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ORIGINAL ARTICLE

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A comparison of muscular activity during single and double mouse clicks

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Abstract Work-related musculoskeletal disorders (WMSDs) in the neck/shoulder region and the upper extremities are a common problem among computer workers. Occurrences of motor unit (MU) double discharges with very short inter-firing intervals (doublets) have been hypothesised as a potential additional risk for overuse of already exhausted fibres during long-term stereotyped activity. Doublets are reported to be present during double-click mouse work tasks. A few comparative studies have been carried out on overall muscle activities for short-term tasks with single types of actions, but none on occurrences of doublets during double versus single clicks. The main purpose of this study was to compare muscle activity levels of single and double mouse clicks during a long-term combined mouse/keyboard work task. Four muscles were studied: left and right upper trapezius, right extensor digitorum communis (EDC) and right flexor carpi ulnaris. Additionally, MU activity was analysed through intramuscular electromyography in the EDC muscle for a selection of subjects. The results indicate that double clicking produces neither higher median or 90th percentile levels in the trapezius and EDC muscles, nor a higher disposition for MU doublets, than does single clicking. Especially for the 90th percentile levels, the indications are rather the opposite (in the EDC significantly higher during single clicks in 8 of 11 subjects, $P < 0.05$). Although it cannot be concluded from the present study that double clicks are harmless, there were no signs that double clicks during computer work generally constitute a larger risk factor for WMSDs than do single clicks.

Keywords Computer mouse · Muscle activity · Motor units · Doublets

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Introduction

Work-related musculoskeletal disorders (WMSDs) in the neck/shoulder region and the upper extremities are a common problem among computer workers in Sweden, especially for women (Wigaeus Tornqvist et al. 2000; Öberg and Åström 2000). Similar conditions have been reported in other countries, e.g. the United States, where the Bureau of Labor Statistics in 1999 documented almost 100,000 new cases of upper limb WMSDs in typing-intensive work such as in technical fields, sales and administrative support (BLS 1999). Several studies report augmented problems with increased computer usage (Wigaeus Tornqvist et al. 2000; Fogleman and Lewis 2002; Blatter and Bongers 2002).The use of computers at work has increased dramatically during the last few years [see e.g. statistics for Sweden (Wigaeus Tornqvist et al. 2000; Broberg and Bastin 2002) and the United States (Kominski and Newburger 1999)].

A subpart of the WMSDs linked to computer work has the character of muscular disorders (Juul-Kristensen et al. 2004). The physiological mechanisms for development of muscular disorders, e.g. myalgia and tension neck syndrome, among computer workers are not yet fully understood. Hägg (1991) formulated the Cinderella hypothesis, which suggests that the low-threshold motor units (MUs) are the first ones to be at risk for selective overuse, e.g. causing fibre injuries, in a sustained activation of the muscle. Both continuously and intermittently active low-threshold MUs have been reported from the upper trapezius muscle (Thorn et al. 2002b) and the extensor digitorum communis (EDC) muscle (Forsman et al. 2002) during long-term static muscle contractions, and from the upper trapezius muscle during long-term computer work (Waersted et al. 1996; Thorn et al. 2002a; Zennaro et al. 2003). The findings of continuously active MUs indicate that some MUs may be at risk of exhaustion during long-term stereotyped work tasks.

Occurrences of MU double discharges with very short inter-firing intervals (MU doublets) have been hypothesised as a potential additional risk for overuse of already exhausted MU fibres during long-term stereotyped activity (Søgaard et al. 2001). In the EDC muscle, doublets have previously been reported to be more frequent during double mouse-click tasks than during slow finger-lifting tasks (Søgaard et al. 2001) or during slow ramp contractions (Sjøgaard et al. 2001). Olsen et al. (2002) compared the MU firing patterns in the EDC muscle during double versus single mouse-click tasks, and reported a tendency for a higher mean and total number of MU firings during the double-click tasks. Laursen et al. (2000, 2001) reported significantly higher mean surface electromyographic (SEMG) activity during a double-click task than during various other mouse tasks (such as single-click, drag or trace tasks) for the right extensor carpi radialis (ECR) muscle, for the right flexor carpi radialis muscle (FCR) in the group of young (< 29 years) subjects, and for the right EDC muscle for elderly (> 55 years) subjects. For the young subjects, on the other hand, the mean EDC activity was significantly higher during the single-click task at self-determined speed. In all studies referred to above, the subjects performed short-term work tasks, each containing a single type of mouse or finger movement action. Thus, comparative data from tasks resembling ordinary computer work is very limited. Furthermore, data on MU doublet occurrences during double-click versus other mouse-click tasks is lacking.

The main purpose of the present study was to compare muscle activity levels of single and double mouse clicks during a long-term combined keyboard-and-mouse computer work task. This was done through SEMG measurement in four muscles. In order to enhance the interpretation of the SEMG results, MU activity during mouse clicks was analysed from intramuscular electromyography (iEMG) in a forearm extensor muscle for a subset of the subjects.

Materials and methods

Subjects

Eleven subjects (7 males and 4 females), all right-handed, volunteered to participate in the study. They were all healthy non-smokers without any reported upper limb complaints during the previous month. The Research Ethics Committee at Gothenburg University approved the study. The average age of the subjects was 31 (SD 9.0) years for males and 28 (7.4) years for females.

Measurements

A standard computer workstation with a PC-type computer, 15-inch flat-panel active-matrix liquid crystal display (LCD), a standard keyboard (QWERTY) and a left mouse button force-sensitive Intellimouse (Johnson et al. 2000a) was used. This instrumented mouse facilitated identification of occasions of single and double mouse clicks.

Bipolar SEMG sensors (Medicotest N-00-S, Denmark) were placed over the left trapezius pars ascendens (LTRAP) and right trapezius pars ascendens (RTRAP) muscles 20 mm medial to the midpoint between the seventh cervical vertebra (C7) and the acromion. This position—instead of 20 mm lateral to the midpoint, as recommended by, for example, Mathiassen et al. (1995)—was chosen in order to ensure needed muscle thickness for insertion of intramuscular EMG electrodes (Thorn et al. 2002a). For the right EDC and right flexor carpi ulnaris (FCU) muscles, the electrodes were placed approximately at one third of the distance from the lateral epicondyle to the lateral styloid, and with final position confirmed by palpation while moving the index finger. The inter-electrode distance was 20 mm for each muscle site, according to the general recommendation by the SENIAM project (Freriks et al. 1999). The SEMG data from the four locations and the mouse force data were low-pass filtered with a cut-off frequency of 8 kHz and simultaneously recorded on a PC at a sampling rate of 20 kHz. Additionally, three-channel iEMG was simultaneously recorded from the right EDC muscle by a quadrifilar wire electrode (Forsman et al. 2001) in three of the subjects. The iEMG insertion point was centred between the two SEMG electrodes.

Protocol

The subjects were asked to sit in an adjustable chair in front of the computer workstation. The chair, armrest and table were carefully adjusted for each subject, individually, in order to allow the subjects to position their upper arms vertically and to obtain a 90° angle between the upper and lower arm. However, the mouse, keyboard and computer screen positions were placed at the subjects' preference and the positions noted. All subjects placed the mouse to the right of the keyboard and employed their right hand to click or double-click the mouse.

Each subject performed a 60-min combined mouse and keyboard work task (Thorn et al. 2002a), which consisted of editing an English text in which every 20th word was in boldface. The task was to (1) double-click on the boldfaced word, (2) single-click on the boldface icon (i.e. un-bold the word) and (3) retype the word, using the keyboard. Occasionally, the subjects also single-clicked on the vertical scrollbar arrow icons. No time pressure or demands for accuracy were conveyed.

After the 60-min session, three maximal voluntary contractions (MVCs) were performed for the LTRAP, RTRAP, EDC and FCU muscles. The corresponding SEMG maximal voluntary electrical (MVE) activity was computed according to the procedure recommended by Mathiassen et al. (1995). The subjects performed the trapezius MVCs by pressing the elbows upwards against a constraining surface, while having both arms flexed 90° and abducted 90° in the frontal plane, and seated in an upright position. The MVCs for the EDC and the FCU muscles were performed with the fingers pressing upwards (EDC) and downwards (FCU), respectively, against a constraining surface, with the right shoulder abducted 25°, the elbow flexed 60°, and the lower arm and hand resting on a table.

Analyses and statistics

Prior to analysis, the mouse force data were 10 Hz low-pass filtered and the SEMG data were 20–500 Hz band-pass filtered, both with sixth-order Butterworth filters. SEMG RMS curves with a 0.1-s moving window were calculated. For each single and double click sequence, a median and a 90th percentile (p90) value was obtained within a 0.5-s window, approximately centred at the click actuation. Click sequences were defined as time intervals with mouse forces above a chosen threshold level, to distinguish them from, for example, resting the finger on the mouse button or background noise. The click actuation was defined as the time during first negative mouse force flank with maximum slope. The analysed 0.5-s window started 0.2 s before and ended 0.3 s after the click actuation. Owing to non-normal distribution of data, non-parametric statistics were used. For each subject, and for each of the four studied muscles, the median and p90 values during single clicks were compared to the corresponding values during double clicks, using the Mann-Whitney test for independent samples. For the group level of all subjects, the intra-individual medians of the median and p90 values for all single and double clicks, respectively, were calculated and compared using the Wilcoxon signed-rank-test for dependent samples.

For 3 out of the 11 subjects, the MU firing patterns for 50 consecutive mouse clicks (i.e. single and double clicks mixed) was analysed using a semi-automatic classification program (Forsman et al. 1999, 2001). The program decomposed 0.75 s of data before and after each 0.5-s click period, thus a total of 2 s of data for each click. Data about click type were blinded for the decomposition analyst. The program handled the stored data in 20-s periods (i.e. 10 consecutive clicks), which were, after the automatic phase, decomposed manually using the editing and manual clustering options as recommended by Forsman et al. (2001). MU double discharges with inter-firing intervals less than 20 ms were identified as MU doublets. For each subject, the total number of observed doublets during single versus double clicks was compared, using the Fisher exact probability test for independent samples. All calculations were performed using MATLAB, with a 0.05 level of significance for the statistical tests.

Results

Owing to technical failure, the analysis time for one subject was reduced to the first 30 min of the performed work task. In all other subjects, a full 60-min sequence was analysed.

The number of single and double clicks performed was on average 450 (SD 124) and 358 (76), respectively. The average SEMG RMS levels for the complete work session (keyboard and mouse work) were 4.0 (2.2), 6.2 (5.0), 11.7 (5.3) and 2.2 (1.4) %MVE for the LTRAP, RTRAP, EDC and FCU muscles, respectively.

SEMG levels during mouse clicks

For the group of all subjects, the median SEMG RMS values for the LTRAP, RTRAP, EDC and FCU muscles were 4.1, 3.4, 9.2 and 1.4% MVE, respectively, during single clicks, and 3.1, 2.7, 12.1 and 1.9% MVE, respectively, during double clicks. The differences between single and double clicks were statistically significant for the LTRAP and RTRAP muscles ($P<0.001$), but not for the EDC and FCU muscles ($P<0.21$ and $P<0.52$, respectively).

The corresponding p90 SEMG RMS values for the LTRAP, RTRAP, EDC and FCU muscles were 5.7, 7.6, 20.1 and 3.7% MVE, respectively, during single clicks, and 4.5, 4.1, 17.6 and 3.6% MVE, respectively, during double clicks. The differences between single and double clicks were significant for the LTRAP and RTRAP muscles ($P<0.001$ and $P<0.01$, respectively), tended to be different for the EDC muscle ($P<0.06$) and were not significant for the FCU muscle ($P<0.37$).

The median and p90 SEMG RMS results for the group of all subjects are visualised in Figs. 1 and 2, respectively.

The median SEMG RMS and mouse force curve shapes for each of the 11 subjects are shown in Fig. 3. While the median mouse forces showed to be relatively similar between the subjects, there were large inter-individual differences in median SEMG curve shapes and levels. This was particularly visible for the EDC muscle, and partly for the RTRAP muscle

For the individual results, the LTRAP median and p90 SEMG RMS values were significantly higher during single than double click periods for 10 out of 11 subjects

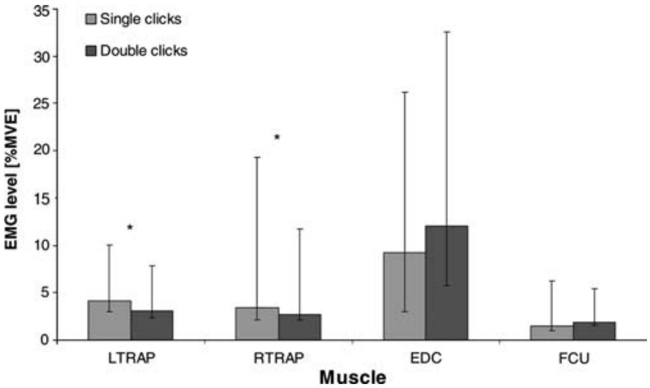

Fig. 1 Median SEMG RMS values during single and double mouse clicks, shown as group medians and 10th/90th group percentiles, in four different muscle sites. Statistically significant differences ($P < 0.05$) are marked with *asterisks*

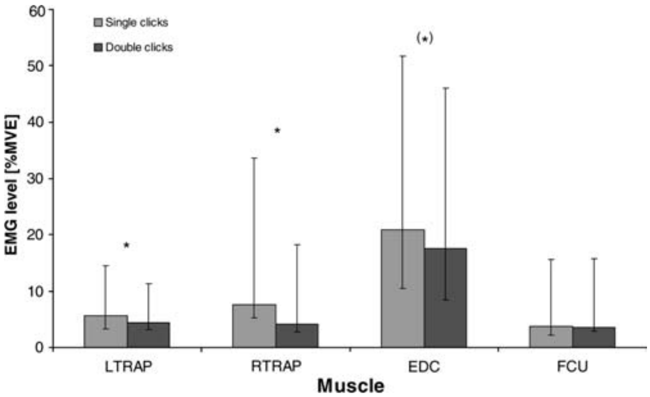

Fig. 2 p90 SEMG RMS values during single and double mouse clicks, shown as group medians and 10th/90th group percentiles, in four different muscle sites. Statistically significant differences ($P < 0.05$) are marked with *asterisks* and *parentheses* indicate tendencies ($P < 0.1$)

(max $P < 0.05$), while none of the subjects showed significantly lower values during single clicks. For the RTRAP muscle, this was the case for 8 and 10 out of 11 subjects (max $P < 0.05$), respectively.

The EDC median and p90 SEMG RMS values were significantly higher during single clicks in 3 and 8 out of 11 subjects (max $P < 0.05$), respectively, and significantly lower in 7 and 2 of the subjects (max $P < 0.05$), respectively. In Fig. 4, SEMG RMS curves during single and double clicks are shown for one subject, visualising higher p90 EMG RMS values during single clicks, as compared with double clicks.

In Table 1, median and p90 SEMG RMS values are shown for the EDC muscle as an example of the data reduction. Owing to space concerns, corresponding tables for the LTRAP, RTRAP and FCU muscles are not presented here.

For the FCU muscle, the median and p90 SEMG RMS values were significantly higher during single clicks in 4 and 7 out of 11 subjects (max $P < 0.05$), respectively, and significantly lower in 6 and 2 of the subjects (max $P < 0.05$), respectively. For the group of all subjects, the median values were on average 0.44% MVE lower during single clicks while the p90 values were 0.09% MVE higher. However, none of these differences were statistically significant.

Doublet observations in the EDC muscle

As previously described, MU firing patterns were analysed during 50 consecutive mouse clicks for 3 subjects. For 2 of the subjects analysed (subjects 3 and 8), the total number of identified doublets during single/double clicks were 19/16 and 5/0, respectively. None of the differences were statistically significant ($P < 0.11$ and $P < 0.33$, respectively). For the third subject analysed (Subject 2), no doublets were found for either single-click or double-click periods. The classification rate (percentage of classified segments), number of classified MUs and number of analysed single/double clicks for these three subjects are shown in Table 2.

In Fig. 5, the number of firings per click occasion for the four MUs in subject 3 is shown, visualising no clear differences between single and double clicks, and a tendency for an overall higher number of firings per click occasion for the MUs with a more expressed occurrence of doublets.

Discussion

In this study, muscular activity in four muscle sites was analysed during single and double clicks from one hour of combined mouse-and-keyboard computer work. The main result was that double clicking produced neither higher median or p90 muscle loads, nor more doublets, than did single clicking. The indications were rather the opposite, especially for the SEMG p90 levels in the LTRAP, RTRAP and EDC muscles.

SEMG results versus previous findings

As presented above, the average SEMG RMS levels for the complete keyboard-and-mouse work session were 4.0, 6.2, 11.7 and 2.2% MVE for the LTRAP, RTRAP, EDC and FCU muscles, respectively, and the median values during the mouse-clicks were at similar levels. These results are similar to those from previous studies of computer workers. For instance, two field studies of computer-aided design (CAD) operators have demonstrated a median trapezius activity of approximately 4% MVE on the dominant side (Jensen et al. 1998, 1999) and 2% MVE on the non-dominant side (Jensen et al. 1998), respectively. In the latter study, the median EDC activity was approximately 6% MVE. Furthermore, laboratory studies involving mouse work tasks have reported median EDC activities of approximately 8% MVE during low mental, time and precision demands

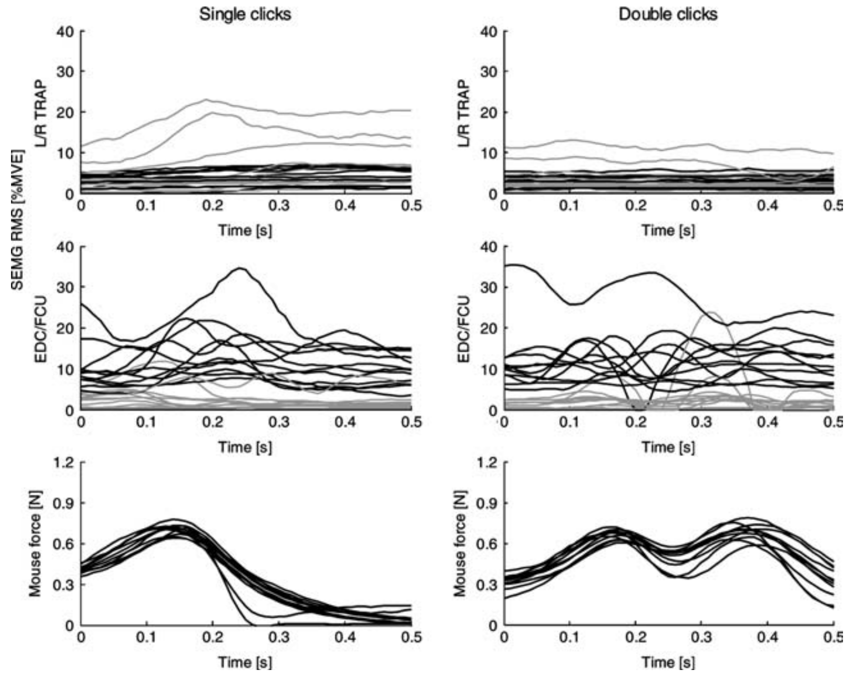

Fig. 3 SEMG RMS and mouse force median curves for each of the 11 subjects during single and double clicks, respectively. LTRAP and RTRAP RMS are plotted in *upper row* (*black and grey curves*, respectively), EDC and FCU RMS in *middle row* (*black and grey curves*, respectively), and mouse force in *lower row*

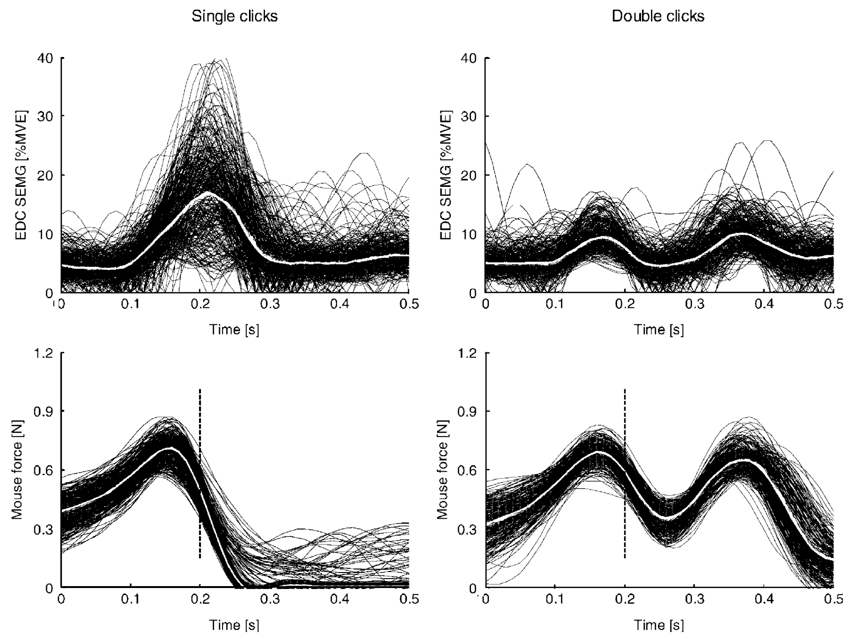

Fig. 4 EDC muscle SEMG RMS curves (*upper row*) and mouse force curves (*lower row*) during single and double clicks for one subject. The median curve shapes are plotted in *white* and are included in Fig. 3. The *dashed lines* denote click actuation

(Birch et al. 2000), 17% MVE during high-precision work (Aarås and Ro 1997) and 8–10% MVE during various mouse tasks and precision demands for young (<29) and elderly (>55) subjects (Laursen et al. 2001). The latter study reported a median activity of approximately 4–6% MVE in the right flexor carpi radialis (FCR) muscle.

In the present study, the median and p90 LTRAP and RTRAP values on a group level were significantly higher during single clicks than for double clicks. For the majority of the 11 studied subjects, these differences were also statistically significant on an individual level. The mouse clicking tasks activated not only the biomechanically necessary muscles, but also the trapezius muscles, which is in line with results previously presented by, e.g. Schnoz et al. (1999). In two previous studies (Laursen and Jensen 2000; Laursen et al. 2001), no statistically significant differences in trapezius mean activity between single and double mouse clicks were found, and comparative analysis of p90 levels was not reported.

For the EDC muscle, the median values on an individual level were significantly lower during single clicks than during double clicks for a majority of the subjects,

Table 1 Median and p90 SEMG RMS values for the EDC muscle during single/double mouse clicks

Subject	Median RMS (percentage of MVE single/double)	*P* value	p90 RMS (percentage of MVE single/double)	*P* value
1	14.9/**15.6**	< 0.01	**24.1**/22.0	< 0.001
2	8.6/**11.3**	< 0.001	13.9/**17.6**	< 0.001
3	**13.4**/12.5	< 0.001	**22.4**/18.5	< 0.001
4	9.1/**12.1**	< 0.001	**23.3**/16.5	< 0.001
5	9.3/**10.2**	< 0.001	13.7/13.7	NS
6	19.6/**27.8**	< 0.001	**40.6**/38.0	< 0.01
7	6.3/**7.4**	< 0.001	9.2/**9.5**	< 0.05
8	**14.6**/13.7	< 0.001	**20.8**/20.3	< 0.05
9	6.2/6.2	NS	**11.0**/8.4	< 0.001
10	**15.1**/13.0	< 0.001	**24.3**/21.6	< 0.001
11	6.2/**6.4**	< 0.01	**16.6**/10.5	< 0.001

NS Not statistically significant. In cases of significant differences, the highest value is written in *boldface*

Table 2 Classification rate, number of classified MUs, number of analysed single/double clicks, and total number of identified doublets for subjects 2, 3 and 8

Subject	Classification rate [%]	No. of MUs classified	No. of single/double clicks analysed	No. of single/double click doublets identified
2	72	4	27/23	0/0
3	90	4	24/26	19/16
8	89	6	40/10	5/0

although these differences were not statistically significant on a group level. This result is consistent with previous findings of significantly lower mean SEMG RMS values during a single-click task than during a double-click task for the right ECR muscle, and for the right EDC muscle for elderly (above 55 years) subjects (Laursen and Jensen2000; Laursen et al. 2001). In the present study, the p90 values were significantly higher

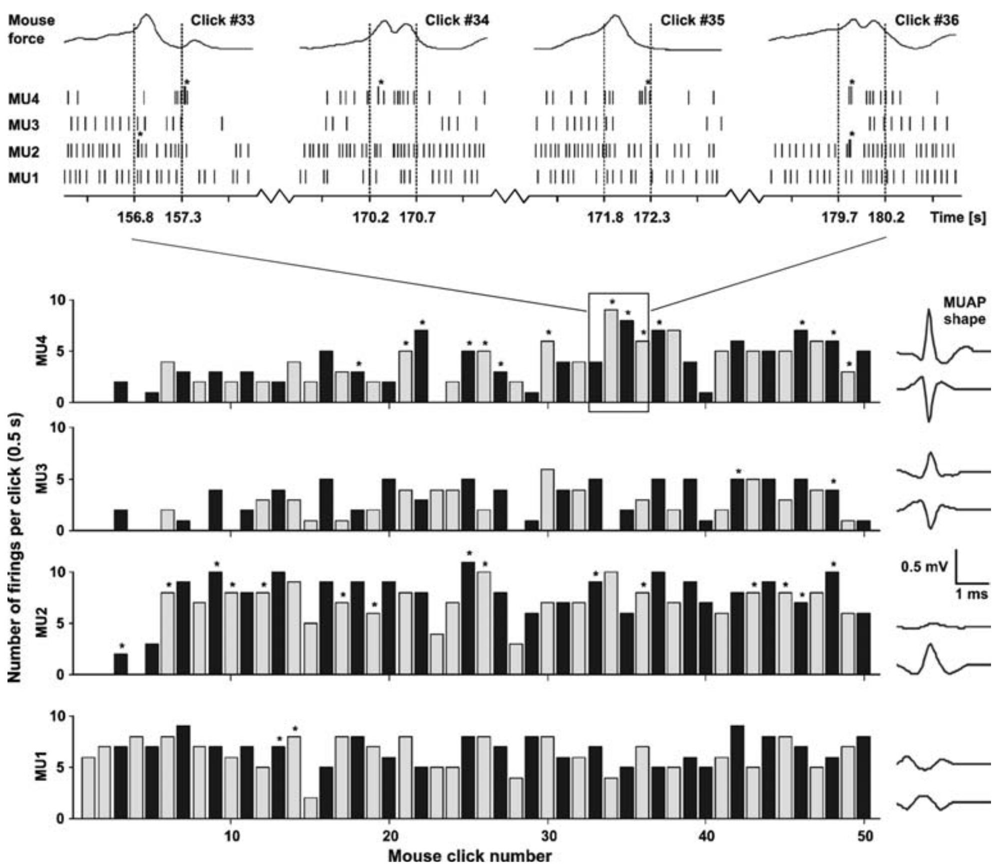

Fig. 5 Motor unit activity during single (*black bars*) and double (*grey bars*) mouse clicks in subject 3, with detailed plot for clicks 33–36. *Asterisks* denote occurrences of MU doublets

during single clicks than during double clicks for a majority of the subjects, and with tendencies toward the same on a group level, while p90 values for specific mouse tasks were not included in the two referred Danish studies. The lack of group level significance for the EDC median and p90 values depends possibly on the large inter-individual differences in SEMG responses, as illustrated in Fig. 3.

For the FCU muscle, there were high individual differences in the SEMG comparisons between single and double clicks in the present study, and no tendencies toward differences were found on the group level, for either median or p90 SEMG RMS values. Single and double clicking are common everyday activities for computer users. The subjects were all experienced keyboard and mouse users. They had probably developed certain habits based on practice, task and/or hand size. Thus, high inter-subject variability could be expected.

A possible explanation for discrepancies in the SEMG results between the present and previous studies may be methodological differences. The task lengths in previous studies were relatively short—between 10 s and 100 s, each task containing one single type of mouse action. Furthermore, the complete tasks were analysed for comparisons, and not just the click occasions as in the present study.

Implications of the SEMG results

An initial occurrence of high-frequency bursts containing MU doublets or triplets is reported to cause a prolonged increase in force without a correspondingly high increase in EMG amplitude (Garland and Griffin 1999; Abbate et al. 2002). Therefore, it could be argued that the lower p90 level during double clicks is a consequence of a higher occurrence of MU doublets during double than single clicks. However, it is difficult to identify neurophysiological evidence for a higher occurrence of MU doublets during double clicks, and the iEMG data do not support such an explanation in this study.

The significantly higher p90 LTRAP and RTRAP values for single clicks, and the tendencies toward higher p90 values during single clicks in the right EDC muscle, imply a larger range of muscle activity during single clicks in these muscles. According to the size-principle of MU recruitment order (Henneman et al. 1965), a higher number of MUs would therefore be expected for recruitment and de-recruitment during single clicks than during double clicks. Previous research has investigated various situations where doublets tend to be more frequent. In addition to being the effect of different neuromuscular diseases (Partanen and Lang 1978) and muscle fatigue (Griffin et al. 1998), doublets have been reported from various muscles:

- During static contractions at the borderline of a MU threshold level (Garland and Griffin 1999)
- At the onset (Desmedt and Godaux 1977; Bawa and Calancie 1983) as well as later in the EMG burst (van Cutsem et al. 1998) of fast, or ballistic, contractions
- At the recruitment and de-recruitment of a MU (Denslow 1948; Bawa and Calancie 1983; Kudina and Alexeeva 1992).

Based on the discussion above, the present SEMG results imply not only an overall higher peak muscle load in the LTRAP, RTRAP and EDC muscles during single versus double clicks, but also that the disposition for occurrences of MU doublets might be higher during the single clicks in these muscles.

iEMG results versus previous findings

In the present study, MU doublets were found in the EDC muscle in two out of three analysed subjects. Doublets were found during both single and double clicks, and the total number of identified doublets was slightly higher, although not statistically significant, during the single clicks. Frequent occurrence of MU doublets has previously been reported in the EDC muscle during double clicking with a computer mouse but not during slow finger-lifting tasks (Søgaard et al. 2001) or during slow ramp contractions (Sjøgaard et al. 2001). Doublets have also been found in the right upper trapezius muscle during double clicking with the right (Blangsted et al. 2001; Olsen et al. 2001) and with the left (Olsen et al. 2001) index finger. Analyses of MU doublets during both single and double mouse clicks have not, however, been previously reported.

Totally, we found 24 doublets in 91 single-click events and 16 doublets in 59 double-click events. In contrast, the studies by Søgaard et al. (2001) and Sjøgaard et al. (2001) reported 72 and 71 doublets, respectively, in 38 double-click events. This discrepancy may possibly be explained by the fact that a needle electrode was used for iEMG detection in these two previous studies, with the position adjusted to record from the MUs more closely related the index finger than to the other fingers, while we used fine wire electrodes not adjusted in that manner. It has been hypothesised, and experimentally supported, in a recently reported study by Keen and Fuglevand (2004) that the EDC muscle is comprised of functional compartments, with each finger being controlled by a discrete population of MUs. Thus, electrical activity from MUs more prone to doublet firings may have been recorded to a higher extent by the needle electrodes, using the above-described protocol, in relation to using the fine wire electrodes.

Another possible explanation for the lower amount of identified doublets in the present results is that the criterion for accepting doublets, in terms of MU action potential (MUAP) shape similarities, was set very restrictively for all subjects. Presumptive doublets were rather excluded than included in doubtful cases. Finally, the classification rate for subject 2 was relatively low, mainly owing to a constant fluctuation of the MUAP shape. All this together may have caused doublets to be missed in the decomposition analysis. However, the comparison between single and double clicks is still relevant since the analysis was blind for click type.

Implications of the iEMG results

The slightly higher number of identified MU doublets in the EDC muscle during single clicks versus double clicks is in line with the implications of the SEMG p90 results above, considering the disposition of MU doublet occurrences. Furthermore, it is interesting to note that the subject with significantly lower SEMG RMS median and p90 values during single clicks (subject 2) showed no doublet events at all, in contrast to the two subjects with significantly higher median and p90 values during single clicks (subjects 3 and 8). This could, however, be explained by, e.g. the lower classification rate for subject 2, as mentioned above. It should also be noted that the presented iEMG results originate from a relatively limited amount of data (three subjects and totally 150 analysed mouse clicks). Nevertheless, the iEMG results from the identified units show no indications that double-clicking a computer mouse produces more doublets than does single-clicking.

As one of the results from a recently completed EU concerted project (PROCID), a list of six recommendations for healthier computer work was developed (Kadefors and Läubli 2002). These include, e.g. suggestions that computer operators should limit repetitive finger movements and constrained postures, be allowed to take frequent breaks and mental relaxation periods and should avoid double clicks using the computer mouse. The last listed recommendation is based on the previously cited hypothesis that MU doublets may cause a potential additional risk of overuse of already exhausted MU fibres during long-term stereotyped activity (Søgaard et al. 2001). Based on the discussion conducted above, the present results do not imply that double clicks during computer work generally would constitute a higher risk factor for WMSDs than do single clicks.

Choice of muscle regions

As mentioned in the introduction, WMSDs are a common problem in the neck/shoulder region and the upper extremities among computer workers. Far from all disorders can be connected with the muscle tissues, i.e. as muscular disorders. As for the neck/shoulder region, an extensive review study of epidemiological findings (Bernard et al. 1997) inferred, however, consistently high odds ratios for tension neck syndrome associated with static postures or static loads. Moreover, a recently performed study by Juul-Kristensen et al. (2004) reported that trapezius myalgia and tension neck syndrome were the two most frequent clinical diagnoses among elderly female computer users with self-reported neck/shoulder complaints. The findings were also significantly more frequent among cases (with complaints) than non-cases (without complaints). According to a study by Ranney et al. (1995) of 146 female workers in highly repetitive industries, neck/shoulder muscular disorders are most common in the trapezius muscles.

Also in the upper extremities, there are indications of the existence of muscular disorders (Ljung et al. 1999; Ranney et al. 1995), although to a lower extent than in the neck/shoulder region. In the latter study, it is further reported that the forearm extensor muscles are major sites for muscular disorders in the upper extremities.

Based on these data, it was decided to aim the present study at investigation of muscular activity, and to choose the left/right upper trapezius and the right EDC as major muscle sites. The FCU muscle was included to facilitate comparisons with other studies, and as a representation of the flexor side musculoskeletal system, which is a less reported region for WMSDs (Gerr et al. 2002).

Protocol and apparatus

Computer work is usually a combination of both keyboard and mouse use. In a 3-day study of office employees doing their regular work, the estimated mouse use was on average 78 (SD 40.7) times per hour, accounting for 23.7% (9.5) of the work time (Johnson et al. 2000b). Therefore, a protocol with combined keyboard and double/single click mouse work was chosen for the present study.

The protocol is, in spite of the keyboard/mouse-work combination, a simplified laboratory setup. A laboratory study by Birch et al. (2000) showed that the shoulder and forearm muscle activity increased with time pressure, compared to that for a self-chosen work pace. In order to limit the amount of independent variables, only a self-chosen work pace was selected, which was judged to be a reasonable representation of common work situations.

It is reasonable to assume that the choice of mouse type would affect the muscle activity results in a computer work task, and several studies have reported significantly different muscle loads using different designs of computer mice (e.g. Aarås and Ro 1997; Gustafsson and Hagberg 2003). As representative of a mouse design commonly used by computer workers, we therefore chose a Microsoft Intellimouse Pro mouse with a scroll wheel. The mouse used in the present study was modified by Johnson and co-workers, was fully operational, and was similar in feel and appearance to a production mouse (Johnson et al. 2000a).

SEMG cross-talk

According to the anatomy of the forearm, there are several muscles neighbouring the EDC and FCU muscles. Close to the EDC muscle are, for example, the ECR brevis and extensor carpi ulnaris muscles. These muscles mainly extend the wrist and adduct/abduct the hand, while the EDC muscle mainly is a wrist and finger extensor (Moore 1985). The flexor digitorum superficialis and the more deeply located flexor digitorum profundus are the two largest muscles surrounding the FCU muscle. While the FCU muscle mainly flexes the wrist and adducts the hand, the former two mainly flex the fingers, the thumb excluded (Moore 1985). Thus, many of the major surrounding muscles have, at least partly, different functions than those of the EDC and FCU muscles, respectively. Owing to their proximity, cross-talk can still be expected to occur in the recorded EDC and FCU SEMG signals. In a study by Mogk and Keir (2003), the cross-talk between forearm extensor and flexor muscle recording sites was reported to be less than 2% during both pinch and grasp tasks, while the corresponding figures within neighbouring extensor and flexor sites were 50% and 60%, respectively. Thus, it would be reasonable to regard the recorded EDC and FCU SEMG signals as forearm extensor and flexor muscle group signals, respectively, with no or very limited extensor versus flexor cross-talk.

Conclusion

The results indicate that double clicking produces neither higher median or p90 levels in the trapezius and EDC muscles, nor a higher disposition for MU doublets, than does single clicking. For the majority of the subjects, the p90 levels were instead significantly higher during single clicking. Also the number of identified MU doublets was higher during single clicking, but these differences were small and not statistically significant. Although it cannot be concluded from the present study that double clicks are harmless, there were no signs that double clicks during computer work generally constitute a larger risk factor for WMSDs than do single clicks.

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