An investigation of how acute muscle pain modulates performance during computer work with digitizer and puck

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Abstract

The purpose was to investigate the influence of muscle pain on work performance during computer work with digitizer and puck. Muscle pain was induced by infusion of hypertonic saline in the trapezius and the extensor carpi ulnaris (ECU) muscles on two separate days. Twelve healthy subjects participated. A computer task was performed in three 6 min sessions: baseline, pain, after pain. The computer task comprised production of drawings at maximal work pace. One drawing was defined as a work cycle. Work cycle time, number of puck button clicks, and screen pixels the cursor had moved per cycle were assessed. Shoulder pain did not influence these variables. Cycle time decreased from 13.8 (SD 2.2) to 13.0 s (SD 1.9) compared to baseline ($p < 0.05$) during ECU muscle pain. The increased or unchanged performance suggests that acute moderate muscle pain has minor influence on performance during computer work with digitizer and puck. 2001 Elsevier Science Ltd. All rights reserved.

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1. Introduction

During the past decades, the number of jobs using visual display units (VDU) has increased substantially (Borg and Burr, 1997), and VDU-work is associated with musculoskeletal disorders of the upper extremities and neck (Punnett and Bergqvist, 1997). Various computer input devices have supplied the keyboard, and there are indications that musculoskeletal complaints from the upper extremities may be associated with intensive use of non-keyboard input devices (Fogleman and Brogmus, 1995; Jensen et al., 1998; Karlqvist et al., 1996).

Several models describing the relationship between exposure and effect during occupational work have been proposed (Armstrong et al., 1993; Sejersted and Vøllestad, 1993; Sjøgaard et al., 1995; Winkel and Mathiassen, 1994). The model by Winkel and Mathiassen (1994) divides exposure into external and internal exposure. The external exposure is completely independent of the operator. In the present study, computer work with high-precision demands and high time pressure comprises the external exposure. In contrast to the external exposure, the internal exposure is dependent on individual factors (Winkel and Mathiassen, 1994). So, when quantifying occupational exposure, it is important to increase the knowledge of factors that may modify the internal exposure. In the present study, we investigate how acute muscle pain influences internal exposure using work performance as an indirect measure of internal exposure.

In a study of technicians working intensively with computer mouse the 12-months prevalence of pain symptoms from hand/wrist, elbow and shoulders of the mouse operating side were 49, 35 and 52\%, respectively (Jensen et al., 1998). With such a high prevalence of musculoskeletal symptoms, it will be valuable to know what influence muscle pain has on internal exposure, which in the present paper is estimated by work performance.

Human experimental muscle pain models can be used to investigate how acute muscle pain influences occupational work (Madeleine et al., 1999). Muscle pain induced by intramuscular injections of hypertonic saline has been applied since the 1930s (Kellgren, 1938; Lewis, 1938), and the saline-induced muscle pain seems to mimic...
occupational and clinical pain to some extent with localised and referred pain (Graven-Nielsen et al., 1997b; Madeleine et al., 1999). The long-term pain induces changes that involve central as well as peripheral mechanism, which cannot be investigated with human experimental pain models. Additionally, emotional stress most likely accompanies longer lasting musculoskeletal symptoms. However, human experimental muscle pain models have the advantage of standardising the origin and the duration of muscle pain (Svensson and Arendt-Nielsen, 1995), and the influence of acute experimental muscle pain may contribute to the understanding of pain mechanisms during occupational work.

According to the pain adaptation model by Lund et al. (1991), muscle pain may cause attenuated work performance. Previous studies have focused on the influence of experimental muscle pain on gross movements such as gait and mastication (Arendt-Nielsen et al., 1996; Graven-Nielsen et al., 1997a; Svensson et al., 1998). The present study focuses on fine co-ordinated motor tasks requiring low force levels, limited range of motion and high manual precision demands.

The aim of the present study was to investigate how acute experimental muscle pain of the upper extremities modulates work performance during standardised computer work with digitizer and puck.

2. Methods and material

2.1. Design

The study consisted of two experiments, separated by 4 weeks. Experiment I: Muscle pain was induced in the shoulder region (the trapezius muscle), and experiment II: Muscle pain was induced in the forearm region (the extensor carpi ulnaris muscle). In each experiment standardised computer work was performed and work performance was assessed.

2.2. Subjects

Twelve healthy young males with no complaints from the upper extremities participated in each experiment of this study with 6 subjects participating in both experiments. All subjects were familiar with computer mouse work. In experiment I, the median age was 22.5 years (20–28 years), height 183 cm (173–193 cm) and weight 75 kg (65–93 kg), and in experiment II, the median age was 23 years (21–26 years), height 183 cm (167–196 cm) and weight 77 kg (65–95 kg).

The local ethic committee approved the study, and all subjects signed an informed consent form prior to the experiment. The studies were in accordance with the Declaration of Helsinki.

2.3. Procedure

A computer workstation was set up in the laboratory, and the subjects adjusted the height of the table and chair individually. The subjects were introduced to a standardised high-precision computer work task performed with the dominant arm using puck and digitizer. The design of the puck was similar to a computer mouse. The subject familiarised himself with the task for 6 min. The standardised computer work task was performed with 3 identical sessions of 6 min separated by 5 min breaks. The first session functioned as a baseline measurement (“before”), then came the pain session (“during”) with infusion of hypertonic saline and the last session was performed after the experimental pain had vanished (“after”).

2.4. The standardised computer work task

The high-precision computer work task was performed using digitizer and puck. The digitizer pad had a width of 39.5 cm and a height of 40.5 cm, and the area on the pad corresponding to representing the screen was set to 12 cm height and 13 cm width. Circular targets with a diameter of 4 screen pixels were shown on the computer screen. The work task consisted of pointing the cursor to the targets that were activated by button clicks on the puck. Lines were automatically drawn between consecutive activated targets, and the task was to activate targets in a specific order to duplicate a drawing that was shown in the upper right corner of the computer screen (Fig. 1). The movement trajectories between the targets were not prescribed. As soon as one drawing was completed the subject activated an accept-icon, and a drawing with the same pattern popped up. The subject was instructed to work as fast and precise as possible, as any influence of muscle pain would most likely be manifested in the maximum performance.

![Image of computer screen](image)

**Fig. 1.** The computer screen picture shown during the standardised computer work task.
2.5. Performance measurement

A work cycle was defined as one drawing. Work cycle time was measured to investigate if maximum work pace was affected by acute moderate muscle pain. To estimate the influence of pain on repetitive finger movement and proprioception, we measured number of clicks on the puck button and number of screen pixels that the cursor was moved per work cycle. That is, position sense may be attenuated leading to failure of maintaining the cursor on the targets during button clicks. Furthermore, movement sense may be attenuated as well, which may be reflected in inaccurate cursor movement (increased cursor movement). The mean of each variable was calculated over all work cycles performed during each of the 3 work sessions.

2.6. Experimental muscle pain

Experimental muscle pain was induced by intramuscular infusion of sterile hypertonic saline (5% NaCl) through a plastic catheter (22G, Venflon) for the trapezius muscle and a cannula (27G) for the extensor carpi ulnaris. These were connected to a computer-controlled syringe pump (IVAC 770) by a tube. To induce muscle pain in the trapezius muscle of the dominant side 0.5 ml hypertonic saline was injected at a rate of 90 ml/h (0.5 ml/20 s), and the plastic catheter was located in the trapezius muscle during all 3 sessions. For the trapezius muscle the catheter was placed midway between the acromion and the seventh cervical spine. In the extensor carpi ulnaris of the dominant arm 0.3 ml was infused at a rate of 54 ml/h (0.3 ml/20 s), but the cannula was only in the muscle during the infusion in order to avoid the discomfort that could be expected in this small muscle during dynamic work. The infusion site was located in the middle of the proximal third of the extensor carpi ulnaris muscle.

2.7. Pain assessment

After each completed work cycle, pain intensity was marked with the left hand on a continuous electronic visual analogue scale (VAS) ranging from 0–10 cm, with 0 being “no pain at all” and 10 being “worst imaginable pain”. The VAS-score was sampled at 0.2 Hz, and analysed with regard to total duration of pain and peak VAS-score. When pain was not present a scoring was simulated on the electronic VAS to minimise any influence from the left hand VAS scoring when comparing pain and baseline sessions. Mean VAS-score was averaged over the pain session. After the pain session the subject marked the distribution of pain on an anatomical drawing.

2.8. Statistics

Data are presented by mean and standard deviation (SD). For testing differences between the exposure variables in the 3 sessions (“before”, “during”, and “after”) the non-parametric Friedman’s test of variance was used, and when significant it was followed by multiple comparisons test. A significance level of $p < 0.05$ was accepted.

3. Results

3.1. Pain assessment

The VAS-score over time for all subjects after experimentally induced pain in the trapezius muscle and in the extensor carpi ulnaris muscle are shown in Fig. 2. Muscle pain induced in the right trapezius muscle, spread around the injection site mainly cranially and towards acromion (Fig. 3a). Infusion of saline into the extensor carpi ulnaris muscle resulted in deep pain radiating distally from the injection site. Moreover, pain was referred to the ulnar side of the hand for 3 subjects (Fig. 3b).

During the 6 min computer work the mean VAS-scores in experiments I and II were on average 3.5 cm (SD 1.4) and 2.0 cm (SD 1.0), respectively. The mean peak VAS score were 4.5 cm (SD 1.6) in experiment I and 3.4 cm (SD 1.4) in experiment II.

Fig. 2. VAS-profiles following intramuscular infusion of hypertonic saline into the trapezius muscle (a) and the extensor carpi ulnaris muscle (b) during the pain session ($n = 12$). The arrows denote the start (20 s) and end (380 s) of the computer mouse work.
3.2. Performance during experimental pain

Muscle pain from the trapezius muscle did not result in any significant changes of the work cycle time during the standardised computer work (Fig. 4). In contrast, muscle pain induced in the extensor carpi ulnaris muscle caused a 6% decrease in work cycle time ($p < 0.05$) during the pain session compared to baseline. That is, the work speed was faster when muscle pain was present. After muscle pain had vanished the work cycle time was 7% shorter than the baseline assessment (Fig. 4). On the other hand, the mean number of button clicks per cycle and the number of pixels that the cursor was moved per cycle did not show any significant changes due to shoulder muscle pain or forearm muscle pain (Figs. 5 and 6).

4. Discussion

Computer work with digitizer and puck is characterised by low-level force and limited range of motion (Jensen et al., 1998). In the present study moderate experimental muscle pain had no large effect on performance during this high specialised and fine co-ordinated motor task.

According to the adaptation hypothesis proposed by Lund et al. (1991) muscle nociception leads to changes in muscle co-ordination of the painful region resulting in decreased velocity and amplitude of movement. This mechanism is interpreted as a protective mechanism. Thus, this hypothesis predicts that the work cycle time will increase, and that the number of mouse clicks and pixels the cursor is moved will decrease to the lowest possible level. Surprisingly, the present study found unchanged or even increased performance during muscle pain. This could be ascribed to the fact that subjects are aware of the muscle pain duration, and are able to override any influence of pain voluntarily. However, several experimental muscle pain studies do support the adaptation hypothesis and report lower maximum voluntary contraction, shorter endurance time, and smaller range of motion (Arendt-Nielsen et al., 1996; Graven-Nielsen et al., 1997a; Svensson et al., 1997). However, the motor tasks in these studies were rhythmic movements such as chewing or walking, or the tasks required higher forces and larger range of motion than computer work requires (Jensen et al., 1998; Karlqvist et al., 1996). The minimum length the cursor should be moved during a work cycle in the present study was constant, and together with a decreased work cycle time this indicates an increased work speed during extensor carpi ulnaris pain, which is contradictory to the adaptation hypothesis. A recently published occupational set-up study reported a longer work cycle time during simulated meat cutting in response to saline evoked trapezius muscle pain (Madeleine et al., 1999).

The decrease in work cycle time found during forearm muscle pain could be the result of a learning effect from baseline to pain session. This is further supported by the
shorter work cycle time that is also present in the session performed after muscle pain has vanished. However, no sign of learning effect was seen during the trapezius experiment.

Since the work performance does not decrease in the present study, the nociceptive mechanisms at the spinal level that potentially would attenuate work performance (Lund et al., 1991) may be inhibited by supraspinal regulation e.g. voluntarily. It has been reported that a mental task (arithmetic) can inhibit both pain sensation and the nociceptive flexion reflex in biceps femoris muscle (Willer et al., 1979). In the present study the computer work task required high manual precision, high visual demand and maximum performance. Whether inhibition of pain responses during mental demanding tasks is a general mechanism in the pain system has not been investigated so far.

An interesting question that the present study raises is, if the work performance during pain is maintained by redistribution of muscles forces used to move the computer mouse. During test contractions in healthy subjects a redistribution phenomenon was found between the shoulder muscles (Palmerud et al., 1995). This has also been indicated during clinical and experimental pain evoked in the trapezius muscle (Madeleine et al., 1999; Michaud et al., 1987). Even though the findings in the present study could not reveal differences in internal exposures, estimated by work performance, muscle activity could very well be different.

To conclude, computer work performance (estimates of movement velocity, repetitive finger movements, proprioception) was unchanged or even increased due to acute moderate experimental pain in the trapezius or extensor carpi ulnaris muscle. Thus, during acute pain the operators may be able to continue their work with the same efficiency despite muscle pain. If this is also the case with returning moderate pain is not known. However, the long-term effect of sustaining the same workspace despite pain may be harmful to the musculo-skeletal system.

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References


Fig. 6. Mean and SD for the number of pixels the cursor was moved per work cycle before, during, and after pain was induced in the trapezius muscle (n = 12) or in the extensor carpi ulnaris muscle (n = 12).


