Eur J Appl Physiol (2006) 96: 209–215
DOI 10.1007/s00421-004-1212-4

ORIGINAL ARTICLE

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Are changes in pain induced by myofeedback training related to changes in muscle activation patterns in patients with work-related myalgia?

Accepted: 28 June 2004 / Published online: 8 September 2004
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Abstract The objective of this explorative study was to investigate to what extent changes in perceived pain, induced by myofeedback training, are correlated to changes in muscle activation patterns. Thirty subjects with work-related myalgia received myofeedback training. Before (T_0), directly after (T_1) and 4 weeks or, in a subset of patients, 3 months after (T_2) this training, surface electromyography (sEMG) measurements of the upper trapezius muscle were performed during standardized computer tasks; a typing and a stress task. Besides this, visual analogue scales (VAS) were filled in to assess the levels of pain in the neck and shoulders. From the sEMG, root mean square (RMS) and relative rest time (RRT, i.e. the percentage of time RMS is below a certain threshold) were used for data analysis. The relationships between RRT, RMS and VAS at T_0 as well as for the changes between T_1–T_0 and T_2–T_0 were investigated using Spearman correlation coefficients. The results revealed no significant correlations between VAS and RMS both at baseline (range $R = -0.22$ to 0.17) and for the observed changes (range $R = -0.33$ to 0.32). Also, for VAS and RRT, low correlations were found for baseline (range $R = -0.27$ to 0.21) and for changes between T_1–T_0 (range $R = -0.02$ to 0.38). However, for the changes between T_2–T_0, correlation coefficients for the VAS for the shoulder and the RRT of the right trapezius during both the typing and stress tasks were significant at the $P = 0.05$ level, whereas the correlation coefficients for the VAS for the neck and both the left and right trapezii during the stress task approached significance ($P = 0.05$ and $P = 0.1$, respectively). These results suggest that decreases in pain observed at long term follow up after myofeedback training might occur as a result of an increased ability to relax but not as a result of decreased muscle activation level. However, the largest correlation found was 0.6. This means that the maximal explained variance (R^2) is low (36%), and that there are also other processes than the changes in muscle activation that contribute to changes in perceived pain.

Keywords Myofeedback · Pain · Muscle relaxation · EMG activity

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Introduction

Models and experimental studies indicate that subjects with chronic pain show different muscle activation patterns compared to healthy controls. This is especially reflected in a decreased ability to relax their muscles (Veiersted et al. 1993; Hägg and Åström 1997; Sandsjö et al. 2000; Nederhand et al. 2002). Subjects are not aware of this as it often concerns rather low levels of activation. Nevertheless, according to the Cinderella hypothesis, these low levels of activation may contribute seriously to the development and maintenance of chronic pain, when occurring over long periods of time (Hägg and Åstrom 1997; Veiersted 1994). Besides being an explanation for the development of muscle pain, the Cinderella hypothesis also provides an important starting point for the prevention and treatment of work-related myalgia. An accurate feedback on the absence of sufficient muscle rest could contribute to a greater awareness of undesirable muscle activation and therefore in diminishing pain.

Results of a first explorative study to gain insight into the effects of a 4-week myofeedback training on changes in muscle activation patterns and pain indeed showed that in the majority of the subjects with work-related myalgia, there was a decrease in muscle activation levels, an increase in muscular rest time and a decrease in experienced pain/discomfort directly after the training period. Further improvements after another 4 weeks were observed during the follow up period (Hermens and Hutten 2002).

The underlying concept of myofeedback training is that a normalisation of the muscle activation patterns, i.e. sufficient muscle rest during the tasks, will contribute to a decrease of pain. However, until now this concept has not been investigated: it is not clear to what extent changes obtained in perceived pain levels are actually related to the changes observed in muscle activation patterns. Therefore, the aim of the present explorative study is to investigate the hypothesis that myofeedback changes muscle activation patterns, and as such, contributes to changes in pain in patients with work-related neck/shoulder problems.

Methods

Subjects

Thirty subjects with work-related myalgia in the neck/shoulder region participated in this study. The criteria for inclusion were: age between 18 and 62 years, performing predominantly computer work, work-related neck/shoulder pain. Inclusion was based on self-reported pain in the neck and shoulders using visual analogue scales. Pain had to be present on a daily basis during the last 7 days or at least on 30 days over the past year. Exclusion criteria were tumours or inflammatory diseases, severe cervical arthritis, joint diseases, upper extremity complaints not related to work, use of muscle relaxants, and colour blindness. The presence of exclusion criteria was self-indicated. The study was approved by the Ethical Committee of the Roessingh Rehabilitation Centre and all subjects gave informed consent to participate in this study.

Myofeedback training

Myofeedback training was provided by a two channel portable myofeedback system in combination with a harness (Fig. 1). The harness enabled a reproducible and comfortable individually adaptable placement of the dry surface electromyography (sEMG) silver-silver chloride electrodes (Hermens and Hutten 2002). In this way, a pair of electrodes was placed on each of the left and right upper trapezius muscles and one reference pair of electrodes on the ribs under the scapula.

The sEMG signal was amplified (15×), digitized (22 bits ADC) and smooth rectified with removal of low frequency components (second order high pass filter, at 30 Hz). Embedded software allowed the calculation of the muscular rest time every 10 s using the preceding 1 min time window. Sensory feedback (vibration) was provided when the muscular rest time was below 20% of the time for the left and/or right upper trapezius. Rest was defined as an EMG value below 10 μV for at least 0.25 s. When subjects received feedback they were instructed to find a way to relax their neck and shoulder muscles, for instance by putting their arms in their laps, changing their position or changing their workplace ergonomics. Subjects used the myofeedback system for 4 weeks and wore the system preferably each day but at least 2 days a week, for 2 h a day with a minimum of 8 h a week. During this time the muscle rest and muscle activation data were continuously stored. In case of absence from work during the first or second week, an additional week of myofeedback training was added. Subjects who were out of work for longer than 1 week of the 4–5 weeks training period were excluded from the study. Each subject was visited every week during the training period to discuss their experiences, in part based on situations of interest identified from the data stored and downloaded from the portable myofeedback system.

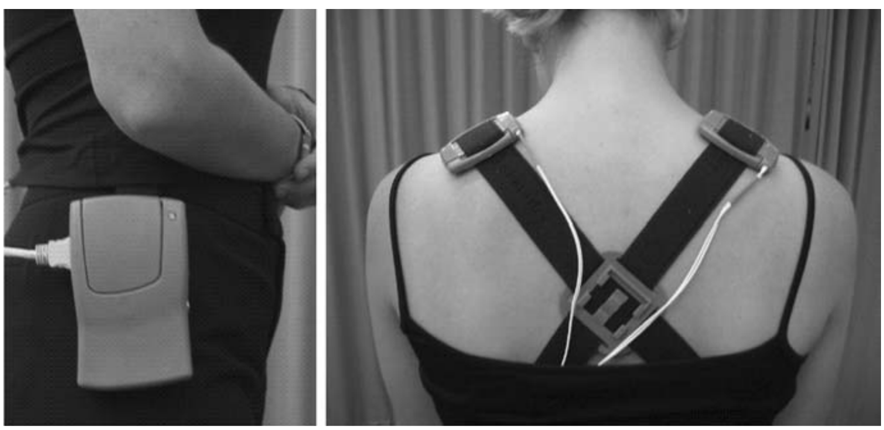

Fig. 1 Myofeedback system with harness

Measurement protocol

Subjects were invited to the laboratory three times for measurements; before the myofeedback training started (baseline; T_0), directly after the training period (T_1) and at 4 weeks, but in some patients at 3 months ($n = 4$) follow up (T_2). During these visits, EMG measurements of the upper trapezius muscles were carried out during standardised computer tasks and the pain/discomfort experienced in the neck/shoulder region was assessed using a visual analogue scale (VAS). The standardised computer tasks consisted of a typing task and a stress-related mouse task. During the typing task subjects were asked to retype a text which was designed in such a way that the left and right sides of the keyboard were used equally. A stress-related mouse task, the STROOP test was used. During this task the words red, green, blue and yellow appear on the computer display in random order and location. The words appear in a colour different from the colour spelled by the word. Subjects have to report the colour of the letters by clicking on the icon with the correct answer using the mouse.

After the first lab visit (T_0) subjects received a detailed explanation about the principles of myofeedback, information on how to wear the apparatus, and how to switch it on and off. The positions of the electrodes were individually adjustable to adhere to the Seniam guidelines (Hermens et al. 1999). After this instruction, a 4-week period of normal work with myofeedback training began.

Outcome measurements

Discomfort/pain

A picture representing different body regions was used to assess discomfort/pain. Subjects had to mark how much pain/discomfort they experienced in the neck and shoulders on a 0 to 10 VAS scale where 0 represents no pain/discomfort, and 10 represents severe pain/discomfort. Numerous investigators have demonstrated the reliability and validity of the VAS (Gift 1989).

Surface EMG measurements

Standardised sEMG measurements were performed to obtain an objective estimate of the muscle activation level. The sEMG was measured for both the left and right upper trapezius muscles. Electrodes were placed according the international guidelines developed in Seniam (Hermens et al. 1999). A reference test was done according to guidelines developed by Mathiassen et al. (1995).

After having completed the reference test, subjects were asked to adjust the workplace to their own design, which was only corrected when strong deviations from the guidelines were chosen. Then, subjects were asked to perform a standardized typing task (10 min) and a stress-related mouse task (STROOP task; 7 min). The order of these tasks was randomised. Both tasks were preceded and followed by a rest measurement during which subjects were asked to take a relaxed sitting position with their arms in their lap and the eyes fixed on a computer screen for about 15 s (rest measurement). The sEMG was measured continuously during all tasks.

Data analysis

Two different parameters were derived from the sEMG analysis. Firstly, the muscle activation level was quantified by calculating the root mean square (RMS) of the sEMG signal. The muscle activation level was determined for each minute during the typing and stress tasks and the average value was expressed as a percentage of that during the reference task. Secondly, the relative rest was quantified by calculation of the relative rest time (RRT). RRT is defined as the amount of time, expressed as a percentage of the total time, during which the RMS value is lower than 10 μV for at least 0.25 s. The RRT was determined for each minute during both the typing and stress task. In order to avoid the effects of movement artefacts in the calculation of the RRT, specific filter settings were used for the raw EMG signal; the sEMG signal was band pass filtered with a bandwidth of 30–250 Hz.

Statistical analysis

Correlation coefficients were used to investigate the relationships between RRT, RMS and VAS for the neck and shoulders at baseline (T_0) and to investigate the relationship between the changes in RRT, RMS and VAS scores between the baseline and at both T_1 and T_2. The correlations at baseline provide a better understanding about the relationship between pain and muscle activation patterns in a group of patients. The correlations of the change scores indicated whether reductions in pain achieved during the myofeedback training were related to changes in muscle activation patterns as expressed in their RMS and RRT values. For all statistical testing $P < 0.05$ was used as the significance level.

Results

Subjects

The mean (standard deviation) age, height and body mass of the subjects were 38 (7) years, 171 (10) cm and 71 (12) kg, respectively. The EMG data of one of the subjects was not suitable for analysis, and the T_2 values are missing for 8 additional subjects. Thus, data from 29 subjects were useful for analysis at T_0 and T_1, and from 21 subjects for T_2. The subjects with missing T_2 data did not differ in their initial values for the EMG parameters and pain scores.

Baseline

The mean reported pain level in the neck and shoulder region at baseline was relatively low; 3.8 (2.4) and 3.5 (2.0) respectively, on a scale from zero to ten. The median RMS values, used because of non-normal distributions, during the typing task were 29% and 26% of the reference task for the right and left upper trapezius, respectively. For the stress tasks median values of 10% were found for both the right and left upper trapezius. The median values for RRT, used because of non-normal distributions, was 1% for both the right and left upper trapezius during the typing task, and 16% and 28% respectively for the stress task. Muscle activation levels during the typing task were significantly higher than during the stress task. In contrast, the RRT was significantly higher during the stress task than during the typing task. Table 1 shows the Spearman correlation coefficients between the RMS and RRT values for the left and right upper trapezius during the typing and stress task and pain scores. No significant correlations were seen between pain and both RMS and RRT at baseline, which suggests that the level of pain intensity is not related to the level of muscle activation and the ability to relax.

Change scores

The median changes in pain and muscle activation level and muscular rest time directly after myofeedback (T_1) and after follow up (T_2) are presented in Fig. 2. The myofeedback training induced changes in the muscle activation patterns quantified by their RMS and RRT values and changes in the perceived pain on a group level. The inter-subject variability, indicated by the 25th and 75th percentile was large. However, Wilcoxon tests showed that on average, significant decreases were found for the perceived pain level in the neck and shoulders, and significant decreases were seen for all RMS values both at T_1 and T_2, except for the RMS value for the right upper trapezius during the stress task. Increases were found for the RRT at both T_1 and T_2 but the changes at T_2 appeared to be much greater. However, only the changes in RRT for the left upper trapezius during typing at T_1 and T_2, and during the stress test at T_2, were statistically significant.

With regard to the hypothesis that decreases in pain achieved during the myofeedback training are related to changes in muscle activation patterns, it was expected that a decrease in pain would be accompanied by a decrease in muscle activation level, i.e. a positive correlation, and by an increase in muscle relaxation, i.e. a negative correlation. Table 2 represents the Spearman correlation coefficients, used because of non-normal distributions, and the *P* values for the relationships between the changes in VAS and the changes in RMS of the left and right upper trapezius both for the T_1–T_0 and T_2–T_0 intervals. None of the correlations between the change in pain and change in RMS were significant, suggesting that the decreases in pain in the neck and shoulder achieved directly after myofeedback and after follow up were not related to the decreases seen in muscle activation levels.

Table 3 presents the Spearman correlation coefficients, used because of nonnormal distributions, and the

Table 1 Spearman correlations between the surface electromyography root mean square (*RMS*) and relative rest time (*RRT*) values during the different tasks and the amount of neck and shoulder pain assessed using a visual analogue scale (*VAS*) at baseline (T_0)

		VAS neck (T_0)	VAS shoulder (T_0)
RMS typing (right, T_0)	Correlation coefficient	−0.204	0.099
	P value (2-tailed)	0.280	0.758
	N	30	30
RMS typing (left, T_0)	Correlation coefficient	−0.220	−0.005
	P value (2-tailed)	0.243	0.980
	N	30	30
RMS stress (right, T_0)	Correlation coefficient	−0.045	0.172
	P value (2-tailed)	0.812	0.363
	N	30	30
RMS stress (left, T_0)	Correlation coefficient	−0.027	0.161
	P value (2-tailed)	0.886	0.395
	N	30	30
RRT typing (right, T_0)	Correlation coefficient	0.075	−0.222
	P value (2-tailed)	0.698	0.247
	N	29	29
RRT typing (left, T_0)	Correlation coefficient	0.101	−0.267
	P value (2-tailed)	0.601	0.162
	N	29	29
RRT stress (right, T_0)	Correlation coefficient	0.182	−0.131
	P value (2-tailed)	0.346	0.498
	N	29	29
RRT stress (left, T_0)	Correlation coefficient	0.206	−0.118
	P value (2-tailed)	0.283	0.542
	N	29	29

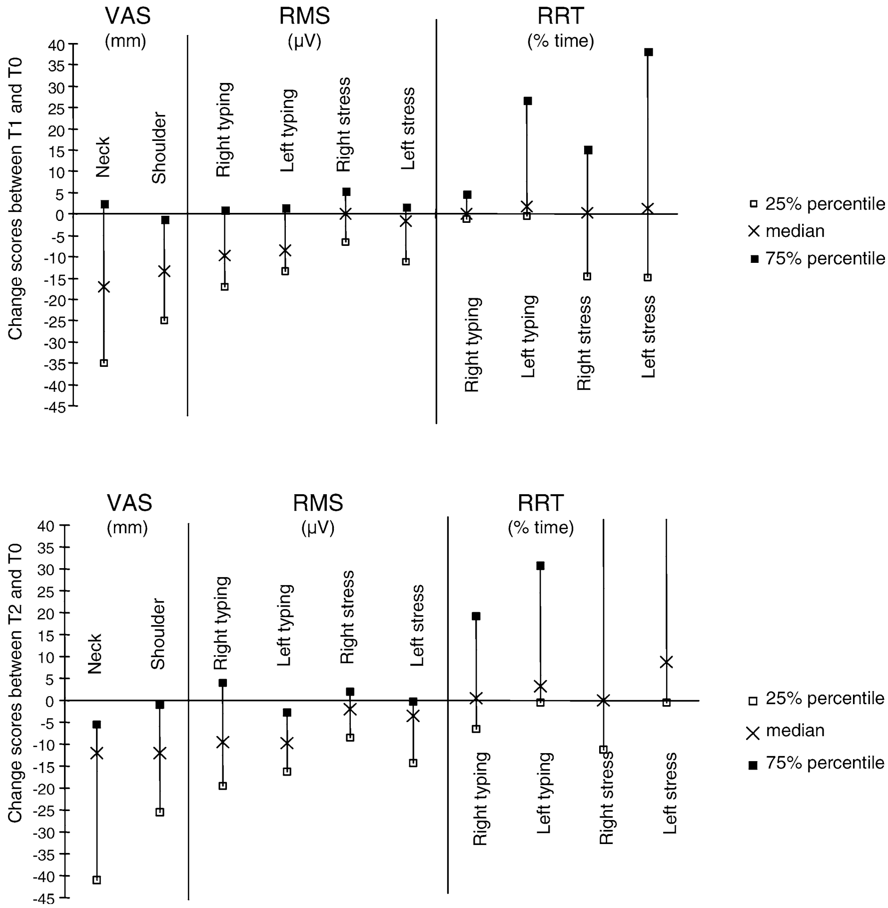

Fig. 2 Median changes (with 25th and 75th percentile in VAS, RMS and RRT for both T_1-T_0 (*upper*) and T_2-T_0 (*lower*); left and right indicate left and right trapezius, respectively. $n=29$ for T_1-T_0 and $n=21$ for T_2-T_0

Table 2 Spearman correlations between the change in RMS scores and the change in VAS scores for T_1–$T_0$and T_2–T_0

		VAS neck T_1–T_0	VAS shoulder T_1–T_0	VAS neck T_2–T_0	VAS shoulder T_2–T_0
RMS typing (right, T_1–T_0)	Correlation coeff.	−0.292	−0.255		
	P value (2-tailed)	0.125	0.165		
	N	29	29		
RMS typing (left, T_1–T_0)	Correlation coeff.	−0.329	−0.171		
	P value (2-tailed)	0.081	0.374		
	N	29	29		
RMS stress (right, T_1–T_0)	Correlation coeff.	−0.120	−0.109		
	P value (2-tailed)	0.536	0.573		
	N	29	29		
RMS stress (left, T_1–T_0)	Correlation coeff.	−0.021	−0.109		
	P value (2-tailed)	0.915	0.575		
	N	29	29		
RMS typing (right, T_2–T_0)	Correlation coeff.			0.025	0.320
	P value (2-tailed)			0.915	0.157
	N			21	21
RMS typing (left, T_2–T_0)	Correlation coeff.			0.165	0.215
	P value (2-tailed)			0.475	0.349
	N			21	21
RMS stress (right, T_2–T_0)	Correlation coeff.			0.188	0.207
	P value (2-tailed)			0.413	0.367
	N			21	21
RMS stress (left, T_2–T_0)	Correlation coeff.			0.147	−0.151
	P value (2-tailed)			0.525	0.513
	N			21	21

Table 3 Spearman correlations between the change in RRT scores and the change in VAS scores for T_1–$T_0$and T_2–T_0

		VAS neck T_1–T_0	VAS shoulder T_1–T_0	VAS neck T_2–T_0	VAS shoulder T_2–T_0
RRT typing (right, T_1–T_0)	Correlation coeff.	−0.015	−0.139		
	P value (2-tailed)	0.938	0.471		
	N	29	29		
RRT typing (left, T_1–T_0)	Correlation coeff.	0.381*	0.308		
	P value (2-tailed)	0.042	0.104		
	N	29	29		
RRT stress (right, T_1–T_0)	Correlation coeff.	−0.121	−0.080		
	P value (2-tailed)	0.532	0.682		
	N	29	29		
RRT stress (left, T_1–T_0)	Correlation coeff.	0.080	0.197		
	P value (2-tailed)	0.679	0.305		
	N	29	29		
RRT typing (right, T_2–T_0)	Correlation coeff.			−0.037	−0.461*
	P value (2-tailed)			0.873	0.035
	N			21	21
RRT typing (left, T_2–T_0)	Correlation coeff.			0.231	0.005
	P value (2-tailed)			0.314	0.983
	N			21	21
RRT stress (right, T_2–T_0)	Correlation coeff.			−0.429	−0.603**
	P value (2-tailed)			0.052	0.004
	N			21	21
RRT stress (left, T_2–T_0)	Correlation coeff.			−0.365	−0.030
	P value (2-tailed)			0.104	0.898
	N			21	21

*Significant at the 0.05 level (2-tailed), **significant at the 0.01 level (2-tailed)

P values for the relationships between the changes in VAS and changes in RRT of the left and right upper trapezius muscles for both the T_1–T_0 and T_2–T_0 intervals. None of the correlations between changes in pain and changes in RRT at T_1 were significant. In contrast, for T_2–T_0 significant correlations were found for the VAS of the shoulders and the RRT of the right trapezius during both the typing and stress tasks, while the correlations for the VAS of the neck and both the left and right trapezii during the stress task ($P = 0.05$ and $P = 0.1$, respectively) approached statistical significance. This result suggests that the decreases in pain achieved at long term follow up may be related to an increase in the ability to relax the muscles. The highest correlation (R) found was 0.6, which means that 36% of the variance (R^2) in pain can be explained by an increased ability to relax the upper trapezius muscles.

Discussion

The objective of this explorative study was to investigate the extent to which changes in perceived pain, induced by a myofeedback training, were correlated to changes in muscle activation patterns.

The results show that before the myofeedback training (T_0), muscle relaxation levels were low during the typing task and to a lesser extent during the stress task in this group of patients with work-related neck/shoulder myalgia. Remarkably, a considerable number of subjects showed low muscle relaxation levels in the upper trapezius muscle of the non-active arm. These findings are in line with results described by Veiersted et al. (1993), who found fewer gaps in the upper trapezius in a group of female employees in a chocolate manufacturing plant. These results are also in line with those of Hägg and Åström (1997) who found higher values for the RRT in the upper trapezius muscle in healthy medical secretaries compared to those of subjects with shoulder myalgia. Similar results were reported by Sandsjö et al. (2000) who studied a group of female supermarket employees. According to the Cinderella hypothesis this inability to relax, when occurring during long periods of time, may contribute seriously to the development and maintenance of chronic pain (Hägg and Åstrom 1997; Veiersted 1994).

Our results showed that there was no significant correlations between experienced pain intensity and the muscle activation level (RMS) or the RRT at baseline. This means that subjects with more pain cannot be characterized by their muscle activation levels and/or relaxation levels. One explanation for this could be that within a group of patients with pain, different mechanisms exist in response to pain (Hasenbring 1999). As a response to pain, subjects alter their muscle activation in such a way that it will contribute to an avoidance of more pain, i.e. they avoid the movements that cause pain. This response can affect muscle activation in different ways; one can avoid activating the muscles or one can stiffen the joints by constantly activating the surrounding muscles. Support for this explanation is found in the very large inter-subject variability observed for both the RMS and RRT values at baseline.

The Cinderella hypothesis has been used as a concept for the development of new myofeedback training methods which aim at diminishing pain by increasing the awareness of muscle relaxation. The present study indeed shows that myofeedback training results in changes in muscle activation patterns (decreases in RMS and increases in RRT) and in a decrease in perceived pain. These results are in line with other studies investigating the effects of traditional myofeedback training on pain (Stuckey et al. 1986; Arena et al. 1995; Rockici et al. 1997). It should be noted that comparison with these other studies is hampered by the fact that the myofeedback training provided in this study is quite different from traditional myofeedback; firstly, it is an ambulatory training in the subjects' own environment, and secondly, feedback is given based on the level of muscular rest instead of on the level of muscle activation.

Concerning the question as to the extent changes in perceived pain, induced by a myofeedback training, are correlated to changes in muscle activation level, our results show that the decreases in pain are not related to the decreases in RMS. This result is in line with the result of Rockici et al. (1997) who investigated the therapeutic mechanisms underlying improvements in tension headache activity and showed that there was no correlation between improvements in headache and EMG activity.

In contrast, we found that a decrease in pain may to some extent be related to an increased ability to relax. This could be considered as initial evidence for an inverse causal relationship between muscle activation and pain, as suggested by the Cinderella hypothesis. The most important clinical consequence for work-related myalgia would be that muscle activation patterns showing too little muscle relaxation can be changed, offering real opportunities for treatment. The treatment chosen in this study was myofeedback, but of course other treatments focussed on increasing awareness of muscle relaxation are also likely to be successful. However, in the present study the highest correlation found between changes in pain and changes in muscle relaxation was an R value of 0.6, which means that a maximum of 36% of the variance in pain is explained by an increased ability to relax. This implies that other factors are also important, and need further exploration. Rockici et al. (1997), investigated the mechanisms underlying improvements in tension headache activity by studying whether changes in tension headache as a result of myofeedback training were related to changes in self-efficacy. They showed that improvements in headache activity were correlated to increases in self-efficacy. These findings, together with the increased improvements in perceived pain level found after cessation of treatment (T_2–T_0) in the present study, suggest that it might be the change in the subject's cognition concerning pain which is also an important factor for successful therapy. An additional important factor is probably that due to the rather continuous feedback and the self-observed changes, the subject's feeling of being in control of his or her pain increases, which does decrease the observed level of pain.

Acknowledgements This work was undertaken within the project Neuromuscular Assessment in the Elderly Worker (NEW), with partial financial support from the EC within the RTD action QLRT 2000 00139.

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