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Effects of Ergorest® Arm Supports on Muscle Strain and Wrist Positions During the Use of the Mouse and Keyboard in Work With Visual Display Units: A Work Site Intervention

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The effects of Ergorest® arm supports on wrist angles and musculoskeletal strain in the neck-shoulder-arm region and electrical activity in the shoulder and arm muscles were studied during typing or the use of the mouse in work with a visual display unit (VDU). Twenty-one women were randomized into 3 groups (1 arm support, 2 arm supports, and control). Measurements were carried out before and after the 6-week intervention. The wrist extension of the mouse hand, the muscle activity of the trapezius muscle, and the subjective discomfort ratings indicated that 2 arm supports were better than 1 in work with a mouse. The Ergorest® arm support alleviates muscle and joint strain in VDU work when used for both arms.

ergonomics   arm support   visual display unit (VDU)   electromyography
wrist angle

1. INTRODUCTION

In Finland, 42% of the work force used a visual display unit (VDU) regularly more than 1 hr a day in their work in 1997 (Piirainen et al., 1997).

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The use of a VDU was the most common in administrative and office tasks (84% more than 1 hr a day and 53% more than 4 hrs a day). The introduction of new automatic dataprocessing applications and a mouse have increased the musculoskeletal load involved in VDU work (Cooper & Straker, 1998). Musculoskeletal discomfort associated with VDU work is attributable to isometric load, repetitive work, and the required force output (Carter & Banister, 1994). This type of muscular work may cause pain in neck and shoulders, and when a mouse is used there can also be pain in the arms and hands (Aarås, 1994; Aarås, Horgen, Bjorset, Ro, & Thompson, 1998; Karlqvist, Hagberg, Köster, Wenemark, & Ånell, 1996).

The etiology of work-related neck, shoulder, and upper limb musculoskeletal problems has been suggested to be a combination of work-related factors, individual characteristics, and external social factors (Armstrong et al., 1993) and preventive measures should be targeted at all of these factors. In this study the primary focus was on the reduction of musculoskeletal work load with arm supports. Previous electromyography (EMG) studies have shown that arm supports decrease muscle load in the shoulders (Erdelyi, Sihvonen, Helin, & Hänninen, 1988; Schüldt, Ekholm, Harms-Ringdahl, Németh, & Arborelius, 1987; Sihvonen, Baskin, & Hänninen, 1989) but that they have minor effects on arm muscles (Milerad & Ericson, 1994).

Ergorest® articulating arm supports (Ergorest Ltd, Finland; Figure 1) were used in this study. The arm supports are attached to the table, and the height of the supports can be adjusted. Both arms are settled in the grooves

Figure 1. Ergorest® articulating arm supports for both arms and mouse pad.

and there is easy mobility. Ergorest® arm supports have been developed particularly to reduce static load in the neck and shoulder area. A recent option for reducing the load on the hand using the mouse is a basic arm support combined with the use of a mouse pad. The effects of Ergorest® arm supports on musculoskeletal load have been evaluated in simulated VDU work (Garcia, Fernandez, & Agarwal, 1997; Garcia, Wong, Fernandez, & Ramesh, 1998) and in light assembly work (Poonawala & Fernandez, 1998). Arm supports have not been studied at actual workstations in an intervention study.

The aim of this worksite intervention study was to assess the effects of Ergorest® arm supports on (a) EMG activity of the upper trapezius muscles and extensor digitorum muscles on both sides of the body, (b) wrist position, and (c) perceived musculoskeletal strain in the neck-shoulder-arm region during VDU work with the use of a mouse and a keyboard.

2. MATERIAL AND METHODS

2.1. Participants

The participants were 21 healthy female VDU users without acute musculoskeletal symptoms (Table 1). They were office employees and researchers with a mean age of 38 years (range 26–54 years). The participants had worked with a VDU more than 20 hrs a week for an average of 5 years (range 4 months to 13 years). All the participants were right-handed, but 3 of them operated their mouse with their left hand. They were informed about the experimental procedures before giving their consent, and they had no previous experience with the use of Ergorest® arm supports.

TABLE 1. Physical Characteristics, Duration of Visual Display Unit (VDU) Use (20 hrs/week) and Use of Mouse for the Participants in Intervention Group 1 and 2 and in the Control Group

	Group 1 (n = 7)		Group 2 (n = 7)		Control (n = 7)	
Variable	*M*	(*SD*)	*M*	(*SD*)	*M*	(*SD*)
Age (years)	40	(7)	39	(12)	35	(4)
Height (cm)	165	(5)	166	(5)	165	(6)
Weight (kg)	65	(12)	63	(6)	66	(5)
Body mass index (kg/m^2)	24	(4)	23	(2)	24	(2)
VDU work (years)	5	(3)	6	(4)	5	(2)
Work with mouse (years)	3	(2)	5	(2)	5	(2)

2.2. Procedure and Design

This was a controlled worksite intervention study. The intervention lasted for 6 weeks, and similar measurements were made before and after the intervention. After the first measurements the participants were randomly assigned to three groups of 7 participants. Group 1 used the basic Ergorest® arm support with the mouse pad with the hand that operated the mouse. Group 2 had Ergorest® arm supports for both hands (a basic arm support with the mouse pad for the mouse hand and the basic arm support for the other hand). The control group had no arm supports, and they were asked to maintain their usual work technique and to avoid all redesign measures at work during the intervention. The participants in groups 1 and 2 were interviewed after the first week of intervention, and possible modifications in the workstations were made.

The same standardized mouse and typing tasks were conducted during the measurements before and after the intervention. The participants used the mouse for 10 min and typed for 10 min at their workstations. In the mouse task the participants used the mouse to choose the middle of three symbols in a box and deleted it with the delete key with the other hand. Then the mouse was moved to the next box on the other side of the display, and the middle symbol was deleted. The participants were asked to continue this task for 10 min. In the typing task the text paper was located on the left side of the screen. The participants were asked to retype the text with their wordprocessing program. They were asked to continue typing for 10 min. The participants were asked to use their normal typing speed and work technique to avoid an atmosphere of competition or examination.

2.3. Methods

The measurements were carried out at the same time of day before and after the intervention. The surface EMG, wrist position, and perceived musculo-skeletal strain were measured. In addition, the participants’ willingness to use arm supports daily and their other comments about the usability of the arm supports in VDU work were recorded after the intervention.

2.3.1. Electromyography

The EMG was recorded from four muscles bilaterally (trapezius pars descendes and extensor digitorum) by a portable ME3000P device and analyzed by ME3000P software (Mega Electronics Ltd, Finland). The ME3000P device fully rectifies the signals from 15 to 500 Hz and averages them with a time constant of 0.1 s to give a root-mean-square value (Remes, Rauhala, & Hänninen, 1984). For the EMG measurements the skin was cleaned with alcohol. Disposable surface electrodes (M-00-S, Medicotest A/S, Denmark) were placed on the skin above the trapezius pars descendes and extensor digitorum muscles bilaterally according to the recommendations of Zipp (1982). The participants were then instructed to perform three isometric maximum voluntary contractions (MVC) during shoulder elevation (Westgaard, 1988) and wrist extension. One practice trial and two repetitions were performed for each MVC. The peak EMG value (in microvolts) was accepted as the maximum for each muscle. Average EMG values were calculated for the use of the mouse and the typing along with the proportion in relation to the maximal EMG (%MVC).

2.3.2. Wrist position

Wrist positions (extension/flexion and ulnar/radial deviation) were measured with two-channel electronic goniometers (Penny & Giles Blackwood Ltd, UK) attached to the wrists of the participants with skin adhesive tape. The output from the goniometers was sampled at a frequency of 200 Hz into a portable device (ME3000P, Mega Electronics Ltd, Finland). The data were averaged for a time constant of 0.1 s and stored in a computer for the analysis by ME3000P software. The validity and reproducibility of the joint angle measurements during the keyboard operations have previously been studied by Smutz, Serina, and Rempel (1994). The average joint angle values (in degrees) were calculated for mouse use and typing.

2.3.3. Musculoskeletal strain

The participants recorded the severity of their musculoskeletal strain in the neck-shoulder-arm region during the past week using a visual analogue scale (VAS) modified from Price, McGrath, Rafii, and Buckinham (1983). The results of each VAS were reported in millimeters (range 0–100 mm with end points of *no strain* and *extreme strain*). The mean value of the VAS lines obtained from the six body regions (neck, shoulder, upper arm, forearm, wrist, hand and fingers) were calculated for the right and left sides.

2.3.4. Usability of the arm supports

The data on arm support usability at different workstations were collected 1 week after the beginning of the intervention and again in the end of the study. After the 6-week intervention the participants were also asked about their willingness to use arm supports daily.

2.3.5. Statistical analyses

The means, standard deviations (*SD*), and ranges were used for the descriptive evaluation of the data. The statistical significance of the changes was first tested with an analysis of variance with repeated measures between the groups and then with pairwise Student *t* test (two-tailed) within the groups. A probability level of $p < .05$ was considered statistically significant.

3. RESULTS

3.1. Electromyography

There were no statistically significant changes in the %MVC values between the groups before and after the intervention (Figures 2–5). The use

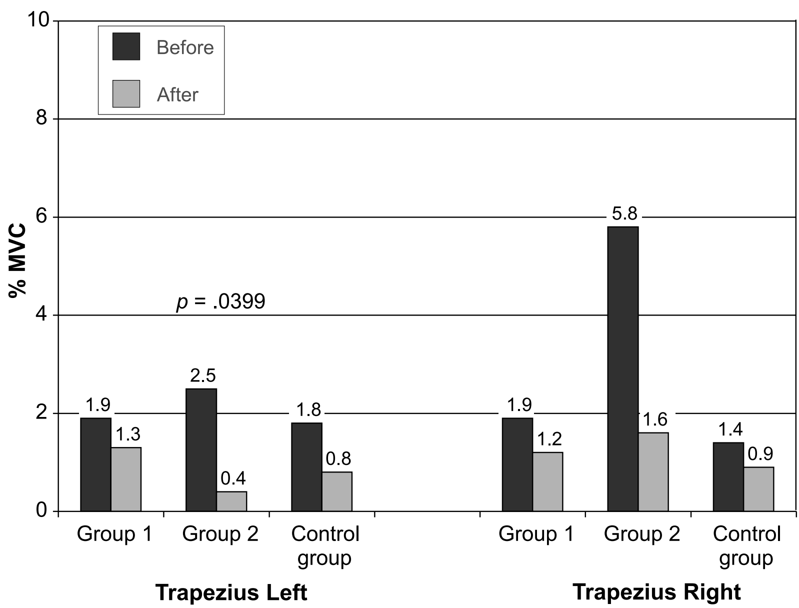

Figure 2. Change of electromyography (EMG, %MVC) in the upper trapezius muscles of both sides of the body *during the use of the mouse* without (before) and with (after) the arm supports in intervention groups 1 and 2 and in the control group.

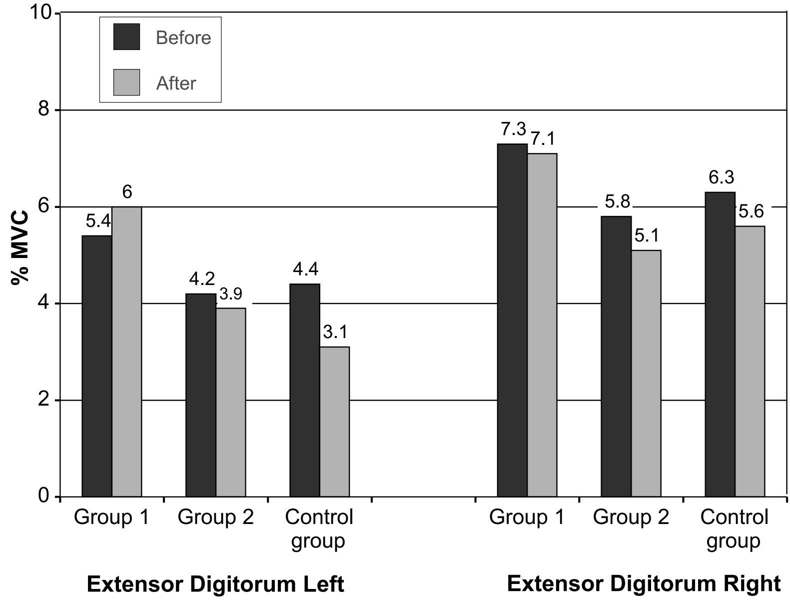

Figure 3. Change of electromyography (EMG, %MVC) in the extensor digitorum muscles of both sides of the body *during the use of the mouse* without (before) and with (after) the arm supports in intervention groups 1 and 2 and in the control group.

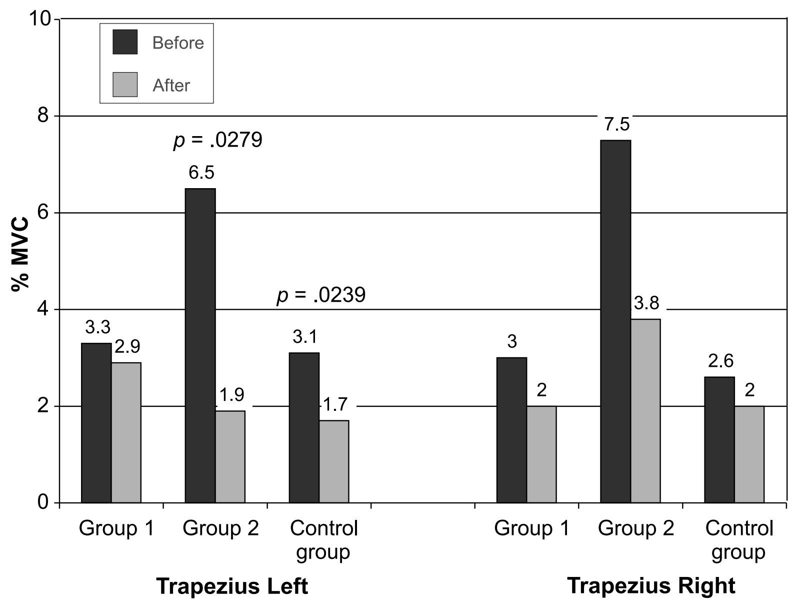

Figure 4. Change of electromyography (EMG, %MVC) in the upper trapezius muscles of both sides of the body *during the use of the keyboard* without (before) and with (after) the arm supports in intervention groups 1 and 2 and in the control group.

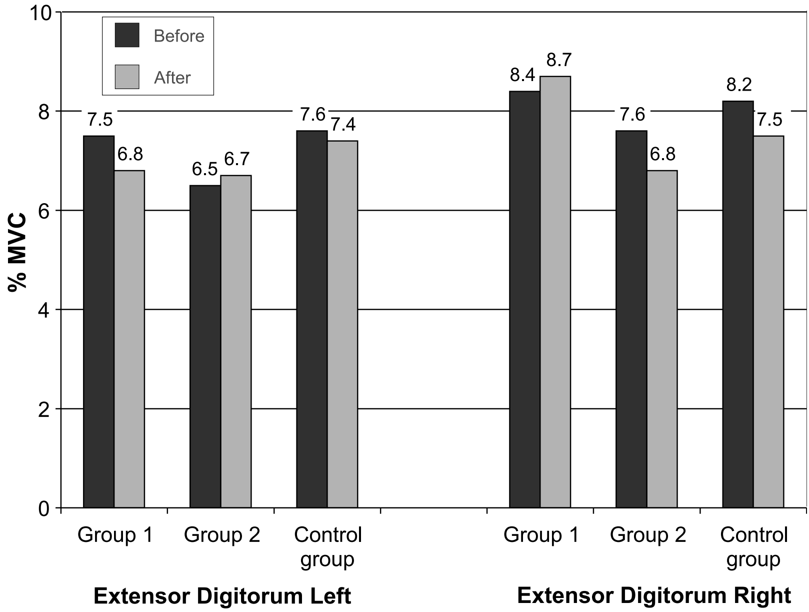

Figure 5. Change of electromyography (EMG, %MVC) in the extensor digitorum muscles of both sides of the body *during the use of the keyboard* without (before) and with (after) the arm supports in intervention groups 1 and 2 and in the control group.

of arm supports reduced the %MVC values of the left trapezius muscle significantly in group 2 during the use of the mouse and the use of the keyboard. In addition the %MVC values of the control group during keyboard use were significantly lower after the intervention period.

3.2. Wrist Position

There was a statistically significant change ($p = .021$) in the angle of the right wrist extension between the groups due to the intervention (Table 2), and after the intervention the right wrist extension was about 10° lower in group 2 than in group 1 and the control group. There was a slight decrease in the left ulnar deviation during the typing in group 1 ($p = .036$) and the control group ($p = .030$) and a slight increase in group 2 ($p = .021$) when the results obtained before and after the intervention were compared.

3.3. Musculoskeletal Strain

No statistically significant changes were observed in the musculoskeletal strain scores either between the groups or within the groups (Table 3).

TABLE 2. Change of Wrist Extension and Ulnar Deviation in the Right and Left Wrist During the Use of the Mouse and Keyboard Without and With the Arm Supports in Intervention Groups 1 and 2 and in the Control Group

	Group 1 (*n* = 6–7)		Group 2 (*n* = 6)		Control (*n* = 5–6)	
	Without	With	Without	With	Without	Without
Variable	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Right extension (°)						
Mouse[1]	27 (4)	28 (4)	23 (9)	16 (6)	27 (7)	26 (5)*
Keyboard	27 (7)	26 (10)	28 (12)	19 (8)	26 (6)	27 (6)
Right ulnar deviation (°)						
Mouse	6 (16)	12 (10)	9 (9)	9 (10)	8 (15)	4 (11)
Keyboard	11 (8)	13 (5)	14 (5)	14 (9)	14 (10)	10 (8)
Left extension (°)						
Mouse	13 (7)	20 (12)	24 (8)	16 (8)	22 (9)	19 (5)
Keyboard	27 (9)	27 (7)	29 (8)	23 (5)	27 (9)	21 (12)
Left ulnar deviation (°)						
Mouse	18 (10)	20 (10)	11 (8)	13 (8)	17 (5)	12 (4)
Keyboard[2]	20 (9)	17 (7)*	13 (9)	18 (8)*	23 (4)	17 (7)*

Notes. 1—change between the groups: *$p < .05$ (analysis of variance with repeated measures); 2—change within each group: *$p < .05$ (pairwise two-tailed Student *t* test).

TABLE 3. Change of Sum Score of the Perceived Muscular Strain in the Neck-Shoulder-Arm Region of the Right and Left Side of the Body Without and With the Use of the Arm Supports in Intervention Groups 1 and 2 and in the Control Group

	Group 1 (*n* = 7)		Group 2 (*n* = 7)		Control (*n* = 7)	
	Without	With	Without	With	Without	Without
Side of Body[1]	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Right	29 (27)	33 (32)	20 (23)	18 (18)	6 (6)	7 (4)
Left	16 (8)	20 (17)	21 (19)	25 (23)	5 (7)	6 (6)

Notes. 1—change of strain between or within groups not significant.

3.4. Usability of the Arm Supports

The data collected about the participants' perceptions on the usability of the Ergorest® arm supports gave more detailed information. The attitudes of the participants towards the usability of the arm supports seemed to be highly individual. Two participants in group 1 and 3 participants in group 2 were willing to start using the arm supports daily. During the first week of arm support use musculoskeletal discomfort was experienced by 3 participants in group 1. One of these participants worked at a workstation that allowed rest for both forearms already before the intervention. In group 2 there were no complaints. The use of the arm supports for both arms was felt to be especially suitable for prolonged text processing with a VDU. If the VDU work consisted of frequent interruptions, the participants felt that it took too much time to get their arms in a good position in the supports. In group 1, with the arm support used on the mouse arm only, the participants reported that the arm support was particularly applicable for work with the mouse. In this group, 6 participants considered the arm support to be uncomfortable while typing. Two participants responded that typing errors were more common with the one-arm support. One participant stated that the use of the arm support led to a straight sitting position.

4. DISCUSSION

4.1. Methodological Concerns

Work at least 20 hrs a week with a VDU was used as the selection criterion because it had been shown to be associated with an increased excess risk of muscular problems (Bergqvist, Wolgast, Nilsson, & Voss, 1995). That amount of VDU work during the 6-week intervention was also expected to be adequate for the participants to become accustomed to the Ergorest® arm supports.

EMG measurements during the use of mouse and typing were related to attempted isometric MVC of each muscle so that inter- and intraindividual comparisons could be made for the participants. The participants were healthy, and the MVCs were not supposed to lead to discomfort or injury. According to Westgaard (1988) untrained participants may not be able to generate an actual MVC, but the value attained can be considered adequate for an analysis of muscle strain as the work is performed with relatively slow and standardized movements. In this study, 1 participant in group 2 had exceptionally high EMG values for the right shoulder while typing (32% MVC before and 17% MVC after the intervention). These high values may have resulted from individual differences in response, as previously reported by Onishi, Sakai, and Kogi (1982). The measurement of the MVC was made in the same sitting position as the measurements during the work.

Special attention was also paid to the electrode positions in regarding to the longitudinality to the muscle fibers, a factor important to be consistent in repeated measurements (Veiersted, 1991).

There were some technical problems with the measurements of the wrist angles with the electronic goniometers. It is important to ensure that the range of the wrist angle is inside the operative limits of the goniometer. Other electronic devices (i.e., mobile telephones) can also disturb such measurements.

The participants were randomized into two intervention groups and a control group after the first measurements so that the influence of selection bias could be avoided. The EMG of all the muscles was lower also in the control group in the measurements made after the intervention. Positive effects in the control group is a common phenomenon (Hawthorne effect). This result may also have been due to the decrease in psychological stress once the participants have become familiar with the measurement devices. This study indicates the importance of a control group when EMG responses are measured because some of the EMG changes seem to be caused by changes in the degree of anxiety (Fridlund & Cacioppo, 1986). In an attempt to minimize all the intervening factors, the participants were given an accurate explanation of the entire experimental procedure and equipment before they consented to participate. However, individual anxiety can result from unavoidable factors such as the partial removal of clothing and the application of electrodes (Fridlund & Cacioppo, 1986). Thus, repetitive measures within participants design would be applicable to use in ergonomic studies.

During the intervention the participants used arm supports for 6 weeks at their own workstations. Thus it was possible to obtain more profound and qualitative data on the suitability of the arm supports at different workstations and in different tasks than when only laboratory simulations are used.

4.2. Effects of the Arm Supports

In this study, group trends were observed towards lower muscular load on the trapezius muscles during mouse use and typing when the Ergorest® arm supports were used for both arms. A large interindividual variation in the EMG values in similar tasks is a well-demonstrated phenomenon and statistically significant changes demand large groups of participants. In this study, however, significant changes were obtained in the EMG values of the left trapezius muscle in group 2 during both mouse use and typing. However, statistically significant changes were also found for the typing of the control group. In the laboratory the use of the Ergorest® arm supports was found to decrease the EMG value of the trapezius muscle (Sihvonen et al., 1989) or it remained unaffected (Garcia et al., 1998). EMG effects were found only in the left trapezius in group 2 when two supports were used during keyboard work. This result cannot be explained. In our study the EMG value of the extensor digitorum muscles was not dependent on the use of the arm supports, and this finding agrees with the results elicited during manual work demanding precision (Milerad & Ericson, 1994). In group 2, which used 2 arm supports, right wrist extension (of the arm using the mouse) decreased significantly during mouse use when the group was compared with group 1 and the control group. Arm supports for both hands (but not for one arm) enabled the participants to keep their wrists in a neutral position. Arm support only for one arm may cause an asymmetric body position, which may explain this result. There are no apparent reasons for the changes of left ulnar deviation in all study groups.

According to the results, the use of the Ergorest® arm supports for both arms are suitable, particularly for VDU workstations at which prolonged text processing is done. Using the arm support only for the mouse arm may increase the risk of discomfort and pain in that arm and shoulder. Such discomfort may be due to an asymmetric body position that results when the arm support is used for only one arm. However, some participants also benefited from the support when used only for the mouse arm and this finding reflects a variety of individual differences in work techniques.

Ergorest® arm supports cannot be recommended for use with new ergonomic VDU tables that enable adequate rest for both forearms. The arm supports are applicable for most old VDU workstations, however. The arm supports may be applicable also in other jobs, where prolonged holding of the arms is required, such as assembly, dentist, and laboratory tasks. The suitability of the arm supports for workers with physical disabilities (e.g., rheumatism) should be investigated.

5. CONCLUSIONS

According to our study Ergorest® arm supports reduce muscle strain in shoulder muscles, especially when they are used for both arms in VDU work with the mouse and keyboard. The extension of the right wrist decreases when the arm supports are used for both arms. When arm supports are used only for one arm, the risk of pain in the mouse-using hand may increase. Thus the use of two Ergorest® arm supports rather than only one arm support is recommended.

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