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A New Approach to the Mouse Arm Syndrome

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OBJECTIVES: The study validates a new computer mouse concept. The tested device is a small mouse with a pivoting pen-shaped handle. The hypothesis behind the design is the assumptions that the pen grip requires less static tension than the normal mouse grip and that fine-motor, high precision tasks normally are done with finger movements with forearm at rest.
METHODS: Four muscles were monitored with electromyography (EMG) during work with a new mouse and with a traditional mouse.
RESULTS: EMG activity was significant lower, in M. pronator teres—46%, M. extensor digitorum—46%, M. trapezius—69%, and M. levator scapulae—82%, during work with the new mouse as compared to the traditional mouse.
CONCLUSION: Altering the design of the computer mouse can significantly reduce muscular tension.

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computer mouse Repetitive Stress Injury (RSI) Mouse Arm Syndrome
EMG static tension Carpal Tunnel Syndrome (CTS) pen grip
trapezius levator scapulae extensor digitorum pronator teres
ergonomic mouse intuitive interface

1. BACKGROUND

Mouse Arm Syndrome and, in common language, Mouse Arm have become terms used for the most common symptoms, pain conditions, and discomfort in the hand, arm, and shoulder, experienced by computer workers aggravated or caused by extensive work with computer mice.

The issue of repetitive motions and static muscular tension as a possible cause of RSI (repetitive stress injury) is, oddly enough, still politically controversial in some western cultures. Psychosocial factors are often indicated as the main or sole cause of musculoskeletal symptoms (Ekman, Andersson, Hagberg, & Hjelm, 2000).

There is however some evidence that extensive work with computer mice may cause pain conditions (L.K. Karlqvist, Hagberg, Koster, Wenemark, & Nell, 1996; Rempel, Tittiranonda, Burastero, Hudes, & So, 1999; Zennaro, Laubli, Krebs, Klipstein, & Krueger, 2003) and even contribute to or aggravate CTS (carpal tunnel syndrome).

Carpal tunnel pressure has been shown to increase by around 67% during dragging tasks with a mouse as compared to resting posture. In many participants the carpal tunnel pressures measured during mouse use were greater than pressures known to alter nerve function and structure. Recommendations are to minimize wrist extension as well as prolonged dragging tasks and to frequently use the mouse hand for other tasks (Keir, Bach, & Rempel, 1999). However dynamic work movements do not seem to protect the muscles of the shoulder and neck from fatiguing processes in highly repetitive work with short cycle times (Sundelin & Hagberg, 1992).

Mental demands during computer work have also been shown to increase the muscular activity in forearm, shoulder, and neck muscles. Increased muscular activity was found in the neck during the use of the mouse in comparison with the use of the keyboard. This phenomenon may be related to higher visual demands during the use of a mouse than with a keyboard (Laursen, Jensen, Garde, & Jorgensen, 2002), but probably also to higher precision demands.

Even increased forces applied at actuating the button of the computer mouse and at wrist movements have been shown as results of mental stress (Wahlstrom, Hagberg, Johnson, Svensson, & Rempel, 2002). These findings may help to explain the adverse effects of psychosocial work factors on the musculoskeletal system.

Some studies indicate that a variety of interventions may serve to decrease the impact of musculoskeletal disorders in the workplace (Hagberg, Tornqvist, & Toomingas, 2003; Tittiranonda, Rempel, Armstrong, & Burastero, 1999a, b).

A reduction in muscle activation in the neck-shoulder region during standard visual display unit work can be achieved with arm supports (Visser, de Korte, van der Kraan, & Kuijer, 2000).

Few controlled studies have shown very significant effects of intervention (Aborg, Fernstrom, & Ericson, 1998; Baker, Jacobs, & Trombly, 1999; Fernstrom & Ericson, 1996).

Evaluation of a new computer mouse, operated by gripping a stiff handle, with the hand in neutral position, gave decreased muscle activity in the extensors of the forearm and in the first dorsal interossi, compared to the pronated hand on the regular mouse. The participants however showed a decreased productivity and they rated less comfort in work with the new device (Gustafsson & Hagberg, 2003).

The number of electromyography (EMG) gaps for the upper trapezius on the mouse side have been shown to be significantly lower than the values on the non-mouse side, indicating that more continuous activity was present in the upper trapezius muscle on the mouse side and EVA (exposure variation analyses) showed a more repetitive muscle activity pattern on the mouse side (Jensen, Finsen, Hansen, & Christensen, 1999).

Older people have more difficulty performing mouse tasks than the young (Laursen, Jensen, & Ratkevicius, 2001; Smith, Sharit, & Czaja, 1999). As learning new motor skills demands the creation of new neural patterns (Imamizu et al., 2000), such learning becomes harder with age. Learning to ride a bicycle is a challenge for adults and the elderly.

Elderly people also seem to use more muscular force performing mouse work than the young, thus possibly exposing themselves to a higher risk of RSI (Laursen et al., 2001).

The learning curve for pen tablet is very steep and after only one day participants could perform specific standard tasks better than with a mouse. Muscular activity in the biceps brachii, the flexor digitorum superficialis, and the extensor digitorum was reduced compared to work with a traditional mouse (Kotani & Horii, 2003).

Analysis of computer screen cursor trajectories has shown that operators regularly overshoot their targets, spending 70% of movement duration in terminal guidance. Interventions should therefore seek to reduce the terminal guidance phase of cursor positioning (Phillips & Triggs, 2001).

Different ways of moving the mouse have been compared with respect to muscular activity. When using the arm-based method, the participants worked with greater wrist extension, had higher muscular activity in the right and left trapezius muscles, and had the highest ratings of perceived exertion in the neck and shoulder.

The wrist-based method resulted in higher forces being applied to the sides of the mouse and the highest ratings of perceived exertion in the wrist and hand-fingers (Wahlstrom, Svensson, Hagberg, & Johnson, 2000).

Several studies indicate that supporting the forearm reduces muscle load in the neck-shoulder region among computer operators (L.K. Karlqvist et al., 1998). There is also some evidence that operators prefer relaxed, neutral postures of the arm in combination with arm support (L.K. Karlqvist et al., 1998).

Many alternative solutions have been presented, for example, the trackball, which actually was in use by radar operators long before the computer mouse. Most alternative input devices do not however seem to radically change the patterns of physical load.

Exposure to extreme ulnar deviation and wrist extension was observed in the use of computer mouse and trackball. The trackball decreased ulnar deviation but increased wrist extension (Burgess-Limerick, Shemmell, Scadden, & Plooy, 1999). Newer interpretations of the track ball concept, where a sliding roll or surface replaces the ball, are marketed as ergonomic input devices.

M. pronator teres and M. pronator quadratus do not seem to have attracted much attention in the field, which might be due to the fact that they rarely present themselves with pain conditions. However there is reason to believe that these muscles are constantly tensed at normal mouse work and typing, as these tasks normally are performed with the hand in very near maximum pronation. This can be assessed by just sensing the forearm over the muscle sites while pronating into normal typing or mousing position.

Most authors do not discriminate between static tension and dynamic muscle work. This might be due to the fact that the actual movements at least in larger muscles groups are so minute that the activity there basically consists of static tension.

2. PROBLEM ANALYSIS

Factors, identified in the literature as contributing to RSI and discomfort in the upper extremity used for controlling the mouse, are

- static tension in muscles, not designed to be statically tensed, such as trapezius, levator scapulae, hand and finger extensors (Jensen et al., 1998);
- wrist extension (Burgess-Limerick et al., 1999; Chaparro et al., 2000; Keir et al., 1999; Lintula, Nevala-Puranen, & Louhevaara, 2001);
- ulnar deviation (Chaparro et al., 2000; Kelaher, Nay, Lawrence, Lamar, & Sommerich, 2001);
- pronation of the hand (Jensen et al., 1998);
- abduction of the forearm (outward rotation of the humerus; Cook & Kothiyal, 1998; Harvey & Peper, 1997);
- repetitive motions (Finsen, Sogaard, Jensen, Borg, & Christensen, 2001; Jensen et al., 1998; Jensen et al., 1999; Keir et al., 1999);
- fixed working postures (L. Karlqvist, Hagberg, & Selin, 1994);
- long work sessions (L.K. Karlqvist et al., 1996);
- mental stress (Wahlstrom et al., 2002).

One aspect, not found yet in the literature, is the fact that mousing is a high precision task and that high precision work in almost all other situations is carried out by fine-motor control, for example, using fingertips while resting the forearm or at least the hand for reference and for stability. Rarely or never do you see people writing without resting the entire forearm except for the elbow on the desktop.

Writing with a pen does not require

- wrist extension,
- ulnar deviation,
- extreme pronation,
- static tension in forearm extensor and flexors, or
- muscular work to overcome friction between the forearm and the desktop.

3. HYPOTHESIS

A. High precision tasks, like mouse work, performed by shoulder and upper arm muscles require static tension in these muscles.

B. By using the same muscular activities, as are being used for normal writing, to carry out mouse work, the large muscles could be relaxed and forearm muscles could be used more dynamically and less statically.

4. DESIGNING A SOLUTION

Creating an input device that would reduce the discomfort and risks of RSI would require

- minimizing need for extreme positions such as wrist extension, radial or ulnar deviation, and pronation;
- allowing high precision tasks to be carried out, without involving upper arm and shoulder muscles, in other words, while resting the forearm on the desktop;
- allowing click and press functions to involve more flexor muscles than just the index finger flexors, in order to reduce the amount of force needed from each muscle;
- avoiding clicking with stretched fingers (which requires static extensor tension);
- creating a pattern of movements different from that used for typing;
- adapting to skills already trained at early ages to minimize the learning threshold;
- reducing arm movements by reducing the space needed for cursor movements;
- optimizing for perceived comfort;
- intuitive interface, meaning that functionality should be immediately obvious.

Reducing arm movements by reducing the space needed for cursor movements requires optimizing the decoding precision. The higher decoding resolution and precision, the higher mouse acceleration can be used with maintained control and accordingly the amplitude of mouse movements decreases. Thus most commands can be executed without any activity in the shoulder or upper arm muscles, as only finger and hand movements are needed.

In order to allow the same motoric pattern as in writing the pen grip must be maintained while the pen tip is pointed in different directions. This means that a mouse equipped with a pen shaped grip must have a multidirectional joint between the body of the mouse and the shaft. Furthermore the body cannot be allowed to rotate in relation to the pen part for obvious reasons.

Still the shaft has to be kept, when the mouse is not being used, in basically the same position as when being used. Otherwise the process of reorientation would be unacceptable. A high-speed, high-resolution decoding device in a mouse body equipped with a pen grip handle meeting the aforementioned criteria would allow for mouse work being done with the same muscular actions as writing.

Figure 1. The new pen grip controlled concept mouse, UllmanMouse.

5. EVALUATION METHOD

To evaluate the new concept mouse, participants were asked to perform a standard task on a desktop computer, with the concept mouse and with two different traditional reference mice.

The application DotClicker™ was developed for the purpose of providing a standardized precision task. Small dots appear, one at a time, randomly on different locations on the screen. Clicking on the spot immediately triggers the appearance of the next one.

Figure 2. Microsoft Intellimouse.

Hitting within 10 pixels of the center of the dot results in its disappearance and a new dot appearing elsewhere. Speed requirement was presented to the participants as *fairly swift*. The traditional reference mice were Microsoft® Intellimouse Optical and Apple® standard ball mouse.

Figure 3. Apple mouse.

EMG data were collected with a MegaElectronics-ME300 (MegaElectronics, Finland) 2-channel portable electromyograph and adhesive surface electrodes over

- M. trapezius centrally above spina scapulae,
- M. levator scapulae at C5 level (9 participants),
- M. extensor digitorum proximal near maximum forearm diameter (17 participants),
- M. pronator teres proximal near maximum forearm diameter (14 participants).

The first three muscles were chosen as they are commonly associated with pain conditions and pronator teres was chosen to assess possible differences in active pronation.

Demography: 26 participants, age 13–55 years, gender: 9 female, 17 male. Body size: 28% were above 1.80 m, 4% below 1.60 m, 68% between 1.60 and 1.80 m. Physical fitness: 40% work out or practise sports regularily. Eighty-eight percent were used to normal computer use (28% advanced or working with computers daily or both). None of the participants had previously worked with the test mouse.

Test procedure. Participants were instructed to solve the task and try to work as comfortably as possible with all devices and to use the new device just like a pen.

Measurements were started, after application of electrodes, with a period of relaxation when the participants were told to relax and feel calm. When EMG signal level was stabilized, this level was used as reference (resting level) for each measurement and the test task was started. Two measurement periods of about 60–70 s of activity were made, each with the reference mouse and the concept mouse, each time swapping between the mice without moving the electrodes. Between each measurement a 30–60 s relaxing period was allowed. The measurement where the participant reached the highest degree of relaxation at rest was chosen.

From each recording the last 5 s of rest and first 40 s of activity was used for calculation.

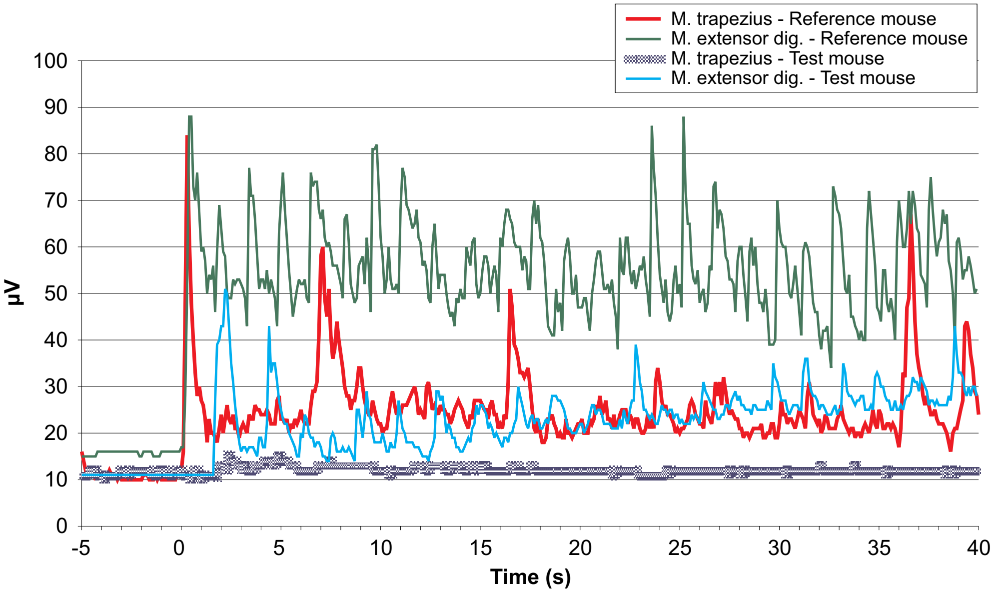

Figure 4. Example of electromyography (EMG) recordings from two muscles simultaneously when using two different computer mice.

6. RESULTS

Muscular activity for each mouse is reported as the increase in muscle activity (µV) between mouse work and resting posture with the hand on the mouse. In all tested muscles the activity was significantly lower for work with the new device (test mouse) than for work with the traditional mice (reference mouse).

In relative measures the mean muscular activity added by or needed for mouse work was reduced by the new mouse in M. trapezius by 69.0%, ($p < .01$); in M. levator scapulae by 81.6% ($p < .05$); in M. extensor digitorum by 46.0% ($p < .01$), and in M. pronator teres by 46.3% ($p < .05$).

TABLE 1. Mean Muscular Activity Added by or Needed for Mouse Work. Reference Mouse Shows Total Recordings for Both the Microsoft Intellimouse and the Apple Standard Mouse. *T* Tests were Calculated on the Comparison of Reference Mouse Versus Test Mouse

	Mouse			
Muscle	Microsoft	Apple	Reference	Test
M. Trapezius				
Mean increase in EMG (μV)	7.2	6.6	6.9	2.1
SD	4.2	7.2	5.4	2.2
Confidence interval 95%	2.2	4.7	2.2	0.9
Number of participants	14	9	23	23
	$p < .01$		$p < .01$	
M. Levator Scapulae				
Mean increase in EMG (μV)	10.4	16.6	13.2	2.4
SD	15.8	10.9	13.4	4.4
Confidence interval 95%	13.9	10.7	8.8	2.9
Number of participants	5	4	9	9
			$p < .05$	
M. Pronator Teres				
Mean increase in EMG (μV)	9.5	5.5	8.4	4.5
SD	6.5	6.9	6.5	3.1
Confidence interval 95%	3.5	6.0	3.1	4.4
Number of participants	13	5	18	18
	$p < .05$		$p < .05$	
M. Extensor Digitorum				
Mean increase in EMG (μV)	42.6	33.1	37.2	20.1
SD	14.3	13.7	14.3	10.1
Confidence interval 95%	11.4	9.5	7.5	5.3
Number of participants	6	8	14	14
	$p < .05$	$p < .01$	$p < .01$	

Notes. EMG— electromyography.

For the participants who use computers in their daily work the difference in levator scapulae activity was greater: 15.6 for the reference mice versus 1.1 for the test mouse ($p < .01$).

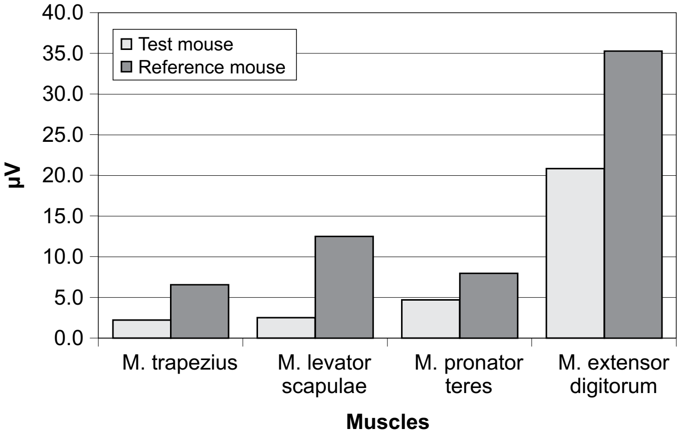

Figure 5. Rise in electromyography (EMG) activity by performing a mousing task as compared to resting with the hand in mouse position.

7. CONCLUSIONS

A significant reduction in activity in the muscles is most commonly associated with computer-work-related RSI. As activity in M. trapezius and M. levator scapulae is reduced this might indicate that participants use the new device with hand movements, rather than arm movements, thus resting the forearm on the desktop.

A significant reduction in forearm extensor activity indicates less active wrist extension. As wrist extension tends to increase carpal tunnel pressure, the new device could contribute to a reduction in the risks or aggravation of the carpal tunnel syndrome.

As the results indicate significant reduction in muscular activity in all four monitored muscle groups, the new concept might cause less fatigue and discomfort than traditional mice do. As static tension in M. trapezius and forearm extensors contribute to the risks or aggravation of musculoskeletal disorders the new device could contribute to a reduction in these risks.

8. DISCUSSION AND CONSIDERATIONS

Normal bias due to participant expectations cannot be fully eliminated as, in Sweden, Mouse Arm Syndrome is a condition well known to the public and the new device has received a fair amount of publicity, as it has been developed to solve Mouse Arm problems.

To compensate for these factors the participants have been given plenty of time to relax and find the most comfortable positions for work with both kinds of mice. Measurements did not start until the EMG signal showed a steady level indicating optimal relaxation. Thus we assume that participants managed to relax before starting the task and that activity levels measured should be relevant. One of the authors, J. Ullman, is biased, having designed one of the tested devices. Therefore he did not participate in the test procedure by informing or instructing participants in any way prior to or during tests.

The fine-motor activity of the hand is controlled by about one third of the motor cortex and another one third controls the rest of the arm, the leg, and the half-torso, whereas the remaining one third controls the face, tongue, and voice. Taking this into consideration one could assume that high precision work was easier to learn and perform using finger and hand movements, than using shoulder and upper arm muscles.

When passively resting the hand and forearm on a desk surface, the hand normally assumes a position much like the one used for writing. It can therefore be assumed that writing normally is done in a more relaxed position than normal mouse work, as the forearm rests relaxed on the desktop. Writing with a pen has not been known to cause the symptoms normally associated with Mouse Arm Syndrome (MAS).

One known exception is customs administrators with lateral epicondylitis spending long hours filling out multicarbon copy forms, squeezing and pressing hard with the pens against the paper.

A simple experiment can be made by sticking a pen through an apple and writing with it, grabbing the apple. This action calls for arm movements initiated in the shoulder and upper arm.

Also trying to write without supporting the forearm on the desktop, quickly becomes very uncomfortable. Not only does the weight of the arm cause tension but also the precision demands are harder to reach without a physical point of reference near the target area.

The steep learning curve for pen tablet use indicates that neural patterns already established could be used for operating the pen. This aspect might be especially relevant for elderly people who sometimes find that getting used to the mouse and gaining skill and precision takes time.

Higher precision and speed demands cause increased muscular tension. Thus, easing the task, by allocating the optimal part of the motor cortex for performing the precision task, could contribute to a reduction in tension.

None of the participants had had previous training with the new device.

Considering the steep learning curve for pen tablets, just a day or two, to gain better speed than with a mouse, it should be of interest to compare EMG results after participants have had a period getting used to the new device.

One interesting observation was that for the participants who use computers on a daily basis, the difference in levator scapulae activity was greater than for the whole group: 15.6 for the reference mice versus 1.1 for the test mouse.

As the lower attachment of this muscle is, maybe, the most common site for computer-work-related pain conditions, this finding could be explained by either that regular users consciously try to relax their shoulder muscles when possible or possibly that untrained users generally tense more muscles than necessary and this specific muscle gets tensed unconsciously by psychological stress.

The large differences in muscular activity cannot be explained by differences in force needed to perform the actual mechanical movement of the mice. Thus increased muscular work does not correspond to differences in the work performed. Therefore it can be assumed that the extra activity should be considered as an increase in muscular tension, and that it, from a physiological perspective, is static rather than dynamic, muscular activity.

Considering the large differences found in the study, we find it important to report the results, as they might point at possible means to reduce suffering for an increasingly growing part of the population.

To validate the actual extent of risk reduction, prospective crossover intervention studies would be needed, where participants use the new device in their normal work for a longer period of time.

To validate the immediate effect on ongoing pain conditions and symptoms, intervention studies could be made with any other alternative input device as reference.

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