Int Arch Occup Environ Health (1995) 67:11–18

ORIGINAL ARTICLE

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A case-control study of trapezius muscle activity in office and manual workers with shoulder and neck pain and symptom-free controls

Received: 26 April 1994/Accepted: 27 September 1994

Abstract A case-control study with matched pairs was initiated to investigate the relationship between shoulder-neck complaints and activity in the upper trapezius muscle. The matching was done so that the physical demands from work (external exposure) were equal for both the case and the control. Each pair was also matched for gender, age, working hours, and employment time. Male (n = 18) and female workers (n = 78) employed in both manual and office work were included. Muscle activation levels and pause patterns during work and muscle activity during tests of attention, coordination, and rest were recorded by surface electromyography. The results showed consistent associations between pain and signs of increased activation of the upper trapezius for the cases in the manual group. No such associations were observed in the office group. The results are consistent with the hypothesis that muscle activation patterns may in some instances, but not in all, explain why some workers develop pain while others do not in work situations where the physical demands are similar.

Key words Electromyography · Trapezius · Shoulder and neck pain · Myalgia · Work

Introduction

The development of work-related complaints in the shoulder and neck region is commonly attributed to excessive loading of the stabilizers of the shoulder girdle, notably the trapezius muscle (Winkel and Westgaard 1992). However, it has proved difficult to demonstrate a relation between complaint level and muscle loading for groups of workers with similar work tasks. This is exemplified by studies of complaints relating to the trapezius muscle among groups of workers performing light manual or office tasks (Jensen et al. 1993a; Westgaard et al. 1993). Several factors may contribute to this paradox, including uncertain diagnoses, selection bias, and differences in age and employment time and in work tasks, masking an underlying exposure dose-effect relationship. However, the result also may be correct: a definite conclusion must await the results of studies that address the above concerns.

A case-control study was therefore designed, matching for gender, age, employment time and type, and working hours. Cases were selected on the basis of reported discomfort in the shoulder and neck region during, the last 12 months. The controls were sympton-free. Activation of the trapezius muscles was recorded in representative and near-identical work activities for each pair. The study design included interview guides relating to personality and psychosocial factors, and psychophysiological tests were administered.

This paper reports the results of the physiological measurements. In the analysis of the vocational electromyography (EMG) recordings, variables quantifying general muscle activation (static, median, and peak activity; Jonsson 1978) were included, as were variables quantifying short periods of inactivity in the EMG recordings (EMG gaps; Veiersted et al. 1990). In a laboratory setup the trapezius activity was also quantified in tests including mental activation, arm movement, and periods of rest, as indicators of general hyperactivity (i.e., muscle activity in excess of that required to meet biomechanical demands) in the trapezius muscle.

The aim of this matched pair study was to investigate whether there was an association between upper trapezius muscle activity patterns and shoulder and neck myalgia presumed to be related to work.

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Materials and methods

The trial was conducted as a case-control study with a stratified design. The strata consisted of women and men in manual and office work. The emphasis in this study is on the women's results, but a small group of men was included to see if their results varied considerably from the women's results.

Subjects

A total of 297 employees within local units at work sites with manual and office work were interviewed. The main selection criterion for cases was the presence of shoulder and neck pain with a localization including the trapezius region for at least 2 weeks during the previous year, and with a symptom level of 3 or higher on a scale from 0 to 6 (Westgaard and Jansen 1992). Those with shoulder and neck pain potentially due to injuries or systemic disease were excluded, as were pregnant women, those with diagnosed fibromyalgia, and those with a range of motion in the neck reduced to less than three-quarters of normal (Saunders 1985). A clinical examination to record trigger points in the trapezius was performed (Travell and Simons 1983). Trigger points were more frequent among cases than controls (59% vs. 31%), but could not be used as a classification criterion. Tender points were not recorded due to a presumed higher risk of misclassification.

Thirty women (15 pairs) were included in the manual group and 48 (24 pairs) in the office group. It was a prerequisite that the subjects in manual and office work had been employed for a minimum of 1 and 2 years, respectively. Pairs (39 female, nine male) were matched on the basis of gender, age, working hours, and length and type of employment. The case and control of the same pair came from the same work site and unit, had performed the same work tasks for similar amounts of time, and were on the same level in the organizational hierarchy. The results of the matching on age and on length of employment are given in Fig. 1. The agreement between cases and controls with regard to age was high, with an agreement index of 0.82 (Fig. 1A). The corresponding agreement index with regard to length of employment was 0.10 (Fig. 1B). Figure 1B shows that the difference in length of employment for the pairs with less than 10 years of mean employment was small. For these pairs all controls had been employed slightly longer than the cases. The difference in length of employment time was allowed to be much larger for pairs with a mean length of employment above 10 years, but there was a stringent matching of work tasks and working hours during the last few years prior to this study. The focus on the conditions of employment during the last few years prior to the study was based on previous findings showing that work-related muscular complaints usually develop within 1–2 years of the start of employment (Veiersted and Westgaard 1993; Wærsted and Westgaard 1991). Thus, the development of complaints in those performing light work is most likely caused or maintained by recent exposure conditions.

The study design aimed for 24 female pairs in both work groups to obtain a statistical power of $\geqslant 0.995$ for differences in group means of 1 SD. Circumstances only allowed 15 female pairs in the manual group, reducing the power to 0.92. Age, length of employment, body weight, and height are given in Table 1. There was no significant difference between cases and controls in either work category. All but one control in the manual group and two cases and two controls in the office group were right-handed. Exposure time parameters are given in Table 2. The cases in the office group worked significantly more overtime than the controls ($P = 0.01$).

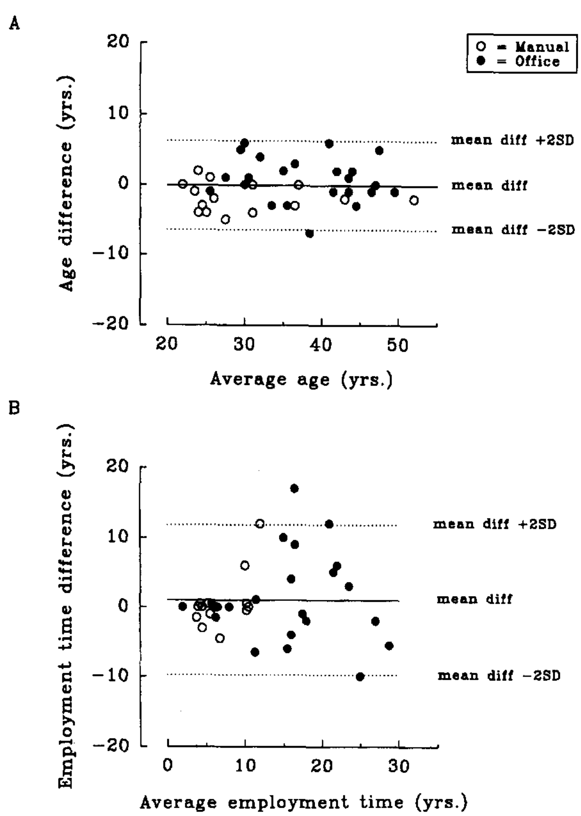

Fig. 1 Matching of pairs with respect to age (**A**) and length of employment (**B**). The *circles* represent the matching results for each pair, with the difference within each pair as a function of the mean value for the pair. A positive difference signifies that the case has the higher value

Table 1 Mean age, length of employment, body weight and height for cases and controls in both work groups. Range is given in parentheses

	Manual work		Office work	
	Cases	Controls	Cases	Controls
Age (yrs)	29.3 (22–51)	31.1 (22–53)	38.2 (25–50)	37.2 (26–50)
Length of employment (yrs)	4.9 (1–18)	5.0 (1.5–10)	14.3 (2–26)	13.3 (2–31.5)
Body weight (kg)	56.7 (45–75)	63.5 (53–82)	64.5 (52–95)	62.0 (48–70)
Body height (cm)	164.7 (157–176)	166.3 (160–179)	167.6 (160–178)	169.5 (159–179)

Table 2 Overtime and working hours for cases and controls in both work groups. The values indicate number of subjects

	Manual work		Office work	
	Cases	Controls	Cases	Controls
Overtime:				
0 h/wk	7	5	5	9
1–3 h/wk	6	7	8	11
> 3 h/wk	2	3	11	4
Part-time (< 30 h/wk)	6	6	7	5
Full-time (37.5 h/wk)	9	9	17	19

The study was approved by the regional medical ethics committee. All participants gave signed informed consent.

Work tasks

Four work sites were selected, these being located at a postal distribution center, a paper mill, a bank, and an insurance company. Work at the first two sites consisted of repetitive manual work, while office work was carried out at the last two sites.

The manual work involved tasks where the arms were used in a larger range of motion than in the office work group. The postal work consisted of sorting bulk deliveries of mail and letters, was repetitive and monotonous, and involved job rotation once or twice a day. The workers typically lifted objects of 1–3 kg on average, with short rest intervals (1–2 s) in between, or sorted letters while standing or sitting. The paper mill work consisted of feeding sheets of packing material into a machine or removing the finished products. The work was machine paced and similar to that of the postal workers with regard to monotony and repetitiveness. Care was taken to ensure that the one or two most representative work tasks were chosen for the EMG recording, and that they were similar for the case and the control of each pair.

The office workers were seated at a desk, performing regular computer and desk work. The VDU work was mostly performed in a data dialogue mode. The general stress level at work appeared higher for the office workers than for the manual workers. The bank employees were under constant strain of awaiting lay-offs, while the insurance company employees were under pressure due to a heavy work load and overtime.

EMG recording procedure

Surface EMG was used to quantify trapezius muscle activity. Integral, integrated-circuit bipolar (Ag) electrodes, 6 mm in diameter and with a 20 mm inter-center distance, were used. The center of the electrodes was placed at a point two-thirds of the distance from the spine of the seventh cervical vertebra (C7) to the lateral edge of the acromion (Jensen et al. 1993b). The signal was amplified 5000× in a two-stage instrumentation amplifier integrated with the electrodes. The signal was bandpass filtered (bandwidth 10–1250 Hz) and stored on a digitizing recorder (Earth Data 128). The system noise level with the electrodes on inert biological material was 1.5 µv RMS, corresponding to 0.15% of the signal amplitude at maximal voluntary contraction.

In the laboratory the EMG signals were reconverted to an analog form and quantified by A/D conversion at 2 kHz on a PDP 11/83 computer. The digitized signals were full-wave rectified and time-averaged at a time resolution of 0.2 s. Artifacts were detected and removed by an artifact rejection procedure, sensitive to sharp transients and slow deviations from the signal baseline.

EMG calibrations with simultaneous recordings of EMG and force were carried out both before and after the vocational recordings. Adjustable straps were positioned over the shoulders and connected to two strain-guage force transducers. Two maximal contractions were performed both in shoulder elevation ("shrugs") and in 90° arm abduction (Jensen et al. 1993b). Arm abduction gave the highest maximal value in 92% of the instances. The contraction that produced the highest EMG amplitude was used as the basis for the EMG calibration procedure (%EMG_{max}). The static, median, and peak EMG levels were determined by using the amplitude probability distribution function of Jonsson (1978). The distribution of micropauses in the EMG pattern was quantified as the number of pauses equal to or longer than 0.2 ("EMG gaps"; Veiersted et al. 1990) or 0.6 s ("long gaps") and as the total time with the EMG level lower than 0.5% EMG_{max} ("gap time").

Vocational recordings

EMG signals were recorded during a 30-min work period. The work cycle in the manual group consisted of active use of arms, handling loads between 0.5 and 10 kg, with an average of 1–3 kg. In the office group the loads were lower (< 0.5 kg) or absent, and the arm movements were much more constricted, being mainly involved with the keyboard in VDU work, handwriting, and "turning pages." During the recording, those in the manual work group were allowed to move about within a circular area of approximately 3 m in diameter, while the office workers maintained their sitting posture throughout the entire recording period.

Work technique was monitored by inclinometers on the upper arms and the upper back (Aarås and Stranden 1988). These results will be reported elsewhere.

EMG test recordings

The muscle coordination or arm movement test was constructed to evaluate the muscle activity of the passive and active trapezius while moving the arm of hand dominance. In the test the dominant arm and hand was required to move between three target areas (circles of 70 mm diameter), at a set speed (88 min^{-1}) provided by a metronome (Westgaard and Bjørklund 1987; Westgaard et al. 1993). The duration of the test was 2 min.

A two-choice reaction time test was administered to study the effect of mentally demanding work on attention-related muscle activity (Westgaard and Bjørklund 1987; Westgaard et al. 1993). The subject was seated with the forearms and hands on a table top at elbow height. A graphical display and an alphanumeric text were presented on a VDU screen. The test was performed with feedback on performance speed and accuracy (Wærsted et al. 1994). No money reward was given. The response was given by a key-press of the left or right index finger on two push buttons placed in front of the subject. Apart from the finger movement, no body movement was required during the test.

EMG recordings at rest

Two periods were selected to quantify resting EMG levels in the upper trapezius. The first test ("uninformed rest"; standing) was recorded while calibrating the inclinometers. The calibration procedure involved the subject (a) bending forward and (b) raising the arms to 90° of abduction and (c) 90° of flexion while standing, followed by periods with the arms hanging down by the side of the body with the eyes fixed on a far point at eye height. The point of this test was to calibrate the inclinometers attached to both arms and the upper back. No instructions or other indications to relax the shoulders were given to the subjects during this session. The EMG signals were sampled during the "rest periods" of this sequence, a total time of approximately 45 s.

During the second test ("informed rest"; standing and sitting), performed by the office workers only, the subjects were instructed to perform five arm movement tasks while seated at a desk and three tasks while standing upright. The tasks were performed continuously, each lasting 30 s, with 30-s rest periods between them. During the rest period the individuals were asked to retain an upright sitting or standing posture without moving the arms or shoulders. Before the start of this session the subjects were told that the aim of the test was to observe muscle relaxation during the rest periods.

Statistical methods

The data were analyzed by the Wilcoxon signed-rank test and by an ANOVA model with repeated measures in order to approach the matched pair case-control design of the study (Altman 1991). In the latter case the data were log transformed when necessary to achieve an approximation of a normal distribution. The two tests gave similar results. However, the nonparametric results are reported, expressed as median values with 95% CI, to achieve a consistent data presentation. All tests relating to the hypothesis that cases have a higher level of muscle activity than controls were carried out one-tailed with a significance level of 5%.

The agreement between cases and controls was evaluated by an agreement index (Altman and Bland 1983; Bland and Altman 1986). The index is based on the SD of the difference between cases and controls divided by the mean of cases and controls, and defined as AI = 1 − [(2 × SD of difference between case and control)/mean (case, control)]. The ± 2SD limits are expected to include about 95% of the observations, defined as the 95% limits of agreement. An agreement index of 1 means a perfect agreement between two measurements or methods, and lower positive values indicate decreasing agreement. A negative value means that the size of the 95% agreement limits is larger than the mean value for the two measurements, which is usually regarded as a poor agreement.

Discriminant analysis was performed to identify the set of predictor variables that most clearly distinguished between cases and controls in both work groups (Hand 1981).

Results

The previous year the prevalence of shoulder and neck pain among women was 44% and 52% in the manual and office work groups respectively; for men the corresponding figures were 33% and 26%. The prevalence for women (n = 188) was 49% and for men (n = 109), 30%. Overall, the women in the manual group were significantly younger than the women in the office group [30.2 (CI, 27.0–33.3) years vs 37.7 (CI, 35.5–39.8) years] and had a shorter length of employment [5.0 (CI, 3.5–6.4) years vs 13.8 (CI, 11.5–16.1) years].

Vocational EMG recordings

Although the work tasks were substantially different between the two work groups, the level and pattern of muscle activity in the trapezius were similar. The peak load in the manual group was significantly higher than that for the office workers (13.3% vs 8.6% EMG_{max}, $P = 0.05$, two-tailed test), and there was a tendency towards fewer EMG gaps in the office group (4.9 vs 3.1 gaps . min^{-1}, $P = 0.06$, two-tailed test). The EMG level was generally low. In the manual group the median value was 1.0% EMG_{max} for the static load level and 4.9% EMG_{max} for the median load level. The corresponding values for the office group were 1.1% and 4.4% EMG_{max}.

Considerable individual variation was seen within the work groups regardless of pain status. In the manual group, static and peak loads were significantly higher for cases vs controls, and there was a tendency towards a significant difference for the median load (Fig. 2, Table 3). There was also a tendency towards a difference between cases and controls in the EMG gap parameters, although this was not significant (Fig. 3, Table 3). In contrast, there was no indication of higher muscle activity level or fewer gaps for the cases relative to the controls in the office group (Figs. 2, 3, Table 3). The only significant difference was found for long gaps, but then in a direction opposite to the hypothesis. Also for EMG gaps and gap time the median values were higher for the cases.

If only pairs in which the case had sought medical help were selected (n = 11, manual work; n = 16, office work), the differences between cases and controls in the manual group increased slightly, while they remained

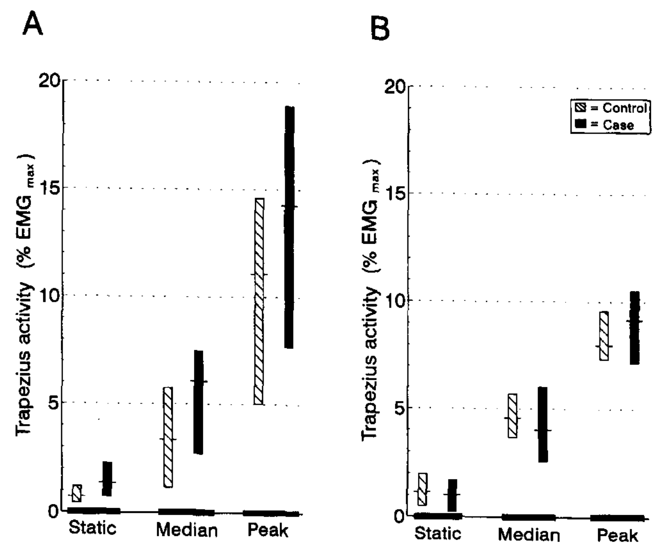

Fig. 2 Trapezius load levels (%EMG_{max}) obtained from the vocational recordings for manual (**A**) and office (**B**) workers. Median values with 95% confidence interval are given for static, median, and peak levels. The highest value from either the left or the right trapezius was used

Table 3 Muscle activity in the upper trapezius muscle, expressed as median values (P_1 one-tailed (Wilcoxon signed-rank)

	Manual work		Office work	
	Control/case	P_1	Control/case	P_1
Static[a]	0.72/1.36	0.05	1.14/1.06	0.33
Median[a]	3.35/6.08	0.06	4.57/4.01	0.33
Peak[a]	11.1/14.3	0.03	7.99/9.17	0.41
EMG gaps[b]	6.71/3.31	0.11	2.98/3.15	0.07
Long gaps[b]	1.45/0.63	0.12	0.86/1.05	0.04
Gap time[c]	2.83/1.61	0.23	2.97/3.71	0.15
Attention[a]	0.25/0.35	0.29	0.65/0.41	0.24
Active arm[a]	2.52/6.81	0.04	3.93/4.29	0.36
Passive arm[a]	0.29/0.41	0.20	0.41/0.34	0.41
Rest uninformed[a]	0.19/2.63	0.03	0.51/1.29	0.13
Rest informed[a]				
Sitting	–		0.12/0.13	0.24
Standing	–		0.23/0.64	0.19

[a] % EMG_{max}
[b] Number of gaps
[c] Seconds per minute

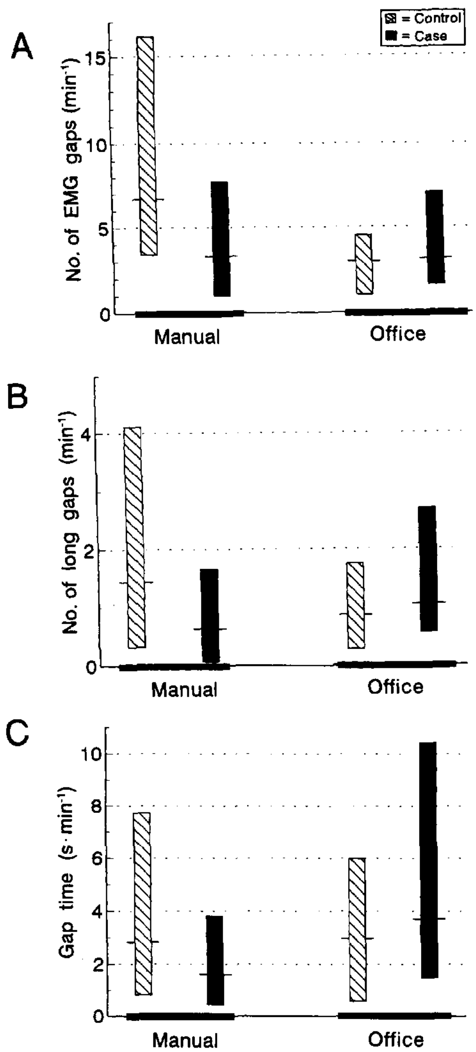

Fig. 3 Trapezius pause patterns obtained from the vocational recordings. Median values with 95% confidence intervals are given for EMG gaps (**A**), long gaps (**B**), and gap time (**C**). The lowest value from either the left or the right trapezius was used

nonexistent in the office group. We were also concerned about the greater amount of overtime (contributing to overall increased exposure) among the cases as compared with the controls in the office group. However, if only pairs in which the case worked less than 3 h overtime per week were selected ($n = 13$), the results were unchanged from those in the total sample.

Test recordings

The laboratory tests of nonvoluntary muscle activity in a mentally demanding work task did not show any difference between the cases and the controls in either of the two occupational groups. The activity level generated in this test was mostly lower than 0.5% EMG_{max} (Table 3).

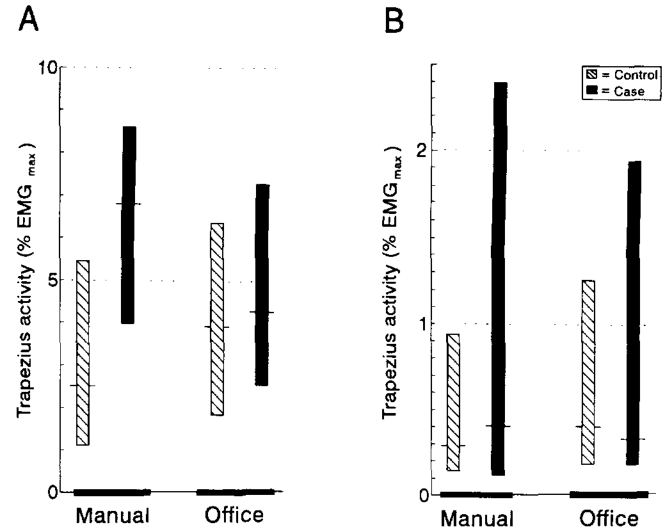

Fig. 4 Trapezius activity during the arm movement test for the active (**A**) and the passive (**B**) side. Median values with 95% confidence intervals are given

The coordination or arm movement test was constructed to study the muscle activity levels in both the active and the passive trapezius while moving the dominant arm. The muscle activity of the active trapezius was significantly higher for the cases in the manual group (Fig. 4, Table 3). There was no difference in the muscle activity of the active trapezius between cases and controls in the office group, nor was there any difference in the muscle activity of the passive trapezius between cases and controls in either of the two occupational groups (Fig. 4, Table 3).

EMG resting levels

Both occupational groups were studied during "uninformed rest," in which the subjects were not informed that the resting level was of interest. Among the manual workers the cases had a median activity level substantially higher than the controls (Fig. 5A, Table 3). There was a weak tendency towards a similar effect among the office workers.

The test in which the subjects were made aware that the resting level was being recorded was applied only to the office workers. It showed no difference between cases and controls. It was found that the resting level was much higher during standing with the arms unsupported as compared to sitting with the arms supported by the table (Fig. 5B, Table 3). There was a marked reduction in muscle activity from the uninformed to the informed condition for office workers in the standing posture.

Discriminant analysis

Linear discriminant analysis was used to identify the set of variables that best differentiated cases and

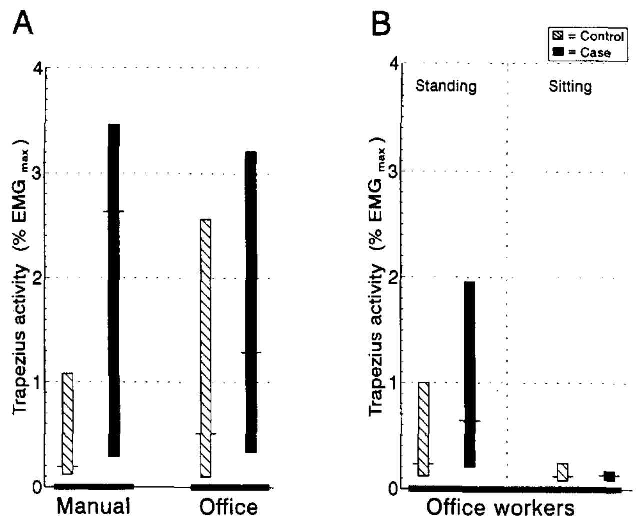

Fig. 5 Trapezius activity at rest during the uninformed (**A**) and the informed (**B**, only office workers) conditions. Median values with 95% confidence intervals are given.

controls. Due to the lack of differentiating results on the EMG variables for the office group, no reliable discriminant function could be constructed for this group. In the manual group, the analysis gave the following function: $-0.52 + 0.30$ uninformed rest, which correctly classified 73% of the subjects. Seven cases and one control were misclassified by this function. Removal of uninformed rest from the analysis gave the following function: $-2.32 + 1.30$ static load $+ 0.13$ gap time, classifying only 63% of the subjects correctly.

Males

Due to the small sample size in the male group ($n = 9$ pairs), no statistical tests were performed, but mean and median values were compared for trends. The results seem to differ between males and females, the results in males often showing opposite trends to those in females. In other words, the associations found for women would weaken if the male and female data were pooled and reported without consideration of gender.

Discussion

The main finding in this study was a consistent difference between the manual and office groups regarding different EMG activity patterns in cases and controls. The cases performing manual work showed higher muscle activity and fewer pauses in the vocational recordings than the controls, almost regardless of what variable was quantified. The cases also had much higher muscle activity at rest. The results in the manual group are consistent with the hypothesis of muscle hyperactivity contributing to the development of muscle pain and with the results of a longitudinal study of manual workers (Veiersted et al. 1993). In contrast, the office workers in this study showed no such trend. The pain status was not reflected in any of the vocational or laboratory recordings. The only exception was the long gaps variable from the vocational recordings, but this difference was in a direction opposite to the hypothesis. It should be pointed out that there was no correction in the statistical analysis for the multiple comparisons performed, but the consistent effect on several variables in the manual group and the complete lack of effect in the office group reduce this concern.

The lack of proper methods in quantifying physical exposure is a major problem in the current literature (Winkel and Westgaard 1992). External exposure parameters describe the physical work task while internal exposure parameters describe the forces in the target tissue (Winkel and Westgaard 1992). The purpose of matching cases and controls in this study was to control for the variation in historical and current external exposure as a confounding factor. The internal exposure level estimated by EMG could then become a better indicator of physical exposure dose and be used to indicate possible exposure-effect relationships. A concern is the validity of using a single 30-min EMG recording as a representation of the vocational muscle activity in general; however, repeated measurements over a week suggest that the reproducibility is acceptable (Veiersted, unpublished). The difference in overtime between cases and controls in the office group suggested a discrepancy in current exposure time, but this difference was probably not critical in view of the similar results for the EMG variables of pairs without overtime and the total sample.

Previous results pertaining to the hypothesis have also been inconsistent. Higher muscle activity levels have been found in patients with shoulder pain during controlled work recordings (Erdelyi et al. 1988) and during the relaxation phase of a cyclic, isokinetic muscle contraction test (Elert et al. 1992). Higher static load and fewer EMG gaps have been observed in manual workers with previous complaints (Veiersted et al. 1990). Fewer EMG gaps and higher EMG activity during uninformed rest characterized the prospective patients in a longitudinal study (Veiersted et al. 1993; Veiersted 1993). In contrast, little or no relation was found between muscle activity and shoulder-neck complaints in other cross-sectional studies (Takala and Viikari-Juntura 1991a, b; Jensen et al. 1993a). It is not clear why some vocational EMG variables reached significance in the manual work group and none at all in the office group. Alternative explanations on the basis of data including psychosocial variables are discussed in other papers from this study (Vasseljen et al. 1994; Vasseljen and Westgaard, unpublished work). It has been suggested that prolonged activation of low-threshold motor units or muscle hyperactivity (i.e., excessive activation of low-threshold motor units above that needed for the task at hand) may be a source of muscle pain (Edwards 1988; Hägg et al. 1990; Wærsted et al. 1993), an effect that is difficult to detect by conventional analysis of vocational EMG recordings. We have therefore used psychophysiological and coordination tests as indicators of muscle hyperactivity, either as a stress reaction or due to poor muscle coordination. One such test is the two-choice reaction time test, which functions well in provoking attention-related muscle activity. In a recent cross-sectional study, office workers with a high EMG response ($> 1\%$ EMG_{max}) both in this test and for the passive arm in the muscle coordination test reported more muscle pain at work than those with low EMG responses (Westgaard et al. 1993). In the present study very few subjects showed a high EMG response to those tests and a similar analysis was therefore not made.

A student population (Wærsted and Westgaard, unpublished) recorded twice the attention-related activity of the subjects in this study, possibly due to a more competitive attitude. Such effects may critically influence the outcome, rendering these tests poor indicators of general muscle tension in cross-sectional comparisons of different groups. Another test with an interesting potential is the recording of muscle activity during resting periods in the standing position when the subject is unaware that the resting level is being recorded. This test may avoid variations related to differences in subjects' attitudes.

It is difficult to see how the difference in vocational muscle activity between cases and controls in the manual group is of pathophysiological relevance. The difference was marginal and considerable individual variations were seen regardless of pain status. The difference in muscle activity at rest is interesting, and can be a marker of hyperactivity in low-threshold motor units. This difference was quite large, and may point to an effect of pathophysiological significance.

This study provides further support for the finding that individual recording of vocational EMG activity as part of a cross-sectional health survey differentiates poorly between those at risk and those not at risk of developing musculoskeletal complaints (Jensen et al. 1993a). The observed difference between cases and controls in the manual group cannot be translated into threshold limit values for acceptable muscle activity in the trapezius. The specific usefulness of EMG recordings in exposure assessment would be to show individual differences in muscle load (internal exposure) under similar work demands (external exposure). Such differences in internal exposure exist, but these are associated only to a very limited extent with shoulder and neck myalgia in cross-sectional studies. Applications of EMG measurements that would still be useful in practical terms are biofeedback and repeated measurements on the same individual to evaluate ergonomic interventions. In conclusion, upper trapezius muscle activity as measured by surface EMG is not a good indicator of work-related shoulder and neck pain at lower load levels and thus cannot be used for screening purposes.

Acknowledgement This study was supported by the Norwegian Research Council.

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