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Impact of time pressure and pauses on physiological responses to standardized computer mouse use—a review of three papers focusing on mechanisms behind computer-related disorders

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This paper reviews three computer mouse studies in our laboratory in which our emphasis was on mechanisms behind computer-related disorders. Our approach was sequentially (i) to determine the validity of a laboratory model for computer mouse use (painting rectangles) for studying musculoskeletal disorders, (ii) to use this model to study time pressure and precision demands on position sense and muscular oxygenation, and (iii) to use this model to determine the effect of pauses (active versus passive) on these parameters. Kinematic data for the painting model showed constrained movements of the wrist similar to that of CAD (computer-aided design) work, a support for its validity for a real-life situation. Changes in forearm oxygenation were associated with time pressure and precision demands, a potential for insight into the underlying pathophysiological mechanisms. Increasing trends in oxygenation and blood volume were associated with pauses, especially active pauses, a possible explanation for the alleviating effect of discomfort experienced in real-life situations when a pause is implemented.

Key terms forearm; gender; near-infrared spectroscopy; position sense; proprioception; review; subjective fatigue; wrist kinematics.

With the current state of technology, computer workers can sit for long hours while performing a variety of tasks by using a keyboard or a computer mouse. Several studies have reported a positive relation between the amount of exposure to computer work and the severity of discomfort (1, 2). Musculoskeletal discomfort among female computer users is higher than that among male computer users (3–5). A recent review by IJmker and his co-workers stipulated that hand–arm, rather than neck–shoulder, symptoms and disorders were more consistently associated with the duration of computer use. Furthermore, these authors observed that the duration of mouse use was more consistently associated with the incidence of hand–arm symptoms than the duration of total computer use and keyboard use. Despite forthcomings in epidemiologic reports, progress in designing preventions and rehabilitations are hampered due to the lack of knowledge of the mechanisms behind musculoskeletal disorders. While researchers are in general agreement that the underlying mechanism is multifactorial (7, 8), different hypotheses have been put forth and are being tested.

One hypothesis that has received attention is the so-called "Cinderella hypothesis". This hypothesis was first proposed by Hägg (9), and it claims that selected low-threshold (type 1) motor units are continually turned on during computer use; over the long-term this use leads to degenerative changes. Ultimately, pain is believed to result from the sensitization of muscle nociceptors due to the metabolic overloading of these fibers (10). To some extent, the Cinderella hypothesis is supported by morphological data (11). The Cinderella mindset has generated several studies that use delicate measurement devices to look at motor-unit recruitment patterns during computer work. For example, select motor-unit activity of the trapezius muscle was shown during a computer

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mouse task that involved clicking and moving (12) and during data entry and keyboard finger tapping (13). Thus these two studies concluded support for the Cinderella hypothesis.

A hypothetical model of the pathogenesis of work-related myalgia proposed by Johansson et al (8) is another of interest. The model is complex and encompasses several submechanisms at different levels of the neuromuscular system; however, most of these submechanisms can be tested experimentally. In brief, the authors proclaimed that continuous long-lasting low-level work may lead to an accumulation of metabolites or inflammatory substances in the muscles, ultimately causing alterations in muscle spindle activity. The reactions of the muscle spindles may also be affected by sympathetic nervous system activity. This effect may be direct via sympathetic nerve innervation of the spindle or indirect due to sympathetically enhanced vasoconstriction, which may hinder the removal of accumulating metabolites and inflammatory substances from the muscles. Since the muscle spindles are crucial for the position and movement awareness of the limbs (ie, proprioception), an alteration in spindle afferent activity may lead to a reduction in proprioceptive accuracy. It could be that the lack of rotation of motor units for the Cinderella hypothesis is a consequence of an abnormal muscle-spindle functioning system (ie, suggesting integration between the two hypotheses).

In this paper, we present a review of the computer mouse studies in our laboratory, in which our emphasis has been on mechanisms behind computer-related disorders. The preceding hypothetical model by Johansson and his co-workers (8) has evolved over several years from original research at our center for musculoskeletal research, and thus it serves as a foundation for many of our experimental designs. Our approach has been sequentially (i) to develop a standardized model of computer mouse use suitable for studying musculoskeletal disorders, (ii) to study the effect of time pressure and precision demands on proprioception (position sense) and muscular oxygenation during computer mouse use, and (iii) to determine the effect of pauses during mouse use on proprioception and tissue oxygenation.

Experimental studies

Validation of a laboratory model for computer mouse use

Since the underlying mechanisms leading to computer-related disorders are multifactorial, it is important to perform controlled laboratory studies of computer-mouse work in which it would be possible to minimize confounders and isolate risk factors systematically. This process would allow a study of the effects of already established risk factors on various psychological and physiological parameters (eg, proprioceptive accuracy). To that end, we adopted the experimental mouse-use model used by Aarås & Ro (14), in which participants filled small squares with paint on the computer screen with the computer mouse. According to the authors, their model requires precise motor control of the movements of the mouse and can be considered representative of mouse usage in many design tasks. Despite this assertion, we aimed to determine the degree of repetitiveness and precision in the motor control required by the model in order to validate claims about the resemblance to real work and to allow comparisons between experimental studies (15). Second, we used the model to evaluate the effects of the painting task on subjective perceptions of fatigue and on wrist position sense. A more-detailed description of the methodology and results has been presented in the original publication (16).

Wrist kinematic assessment. In the first part of the study, wrist kinematics were assessed for 7 participants (4 men and 3 women), while they performed the painting task for 15 minutes. The participants performed the task while seated comfortably in front of a computer with full lower arm support. We modified the object shape to be rectangular (45 × 25 mm) instead of square as originally reported by Aarås & Ro (14). Rectangles were presented, one at a time, at random locations on the screen, and the participants were encouraged throughout to maintain the pace of painting approximately 2 rectangles per minute.

To sample kinematic data, four FASTRAK (Polhemus Inc, Colchester, VT, USA) receivers were attached to the participant's right arm (one on the acromion, one on the dorsal aspect of the upper arm, one close to the wrist, and one on the back of the hand over the third metacarpal bone—only data for wrist movement are presented in this study). Prior to the painting task, the maximum ranges of motion for wrist extension–flexion, radial–ulnar deviation, and pronation–supination were measured for each participant. In addition, the angular data for the hand when resting on the computer mouse were obtained and used as the reference for normalizing the data. Thus the range of motion, mean angle position, mean velocity, and mean power frequency were calculated for the various wrist excursions during the painting.

The normalized data are presented in table 1. Table 2 shows that the percentage of time spent across the maximum voluntary range of motion for the three wrist excursions was unevenly distributed. While for radial–ulnar deviation a few percent of the time was spent above 50%, most of the time was spent below 30% for all of the excursions.

Table 1. Wrist kinematics during painting (7 participants). Mean and standard deviation of the range of motion, normalized mean position, velocity, and the mean power frequency in radial–ulnar deviation, flexion–extension, and pronation–supination. For the mean position, the reference positions were 2.5 (SD 6.8) degrees in radial–ulnar deviation, 17.4 (SD 5.9) degrees in flexion–extension, and 54.0 (SD 7.4) degrees in pronation–supination, for which positive values indicate ulnar deviation, extension, and supination. [Reprinted from the report of Flodgren et al (16) with the permission of Elsevier]

	Radial–ulnar deviation		Flexion–extension		Pronation–supination	
	Mean	SD	Mean	SD	Mean	SD
Range of motion (degrees)	14.9	5.5	14.8	10.6	12.7	4.2
Normalized mean position (degrees)	1.5	6.2	3.3	8.7	-0.7	9.1
Velocity (degrees/second)	3.1	0.9	2.8	1.2	2.3	1.0
Mean power frequency (Hz)	0.37	0.06	0.35	0.08	0.30	0.08

Table 2. Angular distribution during painting (7 participants). Mean values of the percentage of time spent across the maximum voluntary range of motion (MV-ROM) in radial–ulnar deviation, flexion–extension, and pronation–supination. Values in the 0–20% range represent the time spent in relatively neutral wrist positions, whereas values in the 80-100% range represent the time spent in extreme wrist positions. [Reprinted from the report of Flodgren et al (16) with the permission of Elsevier]

	0–20% MV-ROM	20–40% MV-ROM	40–60% MV-ROM	60–80% MV-ROM	80–100% MV-ROM
Radial–ulnar deviation	41	42	16	1	0
Flexion–extension	67	30	3	0	0
Pronation–supination	99	1	0	0	0

Our data indicate that the painting task involved constrained movements (ie, within 30% of maximal excursion). Furthermore, our results appear to be in agreement with the findings of a laboratory study of computer-aided design (CAD) applications (17), in which the mean power frequency was 0.31 Hz and the velocity was 2.9 degrees/second in the flexion–extension of the right wrist. In a workplace study of CAD operators, Jensen and his co-workers (4) reported velocities of the same magnitude in radial–ulnar deviation and flexion–extension of the wrist for work with a computer mouse. Although both CAD studies indicated a greater ulnar deviation and extension of the wrist than what we found for the painting task, the result was likely to be influenced by how the reference position was determined. Thus we interpreted our results as tending to support the contention of Aarås & Ro (14) that this mouse-use model is representative of mouse use in design tasks.

Assessment of position sense and fatigue. In the second part of the study, wrist position sense was determined before and after 45 minutes of painting for an additional 32 participants (16 men and 16 women). A control group of 12 participants (6 men and 6 women) performed the position-sense tests at the allotted time points as for the experimental group but without doing the computer-mouse work. Periodically throughout the painting task, the participants were asked to rate their perception of fatigue in the arm and hand operating the mouse according to the Borg CR-10 (category ratio 10) scale (18).

Position-sense testing was performed with the participants sitting in a modified car chair and with their right arm placed in an adjustable rig that allowed flexion–extension movements about the right wrist joint. They were equipped with goggles and earphones to minimize visual and auditory input. From a starting position of 30 degrees of wrist extension, the hand was moved passively at 30 degrees/second to a target position, where it remained for 6 seconds. It was then passively returned to the starting position. After 3 seconds, the participants were instructed, via the earphones, to actively move their hand in an attempt to match the target position. When they felt that they had reached the target position, they pressed a button held in their left hand, which registered the reproduced position. The participants performed 15 position-matching trials, in which target positions were randomized between 0 degrees and 30 degrees of flexion. A detailed description of the equipment and data acquisition is provided in a previous publication from our laboratory (19).

For each position-matching trial, a position error was calculated by subtracting the target position from the reproduced position. The standard deviation of the errors (variable error), as well as the mean of the absolute values of the errors (absolute error), were computed for each participant and used as outcome measures.

For the group that painted 45 minutes, we found a significant increase in the mean absolute error from 4.6 (SD 1.8) before to 5.5 (SD 2.5) after ($P=0.02$). No difference in the variable error was noted [4.4 (SD 1.7) before to 4.6 (SD 1.3) after, $P=0.66$]. There were no gender differences in the absolute error or variable error before, or in response to, the mouse-operated painting task ($P>0.05$). For the control group no difference in the absolute error [4.0 (SD 1.4) before to 3.9 (SD 1.6) after, $P=0.75$] or variable error [4.3 (SD 1.2) before to 4.0 (SD 0.8) after, $P=0.16$] was seen after 45 minutes of rest.

A gradual increase in the median Borg ratings of muscle fatigue in the arm and hand (taken every fifth minute) was observed ($P<0.001$). These values ranged from 0.5 (start rating) to 3.5 (end rating). No overall gender difference was detected, except for the ratings after the first 5 minutes of work, for which the men's were higher ($P=0.01$).

Our results show that 45 minutes of the painting task induced subjectively perceived muscle fatigue and may cause a reduction in the overall accuracy of repositioning movements of the wrist. Whether this result has implications for motor control alterations in line with the hypothetical model of work-related musculoskeletal disorders by Johansson et al (8) is questionable. It is important to point out that variation in repositioning error (ie, variable error) reflects the signal-to-noise ratio in a system and thus the limitation for information transfer. In this way, variable error better estimates muscle spindle signals (ie, position sense) than absolute error does, which leads to the interpretation that, in our data, we did not see a change in proprioception.

Impact of time pressure and precision during computer-mouse work

Time pressure and precision demands are commonplace among workers using computers, and these demands are likely contributors to the development of musculoskeletal symptoms. Computer studies using diverse experimental designs of time pressure show a common finding of increased electromyographic (EMG) activity in the upper extremities (20–22). Using time pressure and verbal provocations with a mouse-operated computer task, Wahlström and his co-workers (22) found that heart rate, blood pressure, workpace, and the force applied to the computer mouse increased during the task. In this study, we used our painting model to implement time pressure and precision demands to investigate this effect on muscle oxygenation and position sense in the upper extremities. Of particular interest was tissue oxygenation in the forearm extensor muscles in relation to measurements of wrist position sense.

Subjective ratings of tenseness (ie, general stress feeling) and physical fatigue were also assessed. In addition, autonomic reactivity was measured. These data have not been included here but can be found in our original publication (23). In addition, a more-detailed description of the methodology and results has been presented in the original publication.

Twenty-four participants (12 men and 12 women) participated in the study. The study was designed as a 2 × 2 crossover with each participant attending on two separate occasions separated by 3–6 days. For each, the participants performed 45 minutes of mouse painting. On one occasion, they were instructed to paint approximately two rectangles per minute (the less-demanding task). On the other occasion, time pressure was imposed by limiting the time available for painting a rectangle (the more-demanding task). Also for the more-demanding task, painting times were randomized between 15 seconds and 25 seconds; the participants had no prior information about the allotted time for each rectangle. An alarm sounded when the time was running out. Whenever the participants painted outside the rectangle, a buzzing sound was heard that encouraged them to remain inside. The order of the two task versions was randomized. A momentary pause was taken half way during the task to allow for blood pressure measurements (not included in the present paper), which divided the data into parts 1 and 2. Visual analogue scale (VAS) ratings of tenseness and physical fatigue in the right arm were obtained at the beginning, middle, and end of the task by asking the participants to rate, on a 100-mm scale, how tense they felt at the moment and how fatigued they felt in their right arm.

Position sense was measured as described in the validation study just presented. As before, the standard deviation of the errors (variable error), as well as the mean of the absolute values of the errors (absolute error), were computed for each participant and used as the outcome measures.

Throughout the painting, noninvasive measurements of local tissue oxygenation were obtained for the right trapezius and extensor carpi radialis muscles. These measurements were determined using the near infrared spectroscopy (NIRS) technique. NIRS has been used in several studies for the noninvasive monitoring of continuous changes in skeletal muscle oxygenation, which represents the dynamic balance between oxygen delivery and consumption and for subsequent determinations of changes in blood volume (24). The signals arise mainly from small vessels (ie, arterioles, capillaries, and venules) deep within the muscle and can be obtained by the use of a spectrometer (INSPECTRA Tissue Spectrometer—model 325, Hutchinson Technology Inc, Arnhem, Netherlands) with probes placed on the skin above the muscle. In this study, the position of the probes was marked to ensure the same probe placement on both measurement occasions. The reasons for obtaining NIRS measurements were that (i) they have been shown to be valid for measuring muscle oxygenation in the forearm (25), (ii) muscle oxygenation changes are related to workload (26), and (iii) they respond linearly with sympathetic vasoconstriction during rest and exercise (27).

A detailed description of the equipment and calibration procedures can be found in our original publication (23). The outcome parameter was the percentage of hemoglobin oxygen saturation in tissue (%StO_2), representing the percentage of hemoglobin that was oxygenated.

For position sense, no significant difference in the variable error between the task versions was found ($P=0.13$). However, for absolute error, there was a significant difference between the task versions ($P=0.03$). The absolute error was higher after the less-demanding task than for the more-demanding task (figure 1). Gender did not have an effect on either of the outcome variables.

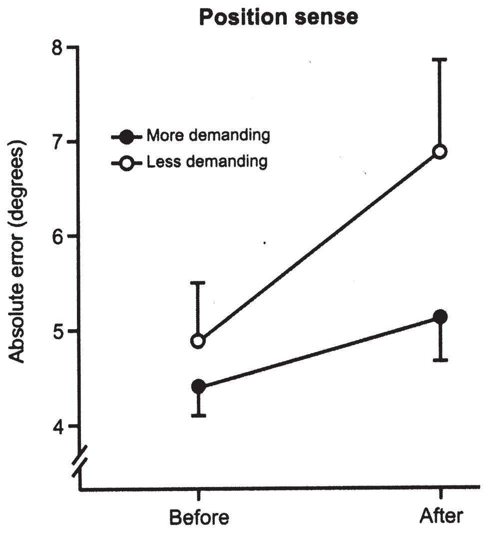

Figure 1. Mean values of absolute error before and after the more-demanding task (solid circle) and the less-demanding task (open circle). The bars represent ±1 standard error of the mean. A significant change between task versions was found (P<0.05). [Reprinted from the report of Heiden et al (23) with the permission of Springer Science and Business Media]

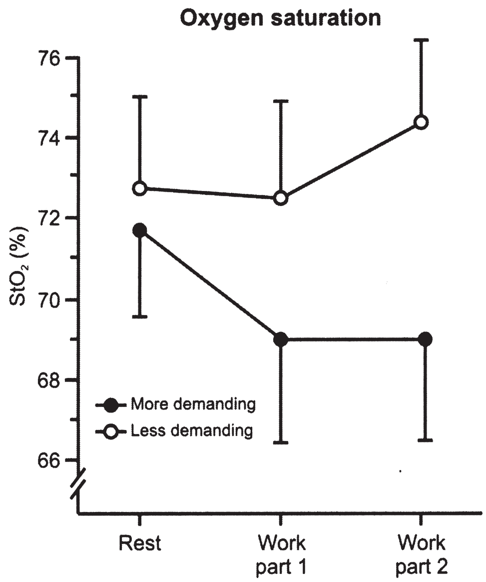

Figure 2. Mean values of the percentage of hemoglobin oxygen saturation in tissue (% StO_2) in the extensor carpi radialis during rest, and part 1 and part 2 of the work for the more-demanding task (solid circle) and the less-demanding task (open circle). The bars represent ±1 standard error of the mean. A significant %StO_2 change between task versions was found (P<0.05). [Reprinted from the report of Heiden et al (23) with the permission of Springer Science and Business Media]

Oxygenation for the extensor carpi radialis differed significantly between the task versions (P=0.02); %StO_2 was lower during the more-demanding task (figure 2). No gender differences were found (P=0.30), nor was there any interaction between gender and the task version (P=0.93). The men, however, had significantly higher oxygen saturation in the extensor carpi radialis than the women throughout the experiment (P<0.001). For the trapezius muscle, no difference in %StO_2 was found between the task versions (P=0.23). In addition, there were no gender differences (P=0.39), but the men had a higher %StO_2 in the trapezius muscle than the women throughout the experiment (P<0.01). For both muscles, the %StO_2 value for the men was ~80, and for the women it was ~65.

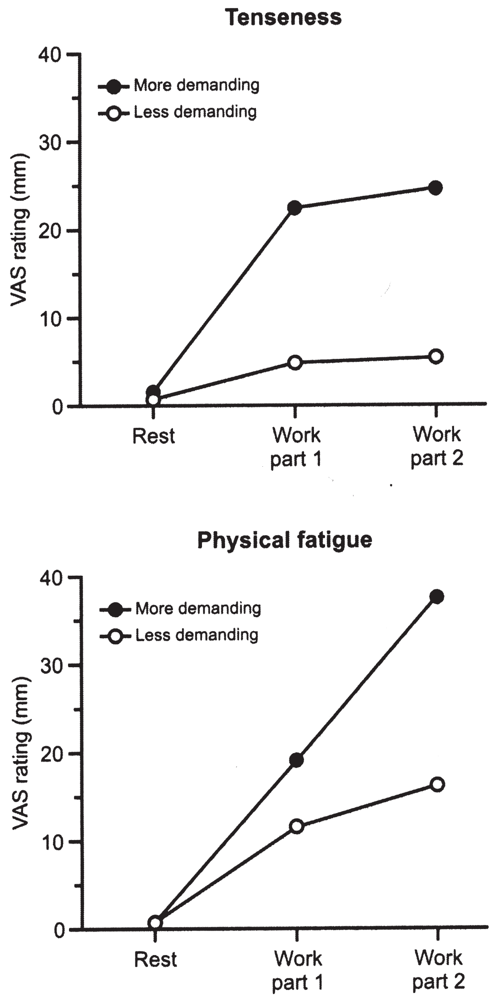

Figure 3. Median values of the visual analogue scale (VAS) ratings during rest and part 1 and part 2 of the work for the more-demanding task (solid circle) and the less-demanding task (open circle). The VAS ratings for tenseness ranged from 1 to 62 mm during the more-demanding task and from 0 to 70 mm during the less-demanding task, whereas the VAS ratings for physical fatigue ranged from 0 to 87 mm during the more-demanding task and from 0 to 78 mm during the less-demanding task. Significant differences in the VAS ratings of tenseness between the task versions were found for part 1 and 2 of the work (P<0.05) and in the VAS ratings of fatigue for part 2 of the work (P<0.05). [Reprinted from the report of Heiden et al (23) with the permission of Springer Science and Business Media]

The VAS ratings of tenseness and fatigue were significantly higher during the more-demanding task than during the less-demanding task (P<0.002) (figure 3). These data were not affected by gender.

We primarily attribute our differences in forearm oxygenation to increased physical performance in association with time pressure and precision demands during computer-mouse work. This conclusion agrees with the fact that the participants performed better (ie, higher number of rectangles painted and less time outside) than for the less-demanding task (23).

Impact of active versus passive pauses during computer mouse work

Frequent breaks during the performance of long-term computer work are often recommended as a preventive measure to offset work-related disorders. Research shows that frequent breaks produce favorable results, as evidenced by a reduction in discomfort and without a loss of production or performance. Most studies have looked at passive pauses (resting). The few studies on active pauses (ie, pauses including some type of activity) report a benefit with respect to discomfort, albeit modest, in comparison with the effect of passive pauses or no pauses (28, 29). In our present study, we implemented active and passive pauses during the use of our computer-mouse painting model and investigated the impact of such a model on muscle oxygenation, position sense, and subjective fatigue and tenseness. Electromyography was also recorded, but these data have not been included here, but, instead, can be found in our original publication (30). In addition, a more-detailed description of the methodology and results has been presented in the original publication.

Fifteen women participated in the study. The study was designed as a 2 × 2 crossover with each participant attending on two occasions separated by 3–6 days. For each occasion, the participants performed 60 minutes of mouse painting divided into three 20-minute periods (note: the more-demanding task, as described, was used on both occasions). On one occasion, the participants performed a 1-minute passive pause (resting) after each 20 minutes of computer work, and on another occasion they performed a 1-minute active pause. The active pause consisted of 10 dynamic wrist extensions against resistance by grabbing a handle assembled to rubber tubing. This activity corresponded to about 80% of a maximal exertion. At the beginning and after each 20 minutes, the participants rated their subjective feeling of fatigue in the right arm on a Borg CR10 scale (18), as well as their feeling of tenseness.

Wrist position sense was measured at the start and at the end of the mouse-painting task, as described.

Tissue oxygenation for the extensor carpi radialis muscle was obtained throughout, as described. In addition to $\%StO_2$, total hemoglobin was determined so that an estimate of the blood volume changes during the mouse work could be obtained (31).

For position sense, no significant change occurred for either the variable error or the absolute error over time (P=0.65 and P=0.73, respectively) or between the pause types (P=0.96 and P=0.20, respectively).

A significant increase in time was found for $\%StO_2$ (P<0.001); furthermore, there was a tendency for the increase in $\%StO_2$ to be higher for the active pause than for the passive pause (P=0.13). For total hemoglobin, there was a significant increase in time (P<0.001) (figure 4); the interaction between pause type and time was also significant (P<0.01). In other words, the trend for the active pause was greater than for the passive pause.

An overall significant increase (albeit small) in the ratings of fatigue was found (P<0.001); however, there was no difference between pause types (P=0.64). For the subjective ratings of perceived stress no significant effects were found.

We attribute our oxygenation data to a hyperemic response in the muscle that was facilitated by the pauses. More importantly, the higher trend in total hemoglobin for mouse use with active pauses, as compared with passive pauses, suggests enhanced blood flow through the muscle due to the high-intensity contractions. In regard to the hypothesis put forth by Johansson et al (8), it is presumed that such contractions could result in an enhancement of circulation that, therefore, enabled the washout of substances accumulated during mouse work. It is interesting to note that the perceptions of fatigue and stress in this study were appreciably less than in our previous study (23), in which the participants worked almost continuously.

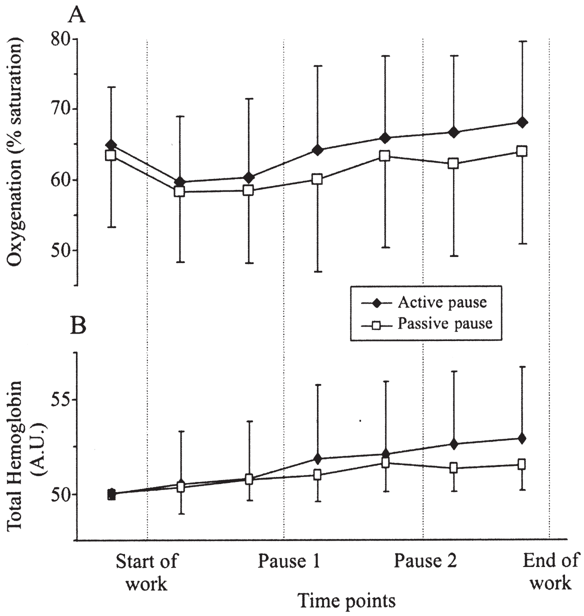

Figure 4. Mean and standard deviations for muscle oxygenation (upper figure) and total hemoglobin (lower figure). [Reprinted from the report of Crenshaw et al (30) with the permission of Springer Science and Business Media]

Discussion

The kinematic data of the mouse-painting model showing constrained movements of the wrist in a range similar to that in CAD work supports its validity as a laboratory model for a real-life situation. The generation of muscle fatigue and disturbed repositioning accuracy may endorse its use for studying risk factors related to musculoskeletal disorders among computer users. Furthermore, we could manipulate the model to impose time pressure and precision, which shows flexibility.

The changes in oxygenation during computer-mouse use under time pressure and precision demands could contribute insight into the underlying pathophysiological mechanisms. Whereas, in previous computer studies with time pressure, electromyography was used to gauge muscle exposure, oxygen saturation measurements can give information on the metabolic state of the muscle.

The increasing trends we observed for oxygenation and blood volume with pauses during mouse work, in combination with minimal perceptions of fatigue and stress, may offer an explanation for the mechanism of the alleviating effect of discomfort experienced in real-life situations and for studies when a pause is implemented, especially if some type of activity is involved.

Pressing deadlines, prompting time pressure, which is becoming more of a rule than an exception, the increasing shift from keyboard use to a pointing device for computer input, and the mandating of periodic pauses (although what to do during the pause is uncertain) are current issues for computer workers. Thus the findings and the research approaches taken in our three studies can be looked upon as contemporary.

We begin by advocating that controlled laboratory studies, in which one can minimize confounders and isolate risk factors systematically, are necessary to investigate mechanisms behind computer-related disorders. It is also important that the computer-use model in the laboratory resembles a real-life situation. This emphasis on laboratory studies does not diminish the importance of studies in the field. Ideally, the parameters or methodologies that give suggestive results in the laboratory should be applied in the field for authenticity. In this way, periodic testing of computer workers over the long-term at their workplaces could accentuate the development of intervention and diagnostic tools for computer-related disorders.

It is important to point out that the pathophysiological mechanisms leading up to the condition of disorder may or may not be the same as those which maintain the chronic pain state. Therefore, different parameters may need to be considered in research designs.

The studies included in our present paper have dealt with physiological responses that occur in healthy participants and that can possibly give way to a chronic pain state over long-term use. Thus an obvious extension would be to investigate patients with computer-related disorders. In consideration of studies showing a reduction in blood flow and disturbances in oxidative metabolism in myalgic participants (32), the use of oxygenation measurements in future studies in regard to patients, as well as to gender, are encouraged in our laboratory.

Visual stress during computer work has been acknowledged as a factor in the development of symptoms and disorders (33, 34). In a project that is ongoing in our laboratory, we have manipulated the size of the rectangle and mouse sensitivity during the use of the painting model in order to induce visual- and motor-demanding computer mouse work.

A preeminent step in investigating the hypothetical model of Johansson and his co-workers (8) is to determine the type and magnitude of substances that accumulate in the muscle during activity or are present in pain sufferers. One reliable technique for such an investigation is microdialysis, for which we have gained valuable experience during the past 5 years (35). Studies using microdialysis have investigated metabolites and inflammatory substances during low-level repetitive arm work, and the results are promising (35, 36). However, as far as we know, no study has used this method during computer work. This is an area of interest for us in the future.

References

1. Ignatius YT, Yee TY, Yan LT. Self reported musculoskeletal problems amongst typist and possible risk factors. J Hum Ergol (Tokyo). 1993;22:83–93.
2. Bergqvist U. Visual-display terminal work: a perspective on long-term changes and discomforts. Int J Ind Ergon. 1995;16:201–9.
3. Karlqvist LK, Hagberg M, Koster M, Wenemark M, Ånell R. Musculoskeletal symptoms among computer-assisted design (CAD) operators and evaluation of a self-assessment questionnaire. Int J Occup Environ Health. 1996;2:185–94.
4. Jensen C, Borg V, Finsen L, Hansen K, Juul-Kristensen B, Christensen H. Job demands, muscle activity and musculoskeletal symptoms in relation to work with the computer mouse. Scand J Work Environ Health. 1998;24(5):418–24.
5. Ekman A, Andersson A, Hagberg M, Hjelm EW. Gender differences in musculoskeletal health of computer and mouse users in the Swedish workforce. Occup Med. 2000;50:608–13.
6. Ijmker S, Huysmans MA, Blatter BM, van der Beek AJ, van Mechelen W, Bongers PM. Should office workers spend fewer hours at their computer?: a systematic review of the literature. Occup Environ Med. 2007;64:211–22.
7. Sjøgaard G, Lundberg U, Kadefors R. The role of muscle activity and mental load in the development of pain and degenerative processes at the muscle cell level during computer work. Eur J Appl Physiol. 2000;83:99–105.
8. Johansson H, Arendt-Nilsson L, Bergenheim M, Blair S, van Dieen J, Djupsjöbacka M, et al. Epilogue: an integrated

model for chronic work-related myalgia ”Brussels Model”. In: Johansson H, Windhorst U, Djupsjöbacka M, Passatore M, editors. Chronic work related myalgia; neuromuscular mechanisms behind work-related chronic muscle pain syndromes. Gävle: Gävle University Press; 2003. p 291–300.

9. Hägg GM. Static work loads and occupational myalgia—a new explanation model. In: Anderson PA, Hobart DJ, Danoff JV, editors. Electromyographical kinesiology. Amsterdam: Elsevier Science Publishers; 1991. p 141–4.
10. Sejersted OM, Vøllestad NK. Physiology of muscle fatigue and associated pain. In: Værøy H, Mersky H, editors. Amsterdam: Elsevier Science Publishers; 1993. p 41–51.
11. Hägg GM. Human muscle fibre abnormalities related to occupational load. Eur J Appl Physiol. 2000;83:159–65.
12. Forsman M, Kadefors R, Zhang Q, Birch L, Palmerrud G. Motor unit recruitment in the trapezius muscle during arm movements and in VDU precision work. Int J Ind Ergon. 1999;24:619–30.
13. Kitahara T, Schnoz M, Laubli T, Wellig P, Krueger H. Motor-unit activity in the trapezius muscle during rest, while inputting data, and during fast finger tapping. Eur J Appl Physiol. 2000;83:181–9.
14. Aarås A, Ro O. Workload when using a mouse as an input device. Int J Hum Comput Int. 1997;2:105–18.
15. Kilbom Å. Repetitive work of the upper extremity, part II: the scientific basis (knowledge base) for the guide. Int J Ind Ergon. 1994;14:59–86.
16. Flodgren G, Heiden M, Lyskov E, Crenshaw AG. Characterization of a laboratory model of computer mouse use—applications for studying risk factors for musculoskeletal disorders. Appl Ergon. 2007;38:213–8.
17. Byström JU, Hansson GA, Rylander L, Ohlsson K, Kallrot G, Skerfving S. Physical workload on neck and upper limb using two CAD applications. Appl Ergon. 2002;33(1):63–74.
18. Borg G. Psychophysical scaling with applications in physical work and the perception of exertion. Scand J Work Environ Health. 1990;16 suppl 1:55–8.
19. Lönn J, Crenshaw AG, Djupsjöbacka M, Johansson H. Reliability of position sense testing assessed with a fully automated system. Clin Physiol. 2000;20:30–7.
20. Birch L, Juul-Kristensen B, Jensen C, Finsen L, Christensen H. Acute response to precision, time pressure and mental demand during simulated computer work. Scand J Work Environ Health. 2000;26(4):299–305.
21. Gerard MJ, Armstrong TJ, Martin BJ, Rampel DA. The effects of work pace on within-participant and between-participant keying force, electromyography, and fatigue. Hum Factors. 2002;44:51–61.
22. Wahlström BJ, Hagberg M, Johnson PW, Svensson J, Rempel D. Influence of time pressure and verbal provocation on physiological and psychological reactions during work with a computer mouse. Eur J Appl Physiol. 2002;87:257–63.
23. Heiden M, Lyskov E, Djupsjöbacka M, Hellström F, Crenshaw A. Effects of time pressure and precision demands during computer mouse work on muscle oxygenation and position sense. Eur J Appl Physiol. 2005;94:97–106.
24. Ferrari M, Mottola L, Quaresima V. Principles, techniques, and limitations of near infrared spectroscopy. Can J Appl Physiol. 2004;29(4):463–87.
25. Mancini DM, Bolinger L, Li H, Kendrick K, Chance B, Wilson JR. Validation of near-infrared spectroscopy in humans. J Appl Physiol 1994;77:2740–7.
26. Chuang ML, Ting H, Otsuka T, Sun XG, Chiu FY, Hansen JE, et al. Muscle deoxygenation as related to work rate. Med Sci Sports Exerc. 2002;34:1614–23.
27. Fadel PJ, Keller DM, Watanabe H, Raven PB, Thomas GD. Noninvasive assessment of sympathetic vasoconstriction in human and rodent skeletal muscle using near-infrared spectroscopy and Doppler ultrasound. J Appl Physiol. 2004;96:1323–30.
28. Henning RA, Jacques P, Kissel GV, Sullivan AB, Alteras-Webb SM. Frequent short rest breaks from computer work: effects on productivity and well-being at two field sites. Ergonomics. 1997;40:78–91.
29. Sundelin G, Hagberg M. The effects of different pause types on neck and shoulder EMG activity during VDU work. Ergonomics. 1989;32:527–37.
30. Crenshaw AG, Djupsjöbacka M, Svedmark A. Oxygenation, EMG and position sense during computer mouse work. Impact of active versus passive pauses. Eur J Appl Physiol. 2006;97:59–67.
31. Boushel R, Piantadosi CA. Near-infrared spectroscopy for monitoring muscle oxygenation. Acta Physiol Scand. 2000;168:615–22.
32. Larsson B, Björk J, Kadi F, Lindman R, Gerdle B. Blood supply and oxidative metabolism in muscle biopsies of female cleaners with and without myalgia. Clin J Pain. 2004;20:440–6.
33. Aarås A, Horgen G, Bjorset HH, Ro O, Thoresen M. Musculoskeletal, visual and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions. Appl Ergon. 1998;29:335–54.
34. Treaster D, Marras WS, Burr D, Sheedy JE, Hart D. Myofascial trigger point development from visual and postural stressors during computer work. J Electromyogr Kinesiol. 2006;16:115–24.
35. Flodgren GM, Hellström FB, Fahlström M, Crenshaw AG. Effects of 30 versus 60 min of low-load work on intramuscular lactate, pyruvate, glutamate, prostaglandin E(2) and oxygenation in the trapezius muscle of healthy females. Eur J Appl Physiol. 2006;97:557–65.
36. Rosendal L, Larsson B, Kristiansen J, Peolsson M, Søgaard K, Kjaer M, et al. Increase in muscle nociceptive substances and anaerobic metabolism in patients with trapezius myalgia: microdialysis in rest and during exercise. Pain. 2004;112:324–34.