy subjects. The group (n = 27) of healthy pain-free female subjects, without symptoms or signs from the neck and shoulder regions, recruited from the official census lists of a northern Swedish city, was used for reference data, as described[7,9]. This group is called the comparison group.

Age and anthropometric data for the 3 groups are summarized in Table 1.

All subjects gave informed consent before the study started and the study was approved by the local ethics committee.

Isokinetic dynamometry and EMG. Isokinetic dynamometry and EMG methods were as described[3,4,11]. Briefly, the subjects performed dynamic maximum shoulder flexions using an isokinetic dynamometer (for the comparison group: Cybex II, Lumex Inc., New York, NY, USA; and for the WAD and FM groups: KinCom 500H (Chattecx Corp., Nashville, TN, USA). Both dynamometers were regularly calibrated. Two dynamometers of different trademarks were used because the patient groups were collected in Linköping (south of Sweden) and the control group in Umeå (northern Sweden). It was not possible for practical and financial reasons to use only one type of dynamometer. The subjects were seated in the chair of the dynamometer, which enabled comfortable activity. The dominant arm was held with the elbow extended and the hand pronated, and the arm was attached to the lever arm of the dynamometer and individually adjusted for each subject. Before the electrodes were attached, the skin area was dry shaved and rubbed with alcohol and ether (4:1). EMG signals using surface electrodes (Medicotest, Ølstykke, Denmark; center to center distance 20 mm) were obtained from the descending part of the trapezius and from the infraspinatus muscles, as described[9]. A bipolar multichannel EMG amplifier (EMGAmp, Braintronics BV ISO-2104, Almere, the Netherlands) (CMMR > 100 dB, input noise < 1 µV) was used to register the surface EMG activity. The skin impedance was checked with the common mode test of the amplifier to achieve balance between the electrodes. Test contractions before the test were also done to secure good electrode–skin contact and RMS noise levels < 12 µV. The preset angular velocity chosen was 1.05 rad s^{-1}. Subjects were informed about the aim of the experiment, but not about the number (100) of repeated maximum forward flexions scheduled in the protocol. Before the test started subjects were familiarized with the procedure using submaximal contractions as a warmup. Each contraction cycle started with the hand against the thigh. After having performed a maximal shoulder flexion (i.e., the active isokinetic flexion part of the contraction cycle, ~30°–90°) the subject was instructed to relax completely while the arm was passively extended, following the lever arm/handle down through gravitational torque (i.e., the passive relaxation part of the contraction). When the lever arm/handle reached the thigh the subject was instructed to immediately perform a new shoulder forward flexion. The contraction frequency was thus standardized (i.e., 30 contraction cycles per minute). Subjects were frequently encouraged throughout the experiment to perform maximally during each flexion and to relax completely during the passive extension. All signals were amplified and analog-to-digital converted with 12 bit accuracy in the signal range ± 5 V, with a sampling rate of 2 kHz. Analog low-pass filters of 800 Hz were used to eliminate aliasing of sampled EMG signals. For the biomechanical signals, i.e., torque and position, 40 Hz low-pass filters were used. A high-pass filter of 16 Hz was used to avoid the influence of movement artefacts and low frequency noise of the EMG signals. The data acquisition system MYSAS[11] uses the position signal from the dynamometer for synchronizing the calculation of variables during isokinetic contractions. Calculated variables from EMG and torque signals were root mean square [RMS (µV), i.e., the signal amplitude] and peak torque [PT (Nm)]. The isokinetic part of a phase during the contraction cycle was used to verify that a contraction had a minimum range and at the same time eliminate values outside the active part of the contraction cycle.

The power density spectrum was obtained, after Hamming windowing, using the fast Fourier transform (FFT) technique. To yield a spectral resolution of roughly 2 Hz, a 1024 point FFT (512 ms) was selected. The ability to relax between the maximum shoulder forward flexions was calculated for contraction cycle:RMS passive phase/RMS active phase as a percentage equalling the signal amplitude ratio (SAR). A high SAR means high activity during the passive shoulder extensions and by implication a relative inability to relax; for examples see Figure 1.

Definition of measurement variables. The following measurement variables were used: (1) Biomechanical output. (i) Peak torque initially (PTi): the highest value of one of the 3 initial contractions (Nm) (i.e., strength). (ii) Peak torque endurance level (PTe): mean of peak torque of contractions 51

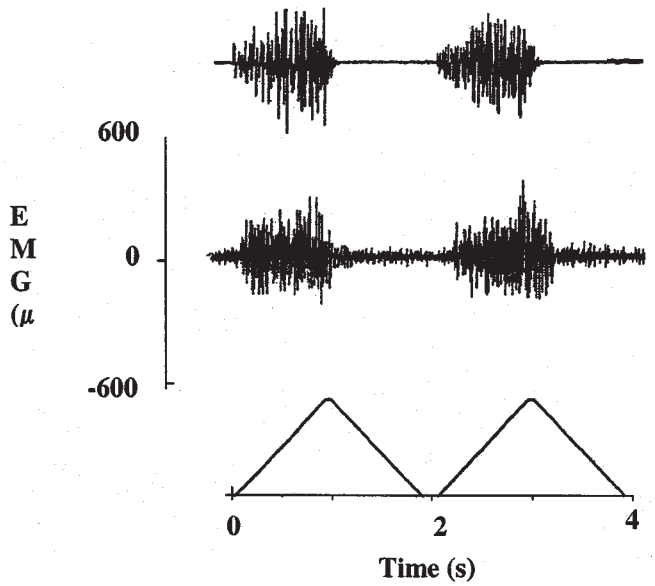

Figure 1. Raw EMG recordings of trapezius from 2 different subjects during maximum isokinetic shoulder forward flexions. Lower panel illustrates the angle, and 2 contraction cycles are shown. Note the raw EMG at the top shows no activity during the passive part of the contraction cycle. The lower EMG shows considerable activity during the passive part of the contraction cycle.

to 100 (Nm) (i.e., endurance). (iii) Peak torque relative endurance level (PTer): the ratio between PTe and PTi (i.e., relative endurance). (2) EMG variables. (i) Signal amplitude ratio initially (SARi): the ratio between RMS of the passive extension phase and RMS of the flexion phase for the contraction cycle corresponding to Pti. (ii) Signal amplitude ratio endurance level (SARe): the ratio between RMS of the passive extension phase and RMS of the flexion phase for each contraction cycle, the mean of contraction cycles 51 to 100.

The one-year reproducibility of SARe is acceptable[5].

Statistical analysis. All analyses were performed using the statistical packages SPSS for Windows (release 9.0). Mean values and one standard deviation (±1 SD) are given for each variable. P values ≤ 0.05 have been considered significant in all tests. Analysis of variance was used to test differences between 3 groups and Student's t test (for independent groups) between 2 groups. Student's t test (for dependent groups) was used for paired comparisons. Cluster analysis (based on the K-means algorithm) was used to classify the subjects into subsets containing subjects with similar characteristics and thus identifying subgroups. Chi-square test was used to test differences in distribution. Multiple linear regression was used to quantify the effects of SAR, pain, BMI, and age upon peak torque. Principal component analysis (PCA without rotation) (using SPSS) was used to detect if a number of variables reflect a smaller number of underlying components (factors). PCA can be viewed as a multivariate correlation analysis. PCA was used since a low subject to variables ratio was present. Components with Eigenvalues ≥ 1.00 (Kaiser criterion) were considered as nontrivial factors. Loadings indicate the relationships between the variables and scores the relationships between subjects. Variables loading upon the same component are correlated and the loading expresses the degree of correlation between the item and the component.

RESULTS

Anthropometric data. The subjects with FM weighed significantly more and had significantly higher BMI than the 2 other groups. The FM group reported longer duration of pain than the WAD group and was somewhat older (Table 1).

Biomechanical output. The comparison group had higher output initially (PTi) and at the endurance level (PTe) than the 2 groups with pain taken together (FM + WAD) (Table 2). There were no significant differences in PTer between the 3 groups.

Table 1. Mean values ± 1 SD for age and anthropometric variables of the 3 groups. Data of the comparison group (C) are published[7,9].

Variable	C Group, n = 27		WAD Group, n = 23		FM Group, n = 36	
	Mean	SD	Mean	SD	Mean	SD
Age, yrs	35.8	11.1	37.4	13.3	44.2	9.6
Height, cm	166.6	5.5	169.3	7.3	164.8	5.9
Weight, kg	64.7	10.2	67.7	13.2	76.0	17.6
BMI, kg/m^2	23.3	3.1	23.6	4.5	27.9	6.0

WAD: whiplash associated disorder, FM: fibromyalgia.

Signal amplitude ratio: SARi. The group with pain (FM group and WAD group together) had significantly higher SARi of the trapezius and the infraspinatus than the comparison group (Table 2). The differences between the WAD group and the comparison group were significant and particularly marked; no significant differences existed between the comparison group and the FM group.

For the mean SARi of the 2 muscles a significant difference existed between the comparison group and the group with pain. The WAD group, but not the FM group, had significantly higher SARi of the 2 muscles than the comparison group.

SARe. The comparison group had significantly lower SARe of trapezius and infraspinatus than the group of patients with pain (Table 2). The FM group had a significantly higher SARe of the trapezius than the comparison group. A similar trend (nonsignificant) was noted for SARe of the infraspinatus.

The mean SARe of the 2 muscles was significantly higher in the pain group than in the comparison group. The FM group had significantly higher SARe of the 2 muscles than the comparison group.

No statistical comparison between the comparison group and the WAD group reached significance for SARe, even though trends toward difference were noted for SARe of trapezius (p = 0.058) and mean SARe (p = 0.058).

Table 2. Mean ± 1 SD for biomechanical output (PTi, PTe, PTer), SARi, and SARe of the trapezius (trap), the infraspinatus (infrasp), and the mean of the 2 muscles in the 3 groups of subjects. To the right are results of statistical evaluations, Pain denotes FM group and WAD group taken together. Data of the comparison group (C) are published[7,9].

Variable	Comparison Group n = 27		WAD Group n = 23		FM Group, n = 36		ANOVA, 3 Groups	p, t test C vs WAD	p, t test C vs FM	p, t test C vs Pain
	Mean	SD	Mean	SD	Mean	SD				
PTi, Nm	67.3	12.1	27.5	14.1	29.9	8.5	0.000*	0.000	0.000	0.000
PTe, Nm	39.6	7.9	15.2	4.7	16.2	4.7	0.000*	0.000	0.000	0.000
PTer, %	59.0	8.2	57.2	18.1	55.8	22.4	0.780	0.674	0.480	0.400
SARi trap, %	12.9	13.0	28.5	23.8	17.3	14.0	0.006*	0.010*	0.214	0.019*
SARe trap, %	8.3	5.6	12.3	8.7	14.8	14.4	0.069	0.058	0.030*	0.006*
SARi infrasp, %	13.1	10.3	27.3	19.5	18.0	12.5	0.003*	0.005*	0.094	0.005*
SARe infrasp, %	8.6	6.6	11.4	9.1	12.9	9.9	0.171	0.233	0.059	0.043*
Mean SARi, %	12.5	9.1	28.2	19.7	17.6	12.0	0.001*	0.001*	0.070	0.009*
Mean SARe, %	8.3	5.1	11.8	7.2	13.8	10.5	0.041*	0.058	0.016*	0.017*

* Significant difference.

Subgroups. Even though significant differences existed between the groups with chronic pain and the comparison group, there was considerable overlapping. Using cluster analysis based upon SARi and SARe of the trapezius and infraspinatus we found 3 clusters where cluster 1 had the highest SAR and cluster 3 the lowest SAR — Cluster 1 (n = 7): SARi trapezius 62.7 ± 15.3, SARi infraspinatus 51.4 ± 16.9, SARe trapezius 18.9 ±6.5, SARe infraspinatus 20.0 ± 15.0. Cluster 2 (n = 22): SARi trapezius 23.8 ± 13.8, SARi infraspinatus 22.3 ± 8.6, SARe trapezius 25.2 ± 12.4, SARe infraspinatus 17.6 ± 10.1. Cluster 3 (n = 55): SARi trapezius 11.3 ± 8.1, SARi infraspinatus 13.2 ± 10.2, SARe trapezius 6.5 ± 4.3, SARe infraspinatus 11.2 ± 8.9. The distribution of the different diagnoses (i.e., FM, chronic WAD, or control) differed significantly (chi-square 15.6, p = 0.004) between the 3 clusters. No subject in the comparison group belonged to cluster 1, and the corresponding figure for cluster 2 was 11.1% and for cluster 3, 88.9%. In the WAD group, 21.7% belonged to cluster 1, 21.7% to cluster 2, and 56.5% to cluster 3. In the group with FM, 5.6% belonged to cluster 1, 38.9% to cluster 2, and 55.6% to cluster 3.

SAR pattern throughout 100 contractions. SAR patterns throughout the test are shown in Figure 2. Significant decreases in SAR throughout the test (i.e., SARi vs SARe) were found when all subjects were pooled — trapezius, p = 0.001 and infraspinatus, p = 0.000. A similar situation was found when the patients with pain were analyzed together — trapezius, p = 0.008 and infraspinatus, p = 0.000. When the 3 groups were analyzed separately all showed significant decreases in infraspinatus. Only the WAD group showed significant decreases in SAR of the trapezius, p = 0.004.

Interrelationships between SAR and output. The principal component analysis (PCA) of Table 3 shows the interrelationships between SARi and SARe and biomechanical output PTi, PTe, and Pter. Using pain as a dummy variable the PCA showed that pain was associated with negative correlations with Pti and PTe and positively with SARi and SARe according to the first component (C1). According to the second component (C2) pain was associated with low PTe and PTer. The third component (C3) identified a negative correlation between PTer and SARe of trapezius. In other words, PCA showed that pain was associated with lower output and higher EMG activity during both initial and endurance phases and that low output and high SAR are associated in the endurance phase.

To compare the influences of SAR and group membership (presence or absence of pain) upon PTi and PTe we performed multiple regression analysis (Table 4). In both these regressions it was possible to establish significant models using SAR (mean of trapezius and infraspinatus), pain, BMI, and age (adjusted R^2: 78–81%). SAR and pain

Table 3. Loadings from the principal component analysis using the following variables: peak torque initial, peak torque endurance, and the relative peak torque, SARi and SARe, of trapezius (trap) and infraspinatus (infrasp) and pain (0 = no pain, 1 = pain, i.e., FM or WAD). Three significant components (factors) were found. Loadings > 0.50 irrespective of sign are given in bold. Eigenvalue and the variance (%) of each significant component are given.

Variable	Components		
	C1	C2	C3
PTi	**–0.88**	0.34	0.27
PTe	**–0.83**	**0.52**	0.02
PTer	0.22	**0.61**	**–0.67**
SARi trap	**0.62**	**0.53**	0.01
SARi infrasp	**0.69**	0.47	–0.08
SARe trap	**0.57**	0.21	**0.64**
SARe infrasp	**0.54**	0.43	0.33
Pain	**0.78**	**–0.54**	–0.12
Eigenvalue	3.61	1.78	1.07
R^2, %	45.11	22.27	13.33

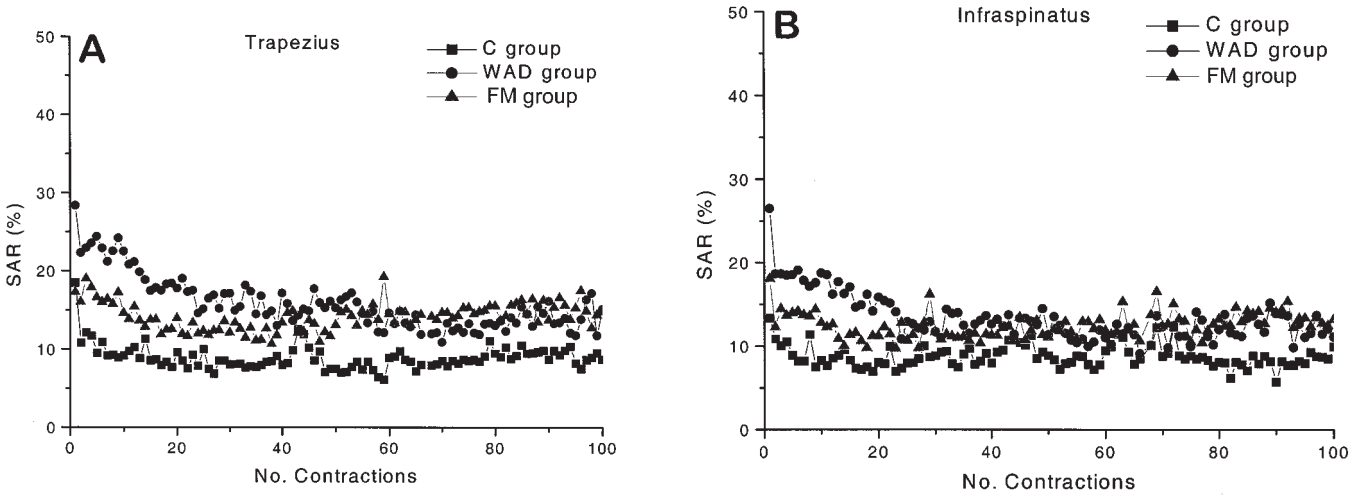

Figure 2. Mean SAR values of the comparison (C), FM, and WAD groups throughout 100 contractions. A: trapezius, B: infraspinatus.

Table 4. Results of multiple regressions of PTi and PTe using mean SARi (in the regression of PTi) or SARe (in the regression of PTe) of the 2 muscles, age, BMI, and pain (1 = present, 0 = absent). Effect estimates (Coeff), 95 confidence intervals (95% CI), beta values, and p values are shown.

		Regressors															
Dependent		SAR				Pain				BMI				Age			
Variable	Adj. R^2	Coeff	95% CI	Beta	p	Coeff	95% CI	Beta	p	Coeff	95% CI	Beta	p	Coeff	95% CI	Beta	p
PTi	81%	–0.36	–0.50, –0.21	–0.25	0.000	–37.14	–41.86, –32.41	–0.82	0.000	0.43	0.02, 0.84	0.11	0.039	–0.10	–0.29, –0.08	–0.06	0.271
PTe	78%	–0.17	–0.33, –0.00	–0.11	0.045	–23.31	–26.33, –20.29	–0.87	0.000	0.10	–0.17, –0.38	0.04	0.465	0.02	–0.10, –0.14	0.02	0.689

were significant regressors in both. The independent influence of pain was stronger than the independent influence of SAR upon PTi and PTe according to the beta values (standardized coefficients). Both pain and SAR showed negative relationships with PTi and PTe. BMI was a significant but weak regressor of PTi. Age had no significant effect in the 2 models. It was not possible to regress PTer using these independent variables.

Relationships between SARi and SARe and age. No significant correlations existed between SARi and SARe of the trapezius and infraspinatus and age in the comparison group, as reported[7]. This pattern was generally confirmed in the group with pain (FM + WAD), except for SARe of infraspinatus ($R = 0.342$, $p = 0.010$).

DISCUSSION

The main results of this study: (1) Chronic pain in the FM and WAD groups was associated with significantly higher muscle tension (SAR) than in pain-free controls. (2) Not all patients with chronic pain had increased muscle tension. (3) Biomechanical output was significantly lower in patients with pain than in pain-free controls.

Biomechanical output (peak torque). Most daily activities involve dynamic muscle activity. However, dynamic activities are difficult to investigate in a standardized way because both output and angular velocity can vary. The isokinetic contraction is a simplification of the natural dynamic contraction in which the angular velocity is predetermined and only output can vary[2]. The contraction cycle used in shoulder flexions in this study consisted of an active flexion and a passive extension. Both phases of the contraction cycle are isokinetic (Figure 1) and during the passive phase it is possible to relax all muscles and let the gravitational effect upon the arm and the isokinetic loading principle bring the lever arm back to the starting position without discomfort. Consistent with other studies of healthy subjects, peak torque decreased significantly during the initial 40–60 contractions (i.e., a significant difference between PTi and PTe). Output both initially and at the endurance level were significantly higher in the comparison group. However, the relative endurance levels were similar in the 3 groups. In our earlier study using small numbers of subjects, we had found no significant differences in peak torque between healthy subjects and patients with FM. Subjects with chronic WAD had significantly lower PTi and PTe than healthy controls[9]. In the literature there is no agreement whether chronic pain is associated with lower strength and endurance or not[8,12-16]. In the multiple regressions (Table 4) both pain and SAR were significant negative regressors of PTi and PTe. In other words, independently of each other pain and high SAR will be linked to lower output. A negative relationship between output and SAR has been reported for healthy subjects[3]. But according to the standardized coefficients (beta values) pain was a more important factor than SAR. The question arises why the output in patients with pain in this study was lower. Different factors such as pain per se inhibits output (i.e., according to the pain adaptation model[17,18]) — pain behavior, fear of pain and/or worsening of pain, and deconditioning might influence and explain the variability in the literature. That BMI was higher in the FM group than in the 2 other groups might indicate that deconditioning, at least in the FM group, was a factor behind the lower output.

Muscle tension, EMG, and pain. Simons and Mense[19] identified 3 sources of unintentional muscle activity — (1) psychological distress or anxiety, (2) overload from sustained or repetitive activity, and (3) inefficient (untrained) use of muscles. They interpreted increased SAR as a form of measurement of the inefficient use of muscle.

These findings confirm the results of our earlier studies of patients with WAD and FM[8,9]. It could be argued that the levels of SARi and SARe (Figure 2) might have been influenced by experience of the test situation, as for instance in novice pilots, who had significantly higher EMG activity during simulated takeoff and landing than experienced pilots[20]. This is an unlikely explanation since neither subjects nor patients had been tested before. However, experience/learning in the test situation might be one factor behind the decrease in SAR throughout the test in all subjects (i.e., SARi vs SARe) (Figure 2). Fatigue (the peak torque decrease) is another factor that might be responsible for the SAR decrease. Fatigue might comprise both central and peripheral components with different underlying physiological changes such as changes in motor unit recruitment, firing rate, etc[21]. In the 2 patient groups reflex inhibition (according to the pain adaptation model[17,18]) might have influenced the decrease in SAR as well.

Our results are in agreement with other studies of dynamic activity. In contrast to studies at rest increased EMG activity has been found in parts of the contraction cycle during dynamic activity[22-25]. Consistent with the pain adaptation model (i.e., decrease in agonist muscle activity and increase in antagonist muscle activity) a patient group with low back pain had significantly increased EMG activity in the swing phase during gait, a phase in which the lumbar muscles are normally silent[23]. Carlson, *et al*, using ambulatory measurements over 3 day periods, did not find increased average EMG activity in subjects with muscle pain[26]. However, the study had several limitations, for instance with respect to normalization of the EMG and subject diagnosis.

The causality between pain and muscle tension is demonstrable when acute muscle pain is induced using hypertonic saline, for example. Such causality in acute experiments does not exclude muscle hyperactivity as a risk factor for chronic myalgia. New female employees in a chocolate manufacturing plant that subsequently developed trapezius myalgia had a lower frequency of EMG gaps (spontaneous short periods of low muscle activity) at the start of employment than the employees who remained healthy, in a prospective study[27]. Among female industrial workers, worsening of complaints in the neck/shoulder regions correlated with high SARe one year earlier[28]. These results indicate that a coordination pattern with high activity may be a risk factor for muscle pain. However, there is no consensus in the literature whether the number of gaps differs between workers with and without shoulder complaints[29]. But in a recent study of 2 female cleaner groups with and without work related trapezius myalgia and a group of healthy teachers, SARe of the trapezius was significantly higher in the cleaners than in the teachers; there was no difference between the 2 groups of cleaners[30]. This could be interpreted as hyperactivity being a consequence of a non-optimal ergonomic situation with high strain upon the trapezius muscle, and not of pain.

In clinically healthy subjects SARe correlated inversely with output[3,4]. This pattern was confirmed in the present study (Table 3, component C1, and Table 4). The mechanisms behind the increased SAR among subjects with FM or chronic WAD are less obvious than for the situations in which acute pain is induced. Our findings indicated (according to the cluster analysis) that a heterogeneity existed among the patients with pain, i.e., not all patients with chronic pain had increased muscle tension even though significant differences existed between controls and patients with pain. Such heterogeneity among chronic pain disorders might reflect, for instance, differences in etiology, differences in pain generating mechanisms, or differences in duration of the pain disorder. It is often suggested that a vicious cycle of pain and hyperactivity exists in chronic pain disorders, but this has not been shown consistently.

In a study of the knee extensors of healthy subjects SARe correlated positively with the proportion of type 1 fibers[31]. This is in accord with the recruitment and derecruitment of motor units according to the size principle. At low output levels mainly type 1 muscle fibers are contracting. Both in work related myalgia and in FM significant changes (for instance ragged-red fibers) have been found particularly in type 1 muscle fibers[32]. Studies are in progress to investigate whether such changes are associated with increased SARe.

In general no significant age effects were noted on SARi and SARe in the 2 groups of patients with pain. We also observed from the comparison group that no significant effect of age or sex was found for SARe of trapezius or infraspinatus[7]. In women employed in home care service those without neck/shoulder complaints who had worked for a shorter time had higher SAR than those who had been employed more than 10 years[33], which might represent a healthy worker effect. In a study of cleaners and teachers[30], SARe and SARi increased with age. Thus studies indicate that the effect of age — eventually biased by healthy worker effects — might have different outcomes, depending upon the group of subjects investigated.

Muscle tension (SAR) may possibly reflect an internal, psychological tension or exposure to stress. Increased signal amplitude levels of the EMG due to psychological and physiological stress have been reported[19,34,35]. A positive correlation has been found between inhibition of aggression (an item of the Karolinska Scales of Personality, which measures stable character traits) and SARe[36]. However, other studies did not find consistent relationships between perceived tension and EMG activity[37,38]. Interestingly, it has been suggested that increased muscle tension (EMG activity) leads to lower pain perception and over time becomes itself a pain-inducing mechanism[34].

Reflex mediated muscle stiffness is another factor that has been proposed to contribute to EMG muscle tension[39]. Acute animal experiments have shown that mechanical stimulation of joint capsules changes the activity of the muscle spindle afferents and thereby might contribute to muscle stiffness[40,41]. The findings are interesting in the discussion of possible mechanisms behind some of the symptoms in acute WAD. Their relevance to chronic WAD is less obvious. Metabolites from muscle contractions also appear to be able to influence gamma motoneurones and thereby stiffness[42]. That the differences in SAR were most prominent initially (SARi) for the WAD group and during the terminal part (SARe) for the FM group (Figure 2) could be due to differences in sensitivity to such metabolites. Signs of central sensitization have been reported in subgroups of patients with FM and chronic WAD[43-47]. However, the prevalence of central sensitization in these 2 groups is unknown and it is unclear if such central nervous system changes per se are linked with increased SARe.

Our study confirms earlier findings that groups of

patients with chronic pain have increased muscle tension and decreased output during dynamic activity compared to pain-free controls. However, the results indicate there is heterogeneity within groups of patients with the same chronic pain disorder and that not all patients with chronic pain have increased muscle tension.

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