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ORIGINAL ARTICLE

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Muscle activity during computer-based office work in relation to self-reported job demands and gender

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Abstract The aim was to investigate whether quantitative job demands influence muscle activity among women, and whether there are gender differences in duration of computer, mouse, and keyboard use and muscle activity of shoulder and forearm muscles during work. The study was carried out in an occupational setting, and 24 women and 11 men from a municipal administration participated. The duration of computer, mouse, and keyboard use was measured by a commercial software package. Quantitative job demands were registered by questionnaire. Electromyography (EMG) was measured bilaterally from the upper trapezius and the extensor digitorum communis muscles. No association was found between self-reported quantitative job demands and muscle activity among the women ($n=24$). The women used the keyboard more frequently ($p=0.020$) and tended to perform fewer mouse clicks compared to men ($p=0.057$), but no difference was seen in EMG activity between men ($n=11$) and women ($n=11$) from the same department. However, office assistants (six women) showed significantly higher static EMG activity levels ($p=0.042$) and almost significantly shorter EMG gap times ($p=0.060$) than the rest of the subjects (5 women and 11 men). This indicated that shorter muscular resting periods among female office assistants as compared to the other subjects were due to differences in job content rather than gender differences.

Keywords Electromyography · Extensor digitorum communis · Gender · Quantitative job demands · Trapezius

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Introduction

The use of computers at work as well as during leisure time is growing worldwide. In Denmark 60% of a representative sample of Danish employees reported using a computer at work in 1999, and 19% reported using the computer for at least 75% of their work time (Burr 2000).

Epidemiological data demonstrate that the prevalence of musculoskeletal symptoms especially in the upper extremities is high among computer users (Gerr et al. 2002; Jensen et al. 2002a). Risk factors for the development of musculoskeletal symptoms when working with a computer include continuous computer use for the entire workday, repetitive computer work, and poor workstation design (Bergqvist et al. 1995; Fogleman and Lewis 2002; Marcus et al. 2002; Punnett and Bergqvist 1997). Furthermore, psychosocial factors may also be important in the development of musculoskeletal symptoms (Bernard et al. 1994; Bongers et al. 1993). In a Danish cross-sectional questionnaire study among employees with intensive computer work, an association between high quantitative job demands and musculoskeletal symptoms in the shoulder and hand/wrist region was found for both women and men (Jensen et al. 2002b). Another cross-sectional survey among newspaper employees showed that frequent deadlines were associated with musculoskeletal symptoms (Polanyi et al. 1997). In addition, laboratory studies have shown that high time pressure during standardized computer tasks resulted in increased muscular activity in the shoulder and extensor muscles of the forearm (Birch et al. 2000). The present study addresses a possible relationship between quantitative job demands and muscle activity levels during normal work.

Female computer users report symptoms in the neck/shoulder, elbow, and hand/wrist region almost twice as frequently as men (Gerr et al. 2002; Jensen et al. 1998, 2002a). It is not clear whether gender differences relate to different exposure at work or biological differences play a role in the higher prevalence of musculoskeletal symptoms among women compared to men. Laboratory studies have shown that female computer users may operate the mouse with more extreme postures such as outward rotation and abduction of the shoulder, wrist extension and ulnar deviation and with increased muscular activity in the shoulder as well as the extensor muscles of the forearm (Karlqvist et al. 1998, 1999; Wahlström et al. 2000). The results of these studies indicate that gender differences in work technique may play a role in the higher prevalence of symptoms among women. It is not clear if women in a typical occupational setting work with muscle activity patterns that may put them more at risk of developing musculoskeletal symptoms than men. Nordander et al. (2000) did not find difference in the muscle activity between female and male office workers. Gender difference in muscle activity was also addressed in the present study.

The study was carried out in a municipal administration where the work consisted of typical administrative office work tasks, and measurements were obtained while the participants performed their normal work. The aims were: (1) to investigate whether job demands related to time pressure and work load (quantitative job demands) influence muscular activity patterns, (2) to study whether women use different patterns of mouse and keyboard use compared to men, and (3) to study whether there are gender differences in the muscle activity of the upper trapezius and the extensor digitorum communis muscles.

Methods

Subjects

Twenty-four women and 11 men from two departments at a municipal administration participated in the study after having provided written informed consent. The mean (range) age, height, and body mass of the women were 38.8 (24–58) years, 1.68 (1.56–1.78) m, and 64.7 (53–90) kg and of the men 38.6 (23–52) years, 1.82 (1.70–1.91) m, and 85.0 (60–110) kg, respectively. Thirteen of the women were employed in the department of taxation while the remaining 11 women and the 11 men were employed in the department of technical services. The local ethical committee approved the study (KF 01–298/00).

Procedures

The analysis of association between quantitative job demands and muscle activity was carried out among all participating female subjects excluding the men in order to avoid an effect of gender. Gender differences were studied among the men and women employed in the department of technical services excluding the women from the department of taxation.

EMG recordings and measurements of the duration of computer work were obtained for 1 h while the subjects performed their normal work. EMG analyses were based on the whole 1-h recording period irrespective of the relative duration of computer work during this hour. However, for the men and women in the department of technical services the EMG analyses were also calculated during periods in the 1 h of work when the subjects performed computer work in order to quantify the muscle activity pattern during computer work only. Registration of keystrokes on the keyboard and clicks on the PC-mouse were also obtained, but for practical reasons this was only carried out for subjects who worked in the department of technical services.

The work of all participants consisted of office work using a computer for the majority of the work tasks. All subjects used a keyboard and an ordinary PC-mouse. The computer-based work tasks were, for both men and women, primarily data entry, word processing, and data processing. However, in the department of technical services 6 of the female subjects were office assistants while the remaining subjects, 5 women and 11 men, had other job titles and they mainly had an academic background. A comparison of the muscle activity patterns of the 6 female office assistants with the remaining subjects was carried out in addition to the comparison of all women with all men in this department.

Electromyography

Electromyography (EMG) was recorded by bipolar surface electrodes (Ag-AgCl electrodes, Medicotest A/S, type 72001-K, Denmark) bilaterally from the upper trapezius muscles and the extensor digitorum communis muscles. For the upper trapezius muscle each pair of electrodes was placed 2 cm lateral to the midpoint between the seventh cervical vertebrae and the lateral end of the acromion (Jensen et al. 1993), and for the extensor digitorum communis muscle the electrodes were placed one-third of the distance between the lateral epicondyle and the radial styloid process (Delagi et al. 1981). The inter-electrode distance was 20 mm. The EMG signal was amplified, low-pass filtered (8^{th}-order Butterworth filter, cut-off 400 Hz), and sampled on dataloggers (Logger Teknologi HB, Lund, Sweden) with a sampling frequency of 1024 Hz. The signals were transferred to a computer, where they were visually checked and high-pass filtered (cut-off 10 Hz), full-wave rectified and root-mean-square (RMS) converted within windows of 100 ms duration. The resting EMG signal was recorded during 5 s of instructed rest with visual feedback from an oscilloscope to eliminate visible EMG activity, and the resting RMS amplitude was quadratically subtracted from all other EMG signals. For normalization the EMG amplitude recorded during maximal voluntary isometric contractions was used. The reference contraction for the trapezius was 90° arm abduction with resistance just proximal to the elbow. For the extensor digitorum communis muscle the reference contractions were wrist extension with a fixed forearm and handgrip using a Jamar dynamometer. Each reference contraction was performed three times. The maximal EMG amplitude (EMG_{max}) during the reference contractions was calculated as the highest mean RMS amplitude obtained with a 1-s window moving in steps of 100 ms. The EMG activity was recorded during 1 h of work and was analysed according to two different procedures: (1) the amplitude probability distribution function (APDF) analysis, which quantifies EMG activity levels (Jonsson 1982), and (2) EMG gap analysis, which quantifies the numbers and duration of "silent" periods in the EMG pattern, defined as periods with an EMG level below 0.5% EMG_{max} for at least 0.2 s (Veiersted et al. 1990).

Computer use

The duration of computer use during the 1-h recording period was measured by video-based observations and/or registration by a commercial software package (WorkPace, Niche Software, New Zealand).

For the video-based observations the data were continuously collected using a minicomputer. Predefined keys were pressed each time a change in the work task was observed. Two different work tasks were observed: (1) computer use, i.e. time spent at the computer with or without (reading on the screen) using the keyboard and mouse, and (2) work tasks not involving the computer (paper work, out of office, etc.).

The software package, WorkPace, recorded the number of keystrokes and mouse clicks and the time spent using the keyboard and the mouse. The total duration of computer use was calculated by the software and the default settings of the software were used. The calculation was based on the duration of the interval between keystrokes and/or mouse clicks. If the interval was shorter than 30 s it was recorded as time spent using the computer, while intervals of a longer duration were recorded as breaks in computer use. The software was installed at the computer of the subjects in the department of technical services and it did not interfere with their work. In the department of taxation the software could not be used and the duration of computer use was measured by observations only. The agreement between the two methods was checked, indicating no differences in the results.

Questionnaire

All female subjects were given a questionnaire quantifying information on quantitative job demands. The questionnaire was constructed from five different questions regarding five aspects of quantitative job demands: (1) work pace, (2) distribution of workloads, (3) time pressure, (4) ability to keep up with deadlines, and (5) the need to do overtime. Each question had five response options (never/hardly ever, seldom, sometimes, often, always), which were weighted equally to construct an index. The weights were: 0, 25, 50, 75 and 100. The index was calculated as a simple average of the weights of each question. Thus, the index value ranged from 0 to 100 (Kristensen et al. 2002).

Statistics

The data were tested for normality by the Anderson–Darling test. Correlations between quantitative job demands and EMG parameters – i.e. EMG gap time and median level of EMG activity – were determined using the Pearson correlation coefficient. This was only performed for the females to avoid any effect of gender. For the male and female subjects employed in the department of technical services a two-way repeated-measures ANOVA was used to test for a main effect of gender for the EMG parameters: EMG gap time, gap frequency, static and median level of EMG activity, and Tukey's post-hoc test was used to identify significant differences. Gender comparisons in computer usage, number of mouse clicks and keystrokes were tested by a *t*-test. Results are expressed as mean (SD), unless indicated otherwise. The level of significance was 0.05.

Results

Quantitative job demands

The women from the department of taxation used the computer 76 (15)% of the work time, while the women from the department of technical services used the computer 55 (18)% of the time. The women from the two departments reported a wide range of quantitative job demands from 25 to 80 on the scale from 0 to 100, but no association was found between quantitative job demands and EMG gap time or median level of EMG activity recorded bilaterally from the upper trapezius muscles (Fig. 1A, B) or from the extensor digitorum communis muscles.

Gender

In the department of technical services the mean duration of computer use during the 1 h of work was 55 (18)% of the time for the women, where as it was 65 (15)% of time for the men (Fig. 2A). The difference was not statistically significant ($p = 0.181$). However, the women had a significantly higher number of keystrokes, on average 2370 and 1550, respectively ($p = 0.020$) (Fig. 2B), while the men tended to perform more mouse clicks compared to the women, on average 312 and 150, respectively ($p = 0.057$) (Fig. 2C).

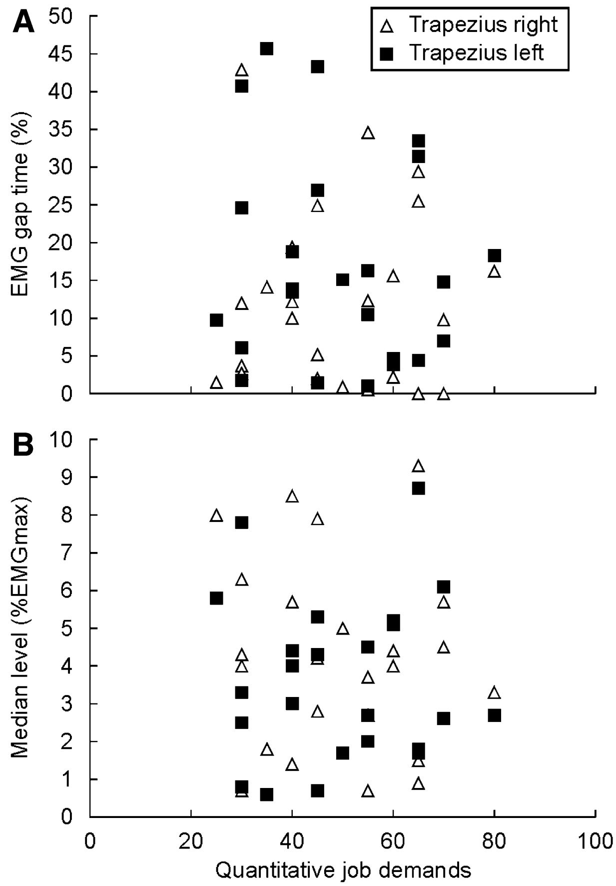

Fig. 1A, B Quantitative job demands vs. total EMG gap time (**A**) and median EMG activity level (**B**) for the right and left upper trapezius muscle among 24 female computer users

The EMG gap time, the gap frequency, and the EMG activity levels were similar when comparing periods of computer work only with the total 1-h work period. For the right upper trapezius muscle the mean EMG gap time and the mean static EMG activity level was 12.8 (14.9)% time and 0.8 (0.7)% EMG_{max} during computer work only and 13.3 (15.6)% time and 1.1 (1.3)% EMG_{max} during the total 1-h work period for the women. For the men the values during computer work only was 22.5 (29.4)% time and 1.1 (1.2)% EMG_{max} and during the total 1-h period 23.1 (29.3)% time and 0.5 (0.9)% EMG_{max}, respectively. The same patterns were seen for the left upper trapezius and the right and left extensor digitorum communis muscles. Thus, in the remaining part we only refer to EMG results for the total 1-h period.

During work no main effect of gender was seen in the EMG gap time ($p = 0.262$), the gap frequency ($p = 0.825$),

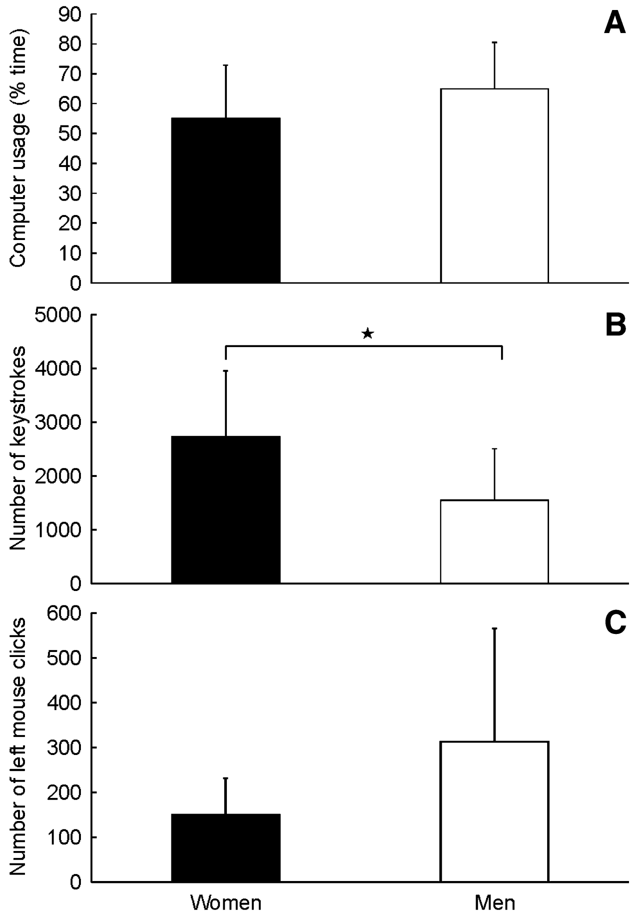

Fig. 2A–C Mean values and standard deviations for computer usage (**A**), the number of keystrokes (**B**), and the number of left mouse clicks (**C**). Significant difference is indicated by ★$p < 0.05$

the static ($p = 0.122$) or the median EMG activity level ($p = 0.795$) for the upper trapezius muscles and the extensor digitorum communis muscles among the employees in the department of technical services (Fig. 3).

However, by comparing the group of office assistants (6 women) with the rest of the subjects (5 women and 11 men), a significant difference was found between the two groups for the static EMG activity level ($p = 0.042$) and a tendency to a significant difference was found for the EMG gap time ($p = 0.060$) (Table 1). For the gap frequency ($p = 0.536$) and the median EMG activity level ($p = 0.795$), no difference was seen between the two groups. Furthermore, the mean EMG values for the women in the group with job titles other than office assistants were similar to the EMG values for the men. For instance, the mean gap times on the right trapezius of these women and the men were 22.4 (18.8)% time and 23.1 (18.6)% time, respectively.

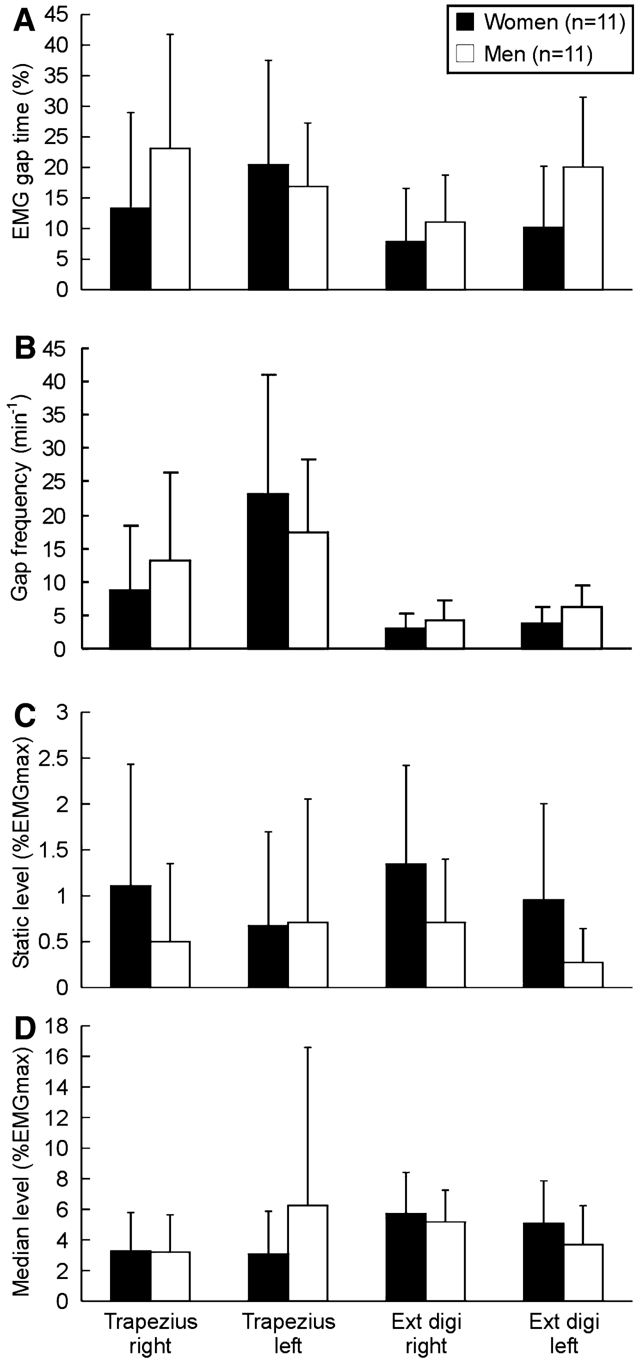

Fig. 3A–D Mean values and standard deviations of the total EMG gap time (**A**), the gap frequency (**B**), the static (**C**), and median (**D**) EMG activity level for the right and left upper trapezius muscles and the right and left extensor digitorum communis muscles (*Ext digi*) among 11 women and 11 men employed in the same department

Discussion

The reported EMG levels of the upper trapezius and the extensor digitorum muscles were similar to those reported during office work as well as during standardized computer tasks in the laboratory (Birch et al. 2000; Nordander et al. 2000), but slightly lower than the levels found during CAD-work (Jensen et al. 1998). The mean EMG gap time and the mean gap frequency recorded from the upper trapezius muscle was longer and higher, respectively, compared to the EMG gap time and gap

Table 1 EMG activity patterns of the upper trapezius and the extensor digitorum communis muscles among 6 female office assistants and the subjects with other job titles (5 women and 11 men) in the department of technical services. Mean values (standard deviations) are shown

Muscle	EMG gap time (%)		Gap frequency (min^{-1})		Static level (%EMG_{max})		Median level (%EMG_{max})	
	Office assistants	Other job titles	Office assistants	Other job titles	Office assistants	Other job titles	Office assistants	Other job titles
Trapezius right	5.7 (7.4)	22.9 (18.0)	6.2 (7.9)	12.9 (12.2)	1.1 (0.7)	0.7 (1.3)	3.6 (1.2)	3.1 (2.8)
Trapezius left	14.8 (16.7)	20.1 (13.0)	18.5 (19.7)	20.9 (13.3)	1.0 (1.3)	0.6 (1.1)	3.3 (2.5)	5.2 (8.8)
Ext digi right	3.4 (2.9)	11.7 (8.4)	2.0 (1,5)	4.1 (2.8)	1.9 (1.0)	0.7 (0.6)	6.9 (2.8)	4.9 (2.0)
Ext digi left	4.7 (4.1)	19.0 (11.2)	2.9 (2.2)	5.8 (3.1)	1.5 (1.2)	0.3 (0.4)	6.2 (3.1)	3.7 (2.3)

frequency measured during CAD-work as well as during deskwork and keyboard work (Jensen et al. 1999; Nordander et al. 2000). Some studies have indicated that absence of EMG gaps may be a risk factor for shoulder disorders among workers performing light manual work or office work (Hägg and Åström 1997; Veiersted et al. 1993). However, such an association has not been demonstrated for the wrist extensor muscles, and laboratory studies have shown a total absence of EMG gaps in the wrist extensor muscles during computer mouse work and simulated computer mouse work (Laursen et al. 2001; Olsen et al. 2001). In the present study EMG gaps were detected for both the right and left extensor digitorum communis muscle. In contrast to the laboratory studies, the subjects performed their normal work during the recordings, which consisted of both work at the computer and other work tasks, e.g. deskwork. Even though our own analyses showed similar EMG results during periods of computer work only, the computer work was probably less intensive compared to the computer tasks in the laboratory studies. This may explain the different findings. The similarity of EMG activity patterns recorded during computer work only with the EMG patterns recorded during the whole recording period indicated that the muscle activity in the present study was independent of the relative distribution of computer-based and non-computer-based work performed during this 1-h period.

Quantitative job demands

The levels of self-reported quantitative job demands among women in two departments of a municipal administration varied widely, which is a prerequisite for detecting any effect of this variable. Nevertheless, the study did not show any association between self-reported quantitative job demands and the median EMG activity level or the EMG gap time of the upper trapezius and the extensor digitorum communis muscles. Previously, laboratory studies have reported an increase in the load on the shoulder and forearm muscles when time pressure and work pace are increased (Birch et al. 2000; Laursen et al. 1998), and cross-sectional epidemiological studies of jobs with intensive computer work, the presence of deadlines and high quantitative job demands have been shown to be associated with musculoskeletal symptoms (Jensen et al. 2002b; Polanyi et al. 1997). An explanation for the lack of association between quantitative job demands and muscle activity could be that the self-reported level of quantitative job demands did not reflect differences in work pace. One of the items used to construct the scale "quantitative demands" was a question on work pace, but little variation was observed within the answers to the individual items, which indicated that work pace did not differ enough between subjects to analyse associations with the EMG results. Furthermore, while the questions on quantitative job demands may relate to measurable objective demands related to time pressure and workload, any questionnaire measures perceived job demands, which may differ considerably from objective job demands. Thus, the clear association between actual work pace and muscle activity as recorded in standardized experiments and the lack of association between self-reported job demands and muscle activity indicated that more research is needed on the relationship between self-reported and objective job demands. Another explanation of this discrepancy could be that high quantitative job demands are not reflected continuously in the muscle activity pattern but only in certain periods during the work. Thus, longer recordings of days or weeks may be required to reflect self-reported estimates of job demands.

Gender

The study of gender differences among the employees in the department of technical services showed that the women performed more keystrokes but fewer clicks on the computer mouse compared to the men during the 1 h of work, although the mean duration of computer use was similar. These results indicated either that the men and women did not use the same work technique or that the type of work tasks differed between men and women.

No statistically significant effect of gender was found in the muscular activity patterns of the upper trapezius or the extensor digitorum communis muscles, but there was a tendency for a lower EMG gap time and higher static levels among the women in general compared to the men. However, the relatively small number of subjects made it difficult to detect small differences in EMG patterns. Norander et al. (2000) have reported comparable results. They found no gender differences for the EMG levels, the EMG gap time or the gap frequency of the upper trapezius muscle among office workers performing their normal work.

A comparison of EMG patterns in the present study between office assistants and subjects performing other jobs showed that the EMG gap times recorded from the right trapezius muscle and the extensor digitorum muscles were considerably shorter for the office assistants than for the other subjects. This indicated that the muscle activity was more continuous, i.e. with fewer periods of inactivity, during work tasks performed by office assistants. The static and mean levels of EMG activity did not indicate differences that could be physiologically relevant, as all levels were small. The only exception could be the static levels of the extensor digitorum muscles, as a static level of 1–2% EMG_{max} may indicate a lack of muscle rest periods, but this was also, and more appropriately, indicated by the EMG gap parameters. A further comparison of EMG patterns of the women and men in the group comprising job titles other than office assistants showed similar mean values for all EMG parameters. Probably the work tasks of the office assistants were less varied than the work tasks of the others, and even though all office assistants were women the results indicated that differences in muscle activity patterns were due to differences in work content rather than gender itself. However, the groups were small and we could not include any male office assistants, so conclusive evidence cannot be presented here.

Conclusions

In conclusion, the study showed no association between self-reported quantitative job demands and the muscle activity patterns of the upper trapezius and the extensor digitorum communis muscles among women. Gender differences were found in mouse and keyboard use, but no significant differences were seen in the EMG activities of women and men from the same department. However, the results indicated that shorter muscular resting periods among female office assistants as compared to the other subjects were due to differences in job content rather than gender differences.

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