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ORIGINAL ARTICLE

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Mechanical performance and electromyography during repeated maximal isokinetic shoulder forward flexions in female cleaners with and without myalgia of the trapezius muscle and in healthy controls

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Abstract This cross-sectional study aimed at investigating the influence of occupational exposure to static and highly repetitive work involving the neck and shoulder muscles, myalgia of and tender point in the trapezius muscle on biomechanical output, and electromyogram (EMG) variables (mean frequency MNF, signal amplitude and ability to relax) during maximal forward flexions of the shoulder muscles. Groups of 25 cleaners suffering from chronic myalgia of the trapezius muscle, 25 cleaners free from myalgia of the trapezius muscle and 21 teachers performed 150 forward flexions using an isokinetic dynamometer. Perception of fatigue was reported and surface EMG was recorded from four muscles during the endurance test. The cleaners were stronger than the teachers. Myalgia was associated with lower levels of endurance and a high degree of perceived fatigue. The ability to relax the trapezius muscle decreased with age and was even lower in cleaners with and without myalgia. Higher MNF of the deltoid muscle but not of the trapezius muscle was found in the group suffering from myalgia compared to the groups free from myalgia. This cross-sectional study indicated that myalgia of the trapezius muscle did not influence the strength but did influence the endurance of the forward flexor muscles of cleaners. The observed decrease in the ability to relax the trapezius muscle in cleaners compared to healthy teachers might be indicative of a future insufficiency in the muscle. Prospective studies are needed to define the significance of the results presented here.

Key words Women cleaners · Electromyography · Endurance and strength · Myalgia · Trapezius muscle

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Introduction

Surface electromyography (EMG) has been suggested in ergonomics research as a tool for investigating workload and reducing the risk of work-related disorders (Hagberg 1981; Jonsson 1988; Veiersted et al. 1993). Two variables have usually been studied, the signal amplitude (root mean square, rms) and the frequency content (mean, MNF, or median, frequency) (Basmajian and DeLuca 1985). It has been suggested that fatigue as determined by the EMG, i.e. a decrease or shift in MNF towards lower frequencies, might be useful as an indicator of an increased risk of the development of myalgia (Maeda 1977; Bjelle et al. 1981) and several studies based on this hypothesis have been performed (Christensen 1986a, b; Suurküla and Hägg 1987). The EMG signs of fatigue in peripheral muscles have been shown, for example, in relation to cleaning work (Winkel 1983; Sögaard et al. 1996). The surface EMG method has thus been established within ergonomics research but a better understanding is needed of how the EMG variables may be influenced by myalgia in the muscle and the particular occupation.

Significantly higher levels of muscle tension, i.e. the ratio between rms of the passive phase and rms of the active phase of the contraction cycle during maximal isokinetic contractions (signal amplitude ratio, SAR), have been found in patients suffering from fibromyalgia (FMS), work-related myalgia and chronic whiplash associated disorders (WAD) (Elert et al. 1992b; Fredin et al. 1997). In clinically healthy subjects SAR has been correlated negatively with output (Elert and Gerdle 1989; Gerdle et al. 1989) and positively with the proportion of type 1 fibres (Gerdle et al. 2000). A high SAR level has been suggested to precede muscle pain (Elert 1991) but this has not been shown. It is a matter of debate in the literature if and how muscle pain and EMG activity relate. In clinical practice it is generally implicit that tense muscles have increased activity and different clinical treatments and interventions are applied to reduce the supposed hyperactivity and thereby the pain.

As has been pointed out by Svensson et al. (1998), there are many studies that have not shown any significant differences in *resting* EMG activity between muscles with and without muscle pain (see Svensson et al. 1998 for references). However, during *dynamic* activity an increased EMG activity has been found in parts of the contraction cycle indicating changes in the pattern of co-ordination (Stohler et al. 1988; Elert et al. 1992b; Arendt-Nielsen et al. 1996; Graven-Nielsen et al. 1997; Fredin et al. 1997). Several of these studies appear to be consistent with the pain-adaptation model suggested by Lund and coworkers (Lund et al. 1989, 1990).

According to this model a decrease in the activity of the agonist muscle and an increase in that of the antagonist muscle will be found. Consistent with this model Arendt-Nielsen et al. (1996) reported that a group of patients suffering from low back-pain had significantly increased EMG activity in the swing phase during gait; a phase in which the lumbar muscles normally are silent. They interpreted the increased EMG activity and thereby the change in co-ordination to be a functional adaptation to muscle pain. The causality is obvious when the muscle pain is induced. Consistent with such a causality it has been reported that patients with chronic WAD had increased SAR (Fredin et al. 1997). However, this causality does not exclude the possibility that hyperactivity, i.e. unnecessary muscle activity between contractions, can also be a risk factor for myalgia.

Among female industrial workers a worsening of complaints of pain in the neck-shoulder region has been found to be correlated with high SAR 1 year earlier (Lundblad et al. 1998). In addition, the results from Veiersted et al. (1990) indicate that the pattern of co-ordination might be a risk factor for development of myalgia. They investigated the pattern of spontaneous short periods of low muscle activity (*gaps*) of the surface EMG during stereotyped work (Veiersted et al. 1990). Workers making complaints of pain had a significantly higher median static muscle load and a significantly lower number of gaps than workers not complaining.

In a prospective study of newly employed women in a chocolate manufacturing plant, employees who subsequently developed myalgia of the trapezius muscle have shown a lower frequency of EMG gaps at the start of employment than have the employees who remained healthy (Veiersted et al. 1993).This would indicate that a co-ordination pattern with high activity can be a risk factor for myalgia. There may be a vicious circle between pain and hyperactivity. Obviously more studies are needed before any definite conclusions can be drawn regarding hyperactivity during dynamic work as a risk factor for myalgia.

Complaints of pain in the neck and shoulder region are common among hospital cleaners. In an epidemiological study of 256 cleaners 30% have been reported to complain of chronic work related myalgia of the trapezius muscle (Nordander et al., in press). Floor cleaning by different methods has implied a level of static loading that may be harmful during long-term work (Hagner and Hagberg 1989; Sögaard et al. 1996, Winkel 1983). Secondary intervention programmes introduced to workers complaining of myalgia often include strength and endurance training. It is thus assumed that strength and/or endurance in neck and shoulder muscles have been decreased by the myalgia. Several cross-sectional studies on this topic have been performed but the results have not been consistent (see, for instance, Holmström et al. 1992). Most daily activities involve dynamic muscle activity. However, dynamic activities are difficult to investigate in a standardised way due to the fact that both the work output and the angular velocity of the limbs can vary. Isokinetic dynamometry has been used to investigate dynamic mechanical performance in humans in a highly standardised manner (Dvir 1995) and it is often combined with surface EMG of the relevant muscles. Using an isokinetic endurance test consisting of maximal repetitive shoulder forward flexions we have found no differences in strength and endurance among home-care personnel complaining or not complaining of pain in the neck-shoulder region (Elert et al. 1992a). Similar results were found in another small study comparing healthy subjects ($n = 9$) and subjects suffering from work-related myalgia (different occupations; $n = 9$; Elert et al. 1992b). These studies have questioned if deconditioning [i.e. loss of strength, endurance, flexibility, co-ordination and fitness (Wadell 1998)] is found in active workers suffering from myalgia. Prospective studies are needed to define how myalgia affects mechanical performance, but such studies are complicated and expensive to perform. At present, cross-sectional studies can be used to indicate whether it would be worth performing such prospective studies.

The present cross-sectional study aimed at investigating to what extent the particular occupation, myalgia and tender point of the muscle influence surface EMG, mechanical performance and the perception of fatigue at different stages of an isokinetic test. The study was based upon an isokinetic endurance test of the shoulder flexor muscles in cleaners complaining ($n = 25$), or not ($n = 25$), of myalgia in the trapezius muscle , and in control subjects (teachers, $n = 21$) without any occupational exposure to highly repetitive and static loads on the muscles of the neck and shoulder.

Methods

Subjects

Female cleaners reporting ($n = 25$) or not reporting ($n = 25$) work-related myalgia of the trapezius muscle (more than 30 days during the previous 12 months) were included in the study – labelled as cleaners with myalgia (CM) and control cleaners (CC), respectively (Table 1). Another control group comprised clinically healthy female teachers ($n = 21$) not complaining of myalgia of the trapezius muscle (teacher controls, TC) (Larsson et al. 2000). The myalgia was reported in a questionnaire and confirmed by a clinical examination. The myalgia was considered to be work-related when it was reported to have started in connection with cleaning work and to be continuously worsening during the work day. Initially the CM group was free of pain during leisure time but gradually the pain became present all the time. Other obvious reasons, including leisure activities, that could have induced the myalgia were excluded by the questionnaire and at the time of the clinical examination. No subject had suffered from trauma to the cervical spine.

The myalgia was considered to be chronic when it had lasted for more than 1 year. Pain duration in the CM group was on average 8 (SD 5) years (range 4–19 years). In the CM group 64% reported experiencing pain every day during the last 12 months, the remaining 36% of the CM group reported experiencing pain on more than 30 days during the last 12 months. The CM group was not free from pain and disorder on the day of the experiment. The CC group reported that they had experienced no neck pain or neck pain for a maximum of 2–3 days during the last 12 months. The CC group was free of pain on the day of the experiment. Anyone taking oral steroids or non- steroidal anti inflammatory drugs or with diabetes mellitus, rheumatic disease, generalised pain, fibromyalgia [defined according to American College of Rheumatism 1990, (Wolfe1996)], systemic inflammatory disease or neuromuscular disorder was excluded from the study. The main work-task of all cleaners was manual floor cleaning which has been shown to make a high work demand on the trapezius muscle (Hagner and Hagberg 1989; Sögaard et al. 1996). The work tasks of the TC group did not involve any extraordinary physical demand on the trapezius muscle.

Anthropometric data and duration of employment are shown in Table 1. The study was approved by the Ethics Committee of the University of Lund. All subjects participating in the study had given their written consent.

Clinical and laboratory investigation

The participants were examined by a standardised clinical examination (Ohlsson et al. 1994) to ensure that inclusion/exclusion criteria were met. The examiner was aware of the group to which each subject belonged. The presence or absence of tender point (a sore point detected by digital palpation performed with an approximate force of 40 N) in the trapezius muscle (2 cm lateral to the midpoint between the spine of the seventh cervical vertebra and the lateral part of the acromion) was investigated. The subject was instructed to indicate the presence of pain.

Isokinetic dynamometry and EMG

The methods have been reported in detail elsewhere (Elert and Gerdle 1989; Gerdle et al. 1989; Karlsson et al. 1994); the following is a summary. The subjects performed dynamic maximal shoulder flexions using an isokinetic dynamometer (Biodex system 2, model 900-800 equipped with Advantage software version 4.5). They were seated in the chair of the dynamometer, which enabled them to be comfortably secured. The arm was held with the elbow extended and the hand pronated, gripping a handle, the length of the lever arm being adjusted for each subject. The dominant arm of each subject was investigated. The EMG signals using surface electrodes (Medicotest, Ølstykke, Denmark; centre-to-centre distance: 20 mm) were obtained from the descending part of the trapezius muscle, the anterior part of the deltoid muscle, and the common belly of the biceps brachii and the infraspinatus muscles. The electrodes of the trapezius muscle were placed 2 cm lateral to the midpoint between the spine of the seventh cervical vertebra and the lateral part of the acromion process. For a detailed description of the electrode positions on the other three muscles see Fredin et al. (1997) and Gerdle et al. (1989). Before the electrodes were attached, the skin area had been dry-shaved and rubbed with an alcohol and ether (4:1) mixture. A bipolar multi-channel EMG amplifier (EMGAmp, Braintronics BV ISO-2104, Almere, The Netherlands, Common Mode Rejection Ratio higher than 100 dB, input noise less than 1 μV) was used to record the surface EMG activity. The skin impedance was checked with the purpose of achieving balance between the electrodes using the common mode test of the amplifier. Test contractions before the test were also made to secure good electrode-skin contact and to ensure rms noise levels less than 10 μV. The preset angular velocity chosen for the limb was $1.05 \cdot rads^{-1}$. Subjects were informed about the intentions of the experiment, but not about the number (150) of repeated maximal forward flexions scheduled in the protocol. Before the test started the subjects were familiarised using submaximal contractions. Each contraction cycle started with the hand held against the thigh. After having performed a maximal shoulder flexion from 30–90° (i.e. the active flexion part of the contraction cycle) 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 perform a new shoulder forward flexion immediately. The contraction frequency was thus standardised (i.e. 30 contraction cycles $\cdot$ min^{-1}). Subjects were encouraged verbally frequently throughout the experiment to perform maximally during each flexion and to relax completely during the passive extension. A category scale with ratio properties was used for rating the perception of muscle fatigue in the shoulder muscles throughout the test (Borg 1982) and the subjects rated their perceived muscle fatigue at every 5th contraction throughout the initial 50 contractions and for every 10th contraction throughout the remaining 100 contractions. All signals were amplified and analogue-to-digital converted with 12 bit accuracy in the signal range ± 5 V, with a sampling rate of 2 kHz. Analogue low-pass filters of 800 Hz were used to eliminate aliasing of the EMG signals sampled. 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 the low-frequency noise of the EMG signals. The data acquisition system MYSAS (Karlsson et al. 1994) used the position signal from the dynamometer to synchronise the calculation of parameters during isokinetic contractions. The parameters calculated from the EMG and torque signals were MNF, rms and peak torque. The isokinetic part of a phase during the contraction cycle was used to verify that a contraction had a minimal range, and at the same time eliminating values outside the active part of the contraction cycle. The time window for the rms calculation was the isokinetic part of the active flexion and the passive extension, respectively (Karlsson et al. 1994). The power-density spectrum was obtained, after applying a Hamming window, using the fast Fourier transform (FFT) technique. To yield a spectrum resolution of approximately 2 Hz, a 1024 point FFT (512 ms) was selected. The ability to relax in-between the maximal shoulder forward flexions was calculated as the ratio of the rms during the passive extension phase to the rms during the active flexion phase of each contraction cycle: the SAR. A high SAR

Table 1 Values for anthropometric data and duration of employment of the three groups. Definitions as for Fig. 1

Variables	CM ($n = 25$)		CC ($n = 25$)		TC ($n = 21$)	
	Mean	SD	Mean	SD	Mean	SD
Age (years)	47	10	46	11	48	6
Height (cm)	164	7	163	6	165	5
Body mass (kg)	65	14	65	11	62	8
Duration of employment (years)	16	6	19	6	20	8

meant a high activity during the passive shoulder extensions and thereby a relative inability to relax.

Definitions of the variables measured

The following variables were measured.

Biomechanical output

1. Peak torque initially (PT_i): the highest value of the three initial contractions (i.e. strength)
2. Peak torque slope (PT_s): the regression coefficient (slope) of peak torque based on contractions 1–40
3. Peak torque endurance level (PT_e): mean of peak torque of contractions 101–150 (i.e. endurance)
4. Peak torque relative endurance level (PT_{er}): the ratio of PT_e to PT_i (i.e. relative endurance)
5. Peak torque shift (PT_{sh}): the difference between PT_i and Pt_e.

Perception of fatigue

1. $Borg_{40}$: the rating on the Borg scale at contraction 40
2. $Borg_{100}$: the rating on the Borg scale at contraction 100
3. $Borg_{150}$: the rating on the Borg scale at the end of the endurance test (i.e. contraction 150).

EMG variables

1. Mean frequency initially (MNF_i): mean of mean frequency of contractions 1–3 (Hz)
2. Mean frequency slope (MNF_s): the regression coefficient of mean frequency derived from contractions 1–40 (Hz)
3. Mean frequency endurance level (MNF_e): mean of mean frequency of contractions 101–150 (Hz)
4. Mean frequency relative endurance level (MNF_{er}): the ratio between MNF_e and MNF_i
5. Mean frequency shift (MNF_{sh}): the difference between MNF_i and (MNF_e (Hz)
6. rms relative endurance level (rms_{er}): the ratio between the mean of rms of contractions 101–150 and the mean of rms of contractions 1–3
7. Signal amplitude ratio initially (SAR_i): the ratio between rms of the passive phase and rms of the flexion phase for each contraction cycle, the mean of contraction cycles 1–3
8. Signal amplitude ratio endurance level (SAR_e): the ratio between rms of the passive phase and rms of the flexion phase for each contraction cycle, the mean of contraction cycles 101–150.

Statistical analysis

All statistical analyses used the statistical packages SPSS for Windows (release 7.5 SPSS Inc., Chicago) and SIMCA-P for Windows (release 7.01 Umetrics AB, Umea). Mean values and one standard deviation (SD) are given for each variable. A value of $P<0.05$ has been considered as significant in all statistical tests. Group differences were tested non-parametrically, using the Kruskal Wallis test to test for differences among the three groups and the Mann-Whitney test to compare any two of the three groups. Multiple linear regression was used to quantify the strength of the association between occupation, myalgia, tender point, and age, and the various output (measurement) variables, after adjusting for differences in length of employment, height, and body mass among the groups that may have influenced the results of the non-parametric tests. In the regression modelling, binary indicator (dummy) variables were used for occupation (1 = cleaner, 0 = teacher), myalgia (1 = present, 0 = absent), and tender point (1 = present, 0 = absent). Predictor coefficients yielding $P > 0.10$ were omitted from the regression models. Multiple linear regression does not account for associations between the various output variables. Principal component analysis (PCA) using SPSS for Windows, was therefore used as a complement to detect if a number of associated output variables reflected a smaller number of underlying components. Principal components with eigenvalues ≥1.00 were considered as non-trivial components. The loading expresses the degree of correlation between the item and the component. Items with high loadings (≥0.50. ignoring the sign) were considered to be of large or moderate importance. Variables with high loadings (ignoring the sign) upon the same component are inter-correlated. Outliers were identified using the two powerful methods available in SIMCA-P:

1. Score plots in combination with Hotelling's t^2 (identifies strong outliers)
2. Distance to model in x-space (identifies moderate outliers). One case was omitted in the PCA after these checks.

Results

Clinical examination

Cleaners suffering from myalgia had in general slightly decreased mobility in the cervical vertebra and a palpatory hard consistency of the trapezius muscle was found in 88% of CM, in 20% of CC and 24% of TC. Corresponding figures for a tight trapezius muscle – that is a feeling of stiffness in the descending region of the trapezius muscle reported by the subject at examination of lateral flexion of the head – were 64%, 20% and 20%, respectively. Few other symptoms were reported from the neck and shoulder region and no signs such as tendonitis or joint affections were found. Both signs and symptoms were predominantly found on the dominant side which was regarded to be the side most exposed to workload. As has been earlier reported (Larsson et al. 2000) tender point in the trapezius muscle [according to American College of Rheumatism criteria (1990), see Wolfe (1996)] was found in 68% of CM; corresponding figures in CC and TC were 28% and 38%, respectively.

Biomechanical output

Peak torque decreased relatively steeply during the initial 40 contractions and then remained constant for the remaining approximately 100 contractions in the three groups (Fig. 1). Significant differences were found among the three groups in PT_i, PT_s and PT_e (Table 2) and the cleaners generally had significantly higher outputs than the teachers. No significant differences were found among the three groups for PT_{er}. The CM group had significantly lower PT_e than CC. No significant differences existed between the two groups of cleaners for the other peak torque variables.

Perception of fatigue

The mean perception of fatigue was generally highest in CM, followed by TC and CC (Table 2). The difference

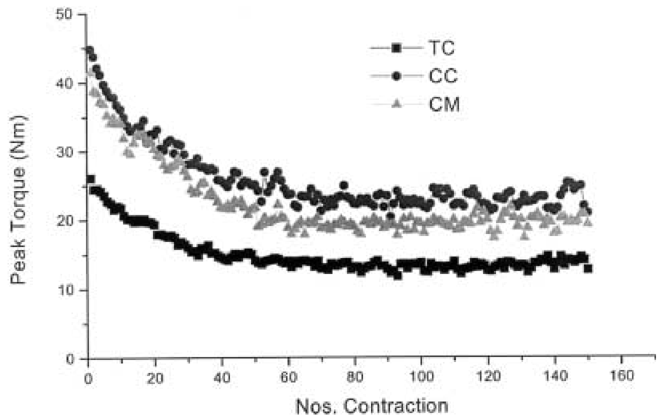


Fig. 1 Mean values of peak torque in the three groups plotted against the sequence of maximal isokinetic shoulder flexions. *CM* cleaners with myalgia, *CC* cleaner controls (without myalgia), *TC* teacher controls (without myalgia)

between CM and CC was significant at all three contractions. Moreover, CM had a significantly higher perception of fatigue compared with TC at contraction 150. Similar, but non-significant, tendencies existed at contractions 40 and 100. The TC group had significantly higher perception of fatigue than CC at contraction 40.

EMG

The MNF_i and MNF_e of the deltoid muscle were significantly higher in CM than in CC (Table 3). A significantly higher MNF_e of the deltoid muscle in CM than in TC was also noted.

Generally no significant differences in rms_{er} were found among groups.

In all groups a small decrease in SAR of the trapezius muscle occurred during the initial 20 contractions (Fig. 2a). Thereafter in TC the SAR of the trapezius muscle was more or less constant. But in the two other groups SAR slowly increased from contraction 60 onwards. In the three other muscles no such difference in pattern was observed among the groups (Fig. 2b–d).

The SAR_i of the trapezius and infraspinatus muscles were significantly higher in CM than in TC (Table 3). No significant differences in SAR_i were found between CM and CC. The SAR_e of the trapezius muscle was significantly higher in CM than in TC. No significant differences in SAR_e between CM and CC were found.

Multiple regressions of the variables of the isokinetic test

Multiple regression estimates of the effect of occupation, myalgia, tender point, and age on the variables of the isokinetic endurance test are given in Table 4. Two muscles, trapezius and deltoid, have been chosen to exemplify the effects. The estimates were adjusted for height, body mass, and length of employment, whenever these factors proved to be of importance, i.e. when $P \leq 0.10$. Generally, length of employment was an unimportant predictor of the measurement variables and had no influence on the other effect estimates of interest.

The regressions of the PT variables were associated with highest adjusted r^2 (Table 4). The regressions confirmed (cf. Table 2) that large differences were present in the PT variables PT_i, PT_e and PT_{sh} with respect to being or not being a cleaner. The presence of myalgia and tender point had smaller and more irregular influences upon these PT variables. The presence of myalgia had, however, a significant negative effect on PT_e and PT_{er}.

The presence of myalgia led to, as would be expected from Table 2, a significantly higher perception of fatigue (Table 4). Being a cleaner was associated with lower perception of fatigue at contractions 40 and 150 (Table 4).

Occupation, and the presence of myalgia and tender point had no significant importance when trying to regress the (MNF variables of trapezius muscle. The presence of myalgia was a significant regressor both for MNF_i and (MNF_e of the deltoid muscle (i.e. higher MNF will be found in subjects with myalgia) as would be expected from Table 3. Being a cleaner was significantly associated with the occurrence of a low MNF_{sh} and a high MNF_{er} for the deltoid muscle. For several of

Table 2 Values of peak torque and perception of fatigue variables of the isokinetic test of the shoulder forward flexors for the three groups. $PT_{i,s,e,er}$ Peak torque, initially, slope, endurance level, relative endurance level, respectively. Borg scale see Borg (1982). Other definitions as for Fig. 1

Variables	CM		CC		TC		Kruskall Wallis test three groups *P*-value	Mann–Whitney test CM vs. CC *P*-value	Mann–Whitney test CM vs. TC *P*-value	Mann–Whitney test CC vs. TC *P*-value
	Mean	SD	Mean	SD	Mean	SD				
PT_i (N · m)	41.2	11.1	43.6	11.7	25.1	4.2	0.000*	0.390	0.000*	0.000*
PT_s	–0.42	0.19	–0.41	0.26	–0.26	0.10	0.011*	0.757	0.002*	0.032*
PT_e (N · m)	20.3	5.4	22.9	4.3	13.3	2.8	0.000*	0.039*	0.000*	0.000*
PT_{er}	47.9	7.7	52.9	11.7	51.6	10.4	0.427	0.238	0.311	0.767
$Borg_{40}$	5.5	2.1	3.3	2.2	4.9	1.8	0.002*	0.001*	0.332	0.011*
$Borg_{100}$	8.8	2.3	6.3	3.4	7.5	2.7	0.034*	0.014*	0.104	0.231
$Borg_{150}$	9.5	1.5	6.8	3.4	8.3	2.4	0.005*	0.002*	0.020*	0.186

* Significant difference

Table 3 Values of the electromyogram variables of the isokinetic test of the shoulder forward flexor muscles for the three groups. (Definitions as for Fig. 1)

Group Variables	CM		CC		TC		Kruskall Wallis test three groups	Mann–Whitney test CM vs. CC	Mann–Whitney test CM vs. TC	Mann–Whitney test CC vs. TC
	Mean	SD	Mean	SD	Mean	SD	*P*-value	*P*-value	*P*-value	*P*-value
Mean frequency initially (Hz)										
Trapezius	86.2	9.4	85.9	11.9	83.5	6.7	0.459	0.741	0.158	0.544
Infraspinatus	115.0	28.3	112.4	16.0	119.5	21.6	0.645	0.496	0.891	0.366
Deltoid	105.7	12.1	97.8	11.9	100.9	11.4	0.138	0.046*	0.284	0.420
Biceps brachii	81.7	15.9	77.7	13.6	82.1	14.2	0.535	0.363	0.973	0.315
Mean frequency slope (Hz · contractions · s^{-1})										
Trapezius	−0.22	0.18	−0.29	0.25	−0.28	0.18	0.509	0.280	0.539	0.501
Infraspinatus	−0.55	0.59	−0.62	0.26	−0.83	0.33	0.075	0.795	0.069	0.033*
Deltoid	−0.56	0.23	−0.56	0.23	−0.69	0.22	0.102	0.897	0.059	0.066
Biceps brachii	−0.27	0.20	−0.29	0.26	−0.32	0.17	0.750	0.968	0.400	0.643
Mean frequency endurance level (Hz)										
Trapezius	77.9	10.1	76.9	12.3	72.4	8.8	0.263	0.928	0.112	0.201
Infraspinatus	91.9	15.4	86.5	14.9	83.3	13.6	0.163	0.215	0.061	0.522
Deltoid	82.5	13.3	74.0	9.3	72.7	10.7	0.037*	0.041*	0.024*	0.437
Biceps brachii	75.2	12.6	69.4	12.6	71.6	13.0	0.258	0.134	0.207	0.715
Mean frequency relative endurance level (%)										
Trapezius	90.5	10.1	90.1	17.9	84.6	9.5	0.220	0.347	0.079	0.424
Infraspinatus	76.0	11.0	76.9	10.4	69.3	8.1	0.015*	0.975	0.022*	0.005*
Deltoid	76.8	11.8	74.6	7.8	69.9	10.7	0.072	0.734	0.070	0.028*
Biceps brachii	92.5	16.4	88.1	13.1	89.3	12.7	0.586	0.337	0.604	0.537
Signal amplitude relative endurance level (%)										
Trapezius	111.5	31.5	104.4	29.9	126.1	32.5	0.139	0.660	0.125	0.061
Infraspinatus	96.3	32.6	93.1	15.6	93.6	24.1	0.976	0.826	0.962	0.891
Deltoid	105.5	25.9	105.0	17.3	119.0	27.3	0.136	0.603	0.081	0.091
Biceps brachii	107.3	26.9	92.9	18.9	94.0	42.0	0.020*	0.029*	0.014*	0.315
Signal amplitude ratio initially										
Trapezius	13.3	8.0	11.7	7.7	8.3	5.7	0.083	0.412	0.029*	0.143
Infraspinatus	9.1	11.4	5.1	2.6	4.4	2.6	0.015*	0.057	0.006*	0.213
Deltoid	10.0	7.7	9.0	5.0	8.2	6.9	0.603	0.968	0.375	0.384
Biceps brachii	9.0	6.5	5.8	4.0	7.7	9.4	0.113	0.069	0.080	0.749
Signal amplitude ratio endurance level										
Trapezius	9.9	7.2	10.3	9.6	6.7	6.5	0.120	0.810	0.036*	0.144
Infraspinatus	6.4	4.2	7.2	7.5	6.1	4.5	0.623	0.327	0.604	0.715
Deltoid	5.9	5.4	4.8	3.6	3.2	1.9	0.163	0.734	0.063	0.152
Biceps brachii	5.9	4.2	4.9	4.3	4.6	2.7	0.293	0.150	0.220	0.927

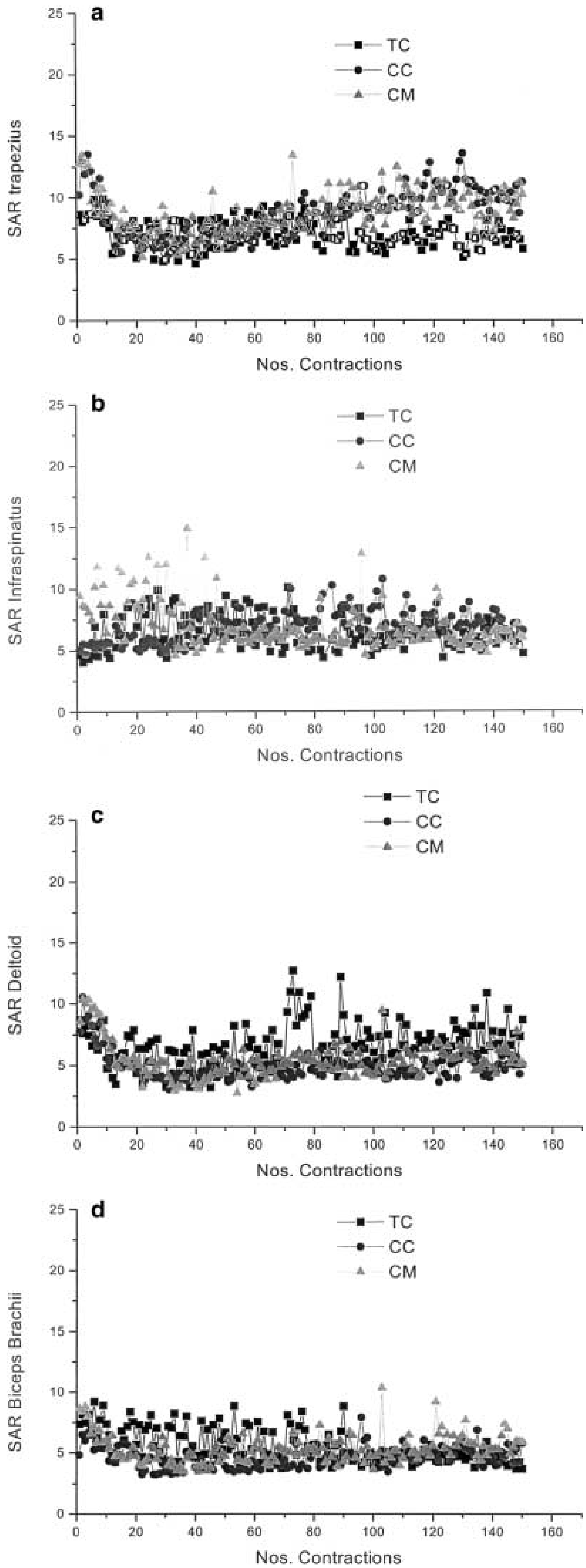
* Significant difference

the absolute (MNF variables of the trapezius and the deltoid muscles we found age dependencies, i.e. decreasing MNF with increasing age (Table 4).

The occupation of cleaner had significant negative effects upon rms_{er} of both trapezius and deltoid muscles. Generally the occupation of cleaner showed significantly increased SAR in the two muscles. Age indicated significantly increased SAR_e of both trapezius and deltoid muscles. When the subjects were split into two groups either side of the median age it was generally evident that the effect of age and occupation on the increased SAR_e was more pronounced in the higher age group (not shown in the table). In the age group 48–63 years, the mean difference in SAR_e of the trapezius muscle between cleaners and teachers was 4.6 [95% confidence interval (CI) −2.7−12] compared with 0.89 (95% CI −3.4–5.2) for the age group 24–47 years. Similarly, the effect of increased age on SAR_e of the trapezius muscle was more pronounced in the older group (mean 0.62, 95% CI −0.12−1.4) compared with the younger group (mean −0.06, 95% CI −0.37−0.26).

Multivariate relationships between variables

The dependent variables shown in Table 4 are in fact intercorrelated and to take into account these intercorrelations three PCA were made for the variables relevant for: (1) the initial contraction, (2) the slope phase and (3) the endurance level together with the dummy variables for myalgia, tender point and cleaner. Generally, the overall patterns and relationships reported in the text above and in the Tables 2–4 were confirmed by the PCA (not presented in tables). However, at the initial contraction, PCA identified five significant components (r^2(cumulative) = 68.1%). The SAR_i of the four muscles together with PT_i, cleaner, and myalgia were variables loaded upon the first component (r^2 = 19.5%). In other



◄
Fig. 2 Signal amplitude ratio (*SAR)* of trapezius (**a**), infraspinatus (**b**), deltoid (**c**), and biceps brachii (**d**) muscles plotted against the sequence of contractions throughout the test. Definitions as for Fig. 1

words, the SAR_i variables were intercorrelated and also correlated positively with PT_i, the occupation of cleaner and the diagnosis of myalgia.

Discussion

The main results of this cross-sectional study were that differences in biomechanical output, perception of fatigue in shoulder muscles and a decreased ability to relax the trapezius muscle between contractions were found between cleaners (with and without myalgia of the trapezius muscle) and healthy teachers. The ability to relax the trapezius muscle was also age-related.

One objection to the results could be that the myalgia could have been mild or have originated from other parts of the body. However, physical examination revealed higher prevalences of tightness, tender points and palpatory hardness of the trapezius muscle in CM compared to the two other groups. The lack of symptoms and signs from others parts of the body at the clinical examination also indicated that the reported pain emanated from the trapezius muscle. Even though our results are interesting, prospective studies are needed to define the clinical significance. Another limitation of the study was that the variables in the multiple linear regression models accounted for a high proportion of the variation only in PT_e and PT_i, but for the other variables regressed there were high individual variations that remained unexplained.

Biomechanical output and perception of fatigue

The two groups of cleaners were stronger than TC. It probably reflected the demands of the working situation and/or selection, on cleaners experiencing higher physical demands- their duration of muscle activity, with frequent static and highly repetitive work tasks, being greater than is the case for teachers, as has been suggested by Winkel (1983), Hagner and Hagberg (1989), and Sögaard et al. (1996). No significant differences in strength (PT_i) were found between CM and CC. Thus, deconditioning in the perspective of PT_i was not present in cleaners experiencing myalgia, despite the myalgia being chronic. The CM group may have represented a *healthy* group of cleaners with chronic myalgia since they were not on long-term sick leave. Deconditioning might then occur not as a primary but as a secondary consequence of myalgia, for example a consequence of reduced physical demands during sick leave.

However, the presence of myalgia was associated with significantly lower endurance levels (PT_e and PT_{er}).

Table 4 The results of the multiple regressions of the variables of the isokinetic test. Effect estimates (*Coeff*), 95% confidence intervals (95% *CI*) and *P*-values are presented for the significant regressors. The estimates presented have been adjusted for height, body mass, and length of employment when these factors proved to be of importance ($P < 0.10$). Trapezius and deltoid muscles have been chosen to exemplify the effects for the electromyogram variables. $PT_{i,e,er,s}$ Peak torque initially, endurance level, relative endurance level, slope, respectively, $MNF_{i,sh,e,er}$ mean frequency initially, shift, endurance level, relative endurance level, respectively, rms_{er} signal amplitude relative endurance level, $SAR_{i,e}$ signal amplitude ratio initially, endurance level, respectively, *Borg* see Borg (1982)

Regressors Dependent variables	Adj. r^2 %	Occupation (1 = cleaner, 0 = teacher)			Myalgia (1 = present, 0 = absent)			Tender point (1 = present, 0 = absent)			Age (years)		
		Coeff	95% CI	P	Coeff	95% CI	P	Coeff	95% CI	P	Coeff	95% CI	P
PT_i	46	17	12–22	< 0.001				−3.9	−8.3–0.6	0.09			
PT_e	58	8.6	6.3–11	< 0.001	−2.3	−4.5 to −0.2	0.03						
PT_{er}	7				−5.9	−11 to −0.7	0.03	4.8	−0.2–9.8	0.06			
PT_{sh}	24	9.1	5.1–13	< 0.001				−3.2	−6.9–0.5	0.09			
$Borg_{40}$	22	−1.5	−2.6 to −0.3	0.02	2.2	1.1–3.3	< 0.001						
$Borg_{100}$	10				1.9	0.4–3.3	0.01				−0.06	−0.13–0.01	0.10
$Borg_{150}$	16	−1.6	−3.1 to −0.1	0.04	2.7	1.2–4.2	0.001				−0.05	−0.12–0.01	0.10
MNF_i trapezius	5										−0.25	−0.49 to −0.01	0.04
MNF_{sh} trapezius	13										−0.27	−0.52 to −0.02	0.03
MNF_e trapezius	8												
MNF_{er} trapezius	18	5.6	−1.0–12	0.09							0.40	0.075–0.73	0.02
MNF_i deltoid	21				6.5	0.9–12	0.02				−0.34	−0.62 to −0.06	0.02
MNF_{sh} deltoid	14	−6.1	−12 to −0.6	0.03							−0.40	−0.66 to −0.13	0.004
MNF_e deltoid	16				9.2	3.7–15	0.001						
MNF_{er} deltoid	12	6.4	1.2–12	0.02							0.31	0.06–0.56	0.01
rms_{er} trapezius	5	−18	−35 to −1.8	0.03									
rms_{er} deltoid	16	−16	−27 to −3.9	0.01				10	−0.6–21	0.06			
SAR_i trapezius	5	4.2	0.4–8.0	0.03									
SAR_i deltoid	3							2.7	−0.4–5.8	0.09			
SAR_e trapezius	12	4.0	0.0–8.0	0.05							0.28	0.08–0.47	0.006
SAR_e deltoid	24	2.7	0.8–4.7	< 0.001							0.20	0.10–0.29	0.007

This could have been due to a deconditioning effect but could also have reflected the significantly higher perception of fatigue in CM than in CC, which was probably influenced by pain during the contractions. If the present laboratory results are applicable to daily life CM may perform biomechanically at lower levels to reduce the perception of fatigue and pain, which in daily life may appear as deconditioning.

In other studies, comparing groups of subjects with and without the experience of pain decreased strength and/or endurance have been reported (Hansson et al. 1992; Henriksson et al. 1996; Friedman 1998), also when comparing the painful side with the non-painful side (Hagberg and Kvarnström 1984) and after induced muscle pain (Graven-Nielsen et al. 1997). On the other hand, there have also been studies that have not found any differences in strength and endurance (Elert et al. 1992a, b). We have no plausible explanation for the heterogeneity of the data in the literature.

Electromyogram

The SAR_i and SAR_e of the trapezius muscle were significantly higher in CM than in TC (Table 3). There were no significant differences in SAR_i and SAR_e of the trapezius muscle between CC and CM. Also SAR_i of the infraspinatus muscle was significantly higher in CM than in TC. These results are in agreement with an earlier study in which subjects with work-related myalgia (different occupations) had a significantly higher SAR_e in the trapezius muscle than clinically healthy physiotherapists (Elert et al. 1992b). However, in the regression analysis of SAR_i and SAR_e of trapezius and deltoid muscles (Table 4) we found that the occupation of cleaner was a more important (and significant) factor than the presence of myalgia (non-significant). Moreover, in the even more multivariate context SAR_i of the four muscles correlated with the presence of myalgia and the occupation of cleaner according to PCA at the initial contraction.

The behaviour of SAR of the trapezius muscle of the cleaners differed from that of the teachers (Fig. 2a). The pattern with an increase in SAR of the trapezius muscle during the terminal part of the test has been described in other groups of individuals suffering from work-related myalgia (Elert et al. 1992b, 1998). Chronic WAD and FMS subjects had a more continuously high SAR throughout the test. Clinically healthy subjects have been found to have significantly lower SAR_e of the trapezius muscle than chronic WAD and FMS and no increase during the terminal part (Elert et al. 1992b; Fredin et al. 1997).

In the multiple regressions of SAR of the trapezius and deltoid muscles SAR_e but not SAR_i increased with age (Table 4). When the subjects were divided into two age groups the effect of age and occupation presented mainly in the higher age group. Progressive degeneration of the nervous system has been considered a major factor underlying structural and functional changes of skeletal muscles with advancing age (Lexell 1997). Lindström et al. (1997) found age-related effects on muscle strength in 16 subjects with a mean age of 73 years. An age-related decreased ability to relax the muscles appeared earlier in the present study and was found in subjects aged between 48 and 63 years. Elert et al. (1992a) reported from a group of 97 randomly selected women employed in the home-care service that those not complaining of neck-shoulder pain who had worked for a shorter time had a higher SAR than those who had been employed more than 10 years, which may represent a healthy worker effect.

To summarise, being a cleaner and being older were prominent factors behind the high SAR even though there are indications that the presence of myalgia to some extent influenced the high SAR. One possible interpretation is that the high SAR of the trapezius muscle was an indicator of an insufficient and potentially harmful situation for the trapezius muscle independent of the pain. Are there any other indications supporting this possibility? In a recent study of the same subjects as in the present study we have found that being a cleaner was associated with the presence of more than double the number of type 1 muscle fibres, with a subsarcolemmal and intermyofibrillar accumulation of mitochondria indicating disturbance of oxidative metabolism, the so-called ragged red fibres (Larsson et al. 2000). The disturbance of the oxidative metabolism might be caused by an energy crisis of the type 1 muscle fibres. An adequate energy supply is essential for normal muscle contraction and relaxation. Such an energy crisis thus might also cause the hyperactivity according to SAR.

These results taken together indicate that a high SAR either is a risk factor as discussed above or indirectly reflects an increased risk for myalgia. Furthermore, the high SAR and the higher prevalence of ragged red fibres in the groups of cleaners also support the "Cinderella theory" of Hägg (1991).

In the present cross-sectional study we did not find any significant differences in MNF_{sh} of the trapezius muscle between women reporting myalgia or not. Öberg et al. (1992) reported significantly steeper decreases in MNF on the non-affected side in subjects with myalgia of the trapezius muscle during static contractions. Hansson et al. (1992) and Hagberg and Kvarnström (1984) have reported no differences between subjects with and without work-related pain or tendencies to more prominent decreases on the painful side in workers with work-related myalgia, respectively. However these studies used a low level static provocation which may partly explain the differences to our results.

No significant differences in the MNF_{sh} with respect to myalgia were found in the trapezius muscle or in the other three muscles. Instead the multiple regressions (Table 4) showed that occupation of cleaner and increasing age were associated with smaller MNF_{sh} of the deltoid muscle.

Both the group comparisons (Table 3) and the multiple regressions (Table 4) showed that CM had significantly higher MNF_i and MNF_e of the deltoid muscle than CC-group. One possibility is that pain in the trapezius muscle necessitated another movement pattern and thereby demanded an altered control of the deltoid muscle in cleaners with myalgia, which was detected by differences in the MNF variables. There are indications in the literature from studies of primates that highly repetitive work tasks have led to measurable changes in the somatosensory cortex of the brain (Byl et al. 1997), which opens up for altered motor control.

Conclusions

This cross-sectional study indicated that myalgia of the trapezius muscle did not influence the strength but did influence the endurance of shoulder forward flexor muscles in cleaners. Cleaners reporting or not reporting myalgia had a decreased ability to relax the trapezius muscle between dynamic contractions when compared to healthy teachers. Prospective studies are needed to define the significance of the results presented in this paper.

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