Original article

Scand J Work Environ Health 2010;36(1):25-33

doi:10.5271/sjweh.2880

Effectiveness of an ergonomic intervention on the productivity of workers with upper-extremity disorders – a randomized controlled trial

by Martimo K-P, Shiri R, Miranda H, Ketola R, Varonen H, Viikari-Juntura E

Affiliation: Finnish Institute of Occupational Health, FI-00250 Helsinki. kari-pekka.martimo@ttl.fi

Refers to the following texts of the Journal: 2003;29(2):106-116 2009;35(1):19-36 2005;31(5):367-374 2008;34(2):120-132 2009;35(4):301-308 2001;27 suppl 1:1-102

The following articles refer to this text: 2011;37(2):120-128; 2013;39(1):37-45; 2015;41(5):491-503

Key terms: ergonomic intervention; ergonomics; fear-avoidance beliefs; MSD; musculoskeletal disorder; presenteeism; productivity; randomized controlled trial; RCT; upper-extremity disorder; work style; worker

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/19960145

Original article

Scand J Work Environ Health 2010;36(1):25–33

Effectiveness of an ergonomic intervention on the productivity of workers with upper-extremity disorders – a randomized controlled trial

by Kari-Pekka Martimo, MD,[1, 2] Rahman Shiri, MD, PhD,[1] Helena Miranda, MD, PhD,[1] Ritva Ketola, MSc, PhD,[1] Helena Varonen, MD, PhD,[3, 4] Eira Viikari-Juntura, MD, PhD[1]

Martimo K-P, Shiri R, Miranda H, Ketola R, Varonen H, Viikari-Juntura E. Effectiveness of an ergonomic intervention on the productivity of workers with upper-extremity disorders – a randomized controlled trial. *Scand J Work Environ Health.* 2010;36(1):25–33.

Objectives The aim of this study was to investigate the effectiveness of an ergonomic intervention on productivity loss at work caused by upper-extremity disorders (UED).

Methods Workers with medically verified UED were invited to participate. The intervention consisted of a physician contacting the worker's supervisor and an occupational physiotherapist conducting an ergonomic assessment at the worksite. Before and after the intervention, the employees self-assessed UED-related productivity loss (ie, decreased quality and quantity of the daily work output). We tested for differences between groups at 8 and subsequently 12 weeks. We also applied generalized estimating equation (GEE) to analyze repeated measures data.

Results Altogether 177 employees were randomized. The overall participation rate was 88%. At baseline, 54% of the intervention group and 58% of the control group reported productivity loss. The magnitude of productivity loss was 17% and 20%, respectively. At 8 weeks, both the proportion and magnitude of productivity loss were lower in the intervention than the control group, but the differences were statistically significant only at 12 weeks (proportion 25% versus 51%, magnitude 7% versus 18%, P=0.001 for both). Using GEE analyses, we also found the differences to be statistically significant (proportion 38% versus 52%, magnitude 12% versus 18%). The intervention only benefitted employees with 0–20% loss of productivity at baseline, not those with a higher initial productivity loss.

Conclusions Early ergonomic intervention, in addition to adequate medical care, is effective in preventing and restoring self-reported productivity loss associated with UED.

Key terms fear-avoidance beliefs; musculoskeletal disorder; MSD; presenteeism; RCT; work style.

Musculoskeletal upper-extremity disorders (UED) pose a challenge to occupational health and safety because they are prevalent in the working-age population (1), and the evidence for their work-relatedness is stronger than for many other musculoskeletal disorders (2). Known occupational physical risk factors for UED include repetition, force, non-neutral postures, and hand-arm vibration, whereas psychosocial or work organizational risk factors include high job demand, low decision latitude, low social support, and few rest break opportunities (2, 3).

UED cause functional impairment leading to sickness absenteeism and even permanent disability (4). In addition, decreased on-the-job performance has been shown to be a substantial part of productivity loss in employees with symptoms in the upper extremities (5–9). The baseline results of the present study showed that productivity loss in workers with a medically verified UED was associated with pain intensity and its interference with work and sleep, as well as high job strain and fear-avoidance beliefs (10).

Due to their work-related etiology and impact on productivity, there is an evident need and potential for early detection and prevention of UED in the occupational setting. A recent systematic review showed

1 Finnish Institute of Occupational Health, Helsinki, Finland.
2 Mehiläinen Occupational Health Care, Helsinki, Finland.
3 Department of General Practice and Primary Care, University of Helsinki, Helsinki, Finland.
4 Kirkkonummi Health Centre, Kirkkonummi, Finland.

Correspondence to: Dr K-P Martimo, Finnish Institute of Occupational Health, Topeliuksenkatu 41 a A, FI-00250 Helsinki. [E-mail: kari-pekka.martimo@ttl.fi]

support for the use of some mechanical and employee-level interventions as approaches for managing UED (11). Trials have mainly included computer workers and shown a modest effect of workplace adjustments, exercise, and advice.

We found two previous intervention studies that included UED-associated productivity loss at work as an outcome measure. In a Dutch study (12), workers with complaints in the neck or upper limb were randomized into (i) a control group, (ii) one intervention group stimulated to take extra breaks, and (iii) another intervention group stimulated to perform exercises during the extra breaks. After an 8-week period, the subjects in the intervention group with only breaks showed higher productivity (more key strokes) than the control group. The stroke accuracy rate in both intervention groups was higher than the control group. However, there were no significant differences between the three groups in the reported severity or frequency of the complaints before and after the intervention.

In another study (13), a group of computer workers in the United States was randomized to receive (i) ergonomics training only, (ii) training plus a trackball or a forearm support, or (iii) both. Despite the fact that forearm support combined with ergonomic training seemed to prevent upper-body musculoskeletal symptoms, there were no significant differences between the intervention groups in either company-tracked productivity measures or self-assessed productivity.

Burton et al (14) have concluded that effective interventions for UED require a multimodal approach in which specific treatment is coupled with workplace accommodation. They also emphasized that an integrative approach by all stakeholders (employer, worker, and health professional) is a fundamental requirement in facilitating early return to work. Others have emphasized the importance of communicating with supervisors and understanding their needs and challenges in addition to tailoring the program to accommodate production and work-task needs and be as least disruptive as possible (15).

Previous studies have included employees with symptoms in the upper extremities. Our aim was to include actively working subjects, whose symptoms were severe enough to require medical assessment, but who were not in need of sick leave. The present study is part of a larger research project focusing on early prevention and recognition of UED. This paper uses self-reported productivity loss at work as the main outcome with the hypothesis that a workplace-based, tailored intervention to improve ergonomics and adapt workplace conditions for employees with UED would be more effective in reducing productivity loss at work during recovery than the more traditional disease and disability management.

Methods

Participants

This randomized controlled study was carried out from February 2006 to December 2007 in collaboration with three occupational health units covering altogether 25 000 employees in the capital area. Finnish occupational physicians work as general practitioners for employees offering not only preventive but also curative services at the primary healthcare level.

We considered as potentially eligible all subjects (18–60 years) seeking medical advice due to symptoms in the upper extremities, provided that the symptoms, or the exacerbation thereof, had started <30 days prior to the medical consultation. The occupational health service personnel offered all potentially eligible employees a possibility to be examined by a trained occupational physician at the Finnish Institute of Occupational Health. This assessment was scheduled to take place within three working days.

Clinical examination included standardized clinical examination protocols for each symptom entity (16). All employees with medically verified lateral or medial epicondylitis, rotator cuff tendinitis, impingement syndrome, de Quervain's or other wrist tenosynovitis, or other disorder (eg, entrapment of the median or ulnar nerve) were informed about the study and invited to participate. Patients whose symptoms did not meet the criteria for any specific disorder were also included in the study with the diagnosis of "non-specific, upper-extremity pain".

The subject was not included in the study if immediate sick leave was required. Other exclusion criteria included: earlier or planned surgery due to UED; active auto-immune disease; malignancy that was being actively treated or had been diagnosed within a year; fibromyalgia; congenital or traumatic deformity of upper extremity; pregnancy; and planned retirement during follow-up.

The employee was interviewed at baseline about pain intensity on a scale from 0 ("no pain") to 10 ("the worst possible pain") and its impact on work, sleep, and leisure during the last week (from 0, "no interference at all", to 10, "the worst possible interference"). The same information was collected via internet or telephone interview after 8 and subsequently 12 weeks' follow-up. At baseline, the employee was also asked about any sick leave(s) taken as a result of UED during the preceding 12 months.

The physician asked the subject to assess the following physical exposures at work: frequency of lifting loads weighing ≥5 kg; working with hand(s) above shoulder level; and whether work required frequent elevations of the arms. The physician also enquired about keying, prolonged forceful gripping, as well as pinch grip that either required forceful exertion or

deviating wrist posture. Each factor was dichotomized using a cut-off point of being exposed for 10% of the work time during a workday.

Job strain was measured with the Job Content Questionnaire (17). The scale comprised five items for job demands and nine for job control. Responses were given on a 5-point scale ranging from "strongly agree" to "strongly disagree". To create a job strain variable, job demand and control scales were dichotomized at the median; the category "high job strain" included cases with both high demand and low control.

The subjects were categorized according to their smoking habits as "never smokers", "former smokers", and "occasional or current smokers". Waist circumference was also measured. Physical activity was inquired as any physical activity for >30 minutes causing increased sweating and breathing ≤2 or ≥3 times a week.

Fear-avoidance beliefs were assessed using four items adapted from Waddell et al (18, 19): "Physical activity makes my symptoms worse"; "If my symptoms become worse, it means that I should stop what I was doing"; "My pain is caused by work"; and "I should not continue in my present job because of the symptoms". Each item had seven alternatives from 0 ("totally disagree") to 6 ("totally agree"). A sum variable was calculated and scores ≥18 out of 24 were considered as elevated. In addition, the individual item on the perceived work-relatedness of the disorder was also analyzed separately and categorized into two classes using the median.

Randomization

The physician performed the randomization using tables of random numbers in three blocks (symptoms in wrist or forearm, elbow, and shoulder). Sealed envelopes were used.

Intervention

All subjects received the best current practice treatment (20). In the intervention group only, the physician contacted each employee's supervisor by phone to discuss potential accommodations at work, and a few days later an occupational physiotherapist visited the workplace. The aim of the worksite visit was to find ergonomic improvements that are beneficial for the recovery from the UED. The assessment looked at the physical work environment, available tools or instruments, working postures, force requirements, work pace and breaks during work, as well as the employee's possibilities to continue working. The suggestions were discussed together with the employee and the supervisor, the latter of whom then made the final decision on the technical and administrative changes.

All physiotherapists working in the Finnish occupational health services have advanced training in occupational health and ergonomics. In addition, the physiotherapists in this study received two two-day courses on the intervention. They also had web-based training and access to a database that included good ergonomic practices in different types of work.

Outcomes

The primary outcome measure was self-assessed productivity loss at work, which was measured at baseline and subsequently at 8 and 12 weeks using two questions published by Brouwer et al (21). The respondent was instructed to consider the most recent full working day when answering the questions. The first question was: "Assess the impact of your upper-extremity symptoms and mark on a scale from 0 (practically nothing) to 10 (regular quantity) how much work you were able to perform when compared to your normal workday". The second question was: " Assess the impact of your upper-extremity symptoms and mark on a scale from 0 (very poor quality) to 10 (regular quality) the quality of your work when compared to your normal workday".

To analyze the proportion of productivity loss, we classified all employees scoring 0–9 in either question as "reporting productivity loss". In order to measure the magnitude of productivity loss (ie, how much productivity was reduced), we used a formula modified from Hoeijenbos et al (22): [1 - (quality/10) × (quantity/10)] × 100%. For subgroup analysis, productivity loss was further classified as "0", "10–20%", and ">20%".

In addition, the employees were asked about the numbers of sick leave episodes due to any reason and exclusively due to UED during follow-up. The contents of the ergonomic interventions were analyzed based on the unstructured reports of the physiotherapists.

Sample size

Due to limited knowledge about self-reported productivity loss caused by medically verified UED, we performed the power calculations of this study using sickness absenteeism as the main outcome. When the power of the study was set at 80% and the level of significance at 0.05, a minimum of 205 participants was considered necessary in both groups. In order to compensate for possible loss during follow-up, we aimed to include 250 subjects in both study groups for a total of 500 subjects. All study participants signed an informed consent form.

In order to examine the effects of a work-related intervention on the total productivity loss caused by UED, sickness absenteeism must be taken into account in addition to the self-assessed productivity loss that was the focus of the present study. Results with the

measurements on sickness absenteeism will be reported later including a one-year follow-up.

Blinding

Due to the nature of the intervention, neither the physician nor the subject could be blinded. However, the researcher conducting the interviews at 8- and 12-weeks follow-up was not aware of the group assignment.

Statistical methods

Data were analyzed according to the intention-to-treat principle. Missing data on productivity at 12 weeks (7 in the control group and 8 in the intervention group) were replaced by the value given at 8 weeks. We used three outcomes: (i) proportion of productivity loss (dichotomized), (ii) magnitude of productivity loss (continuous), and (iii) change in magnitude of productivity loss from baseline (continuous). At 8 and 12 weeks, we tested for differences (2-tailed, $P<0.05$) using chi-squared for proportion and 2-sample t-test for magnitude and change. We applied generalized estimating equation (GEE) to analyze repeated measures data (23). The link function was specified as "logit" for the dichotomized outcome. In addition to allocation group and follow-up time, we included age (continuous), gender, exposure to physical workload factors (lifting loads ≥5 kg, arm elevations or above shoulder, or forceful or pinch grip) and fear-avoidance beliefs (continuous) as covariates in the models.

We aimed to identify some modifiable subgroup variables that could predict the intervention's effectiveness. Subgroup analyses were performed according to the following variables: job demand, job control, fear-avoidance beliefs (all dichotomized using the median), exposure to physical workload factors, and prior sickness absence due to UED. To take into account the difference in the magnitude of productivity loss between the intervention and control groups at baseline, we used the changes in productivity loss during the follow-up for subgroup analyses. We used STATA, version 10 (StataCorp LP, College Station, TX, USA) for the analyses.

Results

Participants

Altogether, 222 employees were examined at the Finnish Institute of Occupational Health. The most common occupations were nurses and other healthcare workers (64%), secretaries and other clerical workers (25%), and warehouse workers (8%). Of these 222 subjects, 45 were excluded because they did not meet the inclusion criteria (figure 1). None of the eligible subjects refused to participate. The study was ended as planned even though the expected number of 500 subjects was not achieved. This was mainly because the recruitment rate was slower than expected. Consequently, 177 participants were randomized to the intervention (91 subjects) and control groups (86 subjects). At the 12-week follow-up, the participation rates were 87% and 88% in the intervention and control groups, respectively (figure 1).

Baseline data

Most participants were female in both groups (table 1). There was no considerable difference in the distribution of age and lifestyle-related risk factors between the intervention and control groups. Pain intensity, pain interference with work, leisure time and sleep, as well as the prevalence of previous sick leaves and high job strain were also similar in the two groups. Both groups had a similar mean score on the fear-avoidance beliefs assessment; however, elevated scores on fear-avoidance beliefs were found almost twice as often in the intervention as in the control group (18% versus 11%). Specific shoulder disorders were more prevalent (35% versus 21%) and exposure to lifting at work was more frequent (38% versus 18%) in the control than in the intervention group. All cases of "other UED" belonged to the intervention group only.

From a total of 531 potential observations, we included 465 (88%) in the analyses. We excluded 9 observations at baseline, 36 at 8 weeks, and 21 at 12 weeks. When comparing with those included in the analyses, the excluded subjects were younger (mean age 42 versus 46 years), they had higher scores on pain intensity (5.4 versus 4.7), and they had been more often on sick leave prior to enrolment in the study (57% versus 36%). In addition, the excluded employees were twice as often exposed to lifting at work than the employees included in the analyses (46% versus 28%).

Of the 66 excluded observations, 30 (46%) and 36 (55%) were from the control and intervention groups, respectively. Compared to subjects excluded from the control group, those excluded from the intervention group *more commonly* reported at baseline: exposure to lifting >5 kg (53% versus 34%); a higher level of pain intensity (mean 5.6 versus 5.1); and pain interference with work (mean 5.5 versus 4.7), leisure time (mean 5.4 versus 4.2), and sleep (mean 4.2 versus 2.4). On the other hand, compared to those excluded from the control group, subjects excluded from the intervention group *less frequently* reported productivity loss (among 39 subjects, magnitude 13% versus 30%) and an elevated score on fear-avoidance beliefs (0 versus 18.5%). No differences were found regarding age, job strain, and sickness absence prior to enrolment.

Eight weeks after enrolment in the study, almost

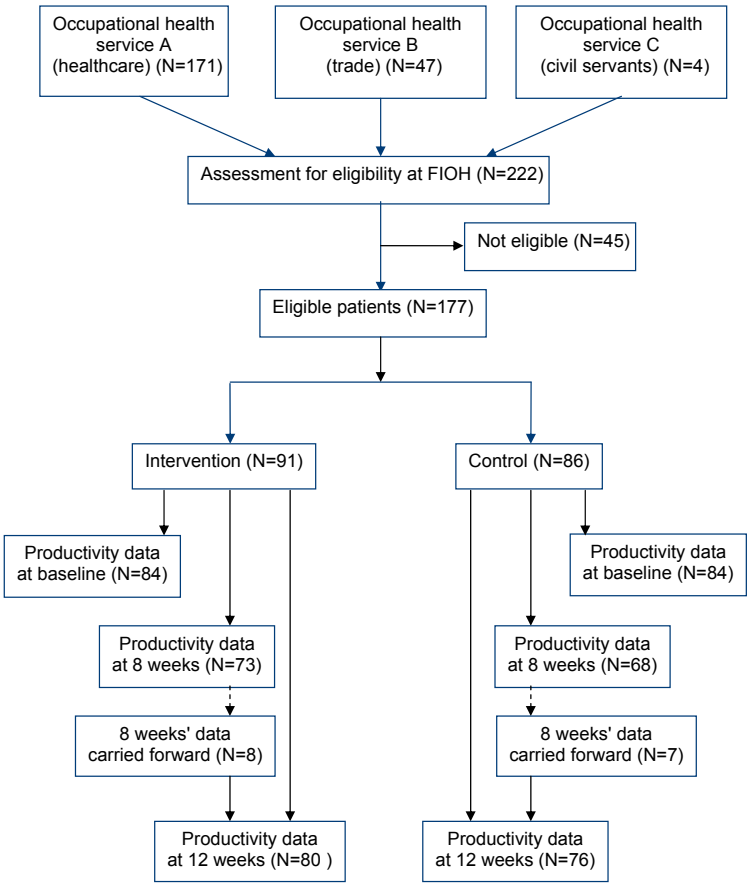

Figure 1. Flow diagram of the study. (FIOH = Finnish Institute of Occupational Health)

all subjects (92%) in the intervention group and 8% in the control group reported that an occupational physiotherapist had visited their workplace. The ergonomic assessment was made most often together with the employee while the supervisor participated in 17% of the assessments. Altogether 412 implemented or planned measures were identified. The majority (60%) were related to guiding the employee in self care, working posture, use of tools and instruments, using both hands in work tasks, and reorganizing work. The recommendations to be implemented in the near future (25% of the measures) included purchasing a new aid or tool, and reorganizing work or its environment. The modifications at work made during the visit (16% of the measures) included changes to the keyboard and monitor, structures of the workplace (including arm rests), and adjustments of the table and the chair.

Outcomes

Of the intervention and control groups, 53.8% and 57.9% reported productivity loss at baseline, respectively (figure 2 and table 2). At 8 weeks, both the proportion and magnitude of productivity loss were lower in the intervention than the control group. However, the differences were not statistically significant. At 12 weeks, the proportion and magnitude of productivity loss were statistically significantly lower in the intervention than the control group (table 2).

The analysis of repeated measures using GEE showed statistically significant differences in the proportion and magnitude of productivity loss between the intervention and control groups after adjustment for age, gender, physical workload factors, fear-avoidance beliefs and follow-up time (table 2). There was an interaction between intervention and time, with the proportion (P=0.009) and magnitude (P=0.033) of productivity loss being lower in the intervention than the control group only at 12 weeks.

Among employees without any productivity loss at baseline, 15.6% in the intervention group had developed productivity loss at 8 weeks, whereas this proportion was almost double in the control group (table 2). The magnitude of productivity loss was 3.7% and 8.1%, respectively. At 12 weeks, there was almost a 4-fold difference in proportion and 8-fold difference in magnitude between the intervention and control groups. With GEE analyses the differences were statistically significant (table 2).

Table 1. Baseline description of subjects in the control and intervention groups - proportion (%), or mean, and standard deviation (SD) [CTS=carpal tunnel syndrome].

Characteristic	Control (N=84)			Intervention (N=84)		
	Proportion (%)	Mean	SD	Proportion (%)	Mean	SD
Age (years)	.	45.6	9.5	.	44.9	10.1
Age group						
20–45 years	46.4	.	.	48.8	.	.
46–64 years	53.6	.	.	51.2	.	.
Female gender	89.3	.	.	84.5	.	.
Smoking status						
Never	55.4	.	.	52.4	.	.
Former smoker	21.7	.	.	31.1	.	.
Occasional or current smoker	22.9	.	.	15.5	.	.
Physical activity						
≤2 times/week	46.4	.	.	54.8	.	.
≥3 times/week	53.6	.	.	45.2	.	.
Waist circumference (cm)	.	84.4	13.0		82.7	12.5
Medical conditions						
Specific shoulder disorder	34.5	.	.	21.4	.	.
Epicondylitis	25.0	.	.	33.3	.	.
Non-specific upper-extremity pain	28.6	.	.	22.6	.	.
Wrist tenosynovitis	8.3	.	.	11.9	.	.
CTS or ulnar nerve lesion	3.6	.	.	6.0	.	.
Other	0	.	.	4.8	.	.
Pain intensity	.	4.8	2.3	.	4.7	2.1
Pain interference with						
Work	.	4.7	2.6	.	4.8	2.8
Leisure time	.	4.3	2.5	.	4.6	2.5
Sleep	.	3.0	2.9	.	3.5	3.1
Physical load factors						
Keying	43.9	.	.	54.8	.	.
Lifting loads, ≥5 kg	37.8	.	.	17.9	.	.
Arm elevations or above shoulder	13.4	.	.	13.1	.	.
Forceful or pinch grip	9.8	.	.	10.7	.	.
High job strain	24.7	.	.	25.0	.	.
Sickness absence in the past 12 months	38.1	.	.	35.7	.	.
Mean score on fear-avoidance beliefs	.	13.1	3.7	.	12.8	4.9
Elevated scores on fear-avoidance beliefs	10.7	.	.	17.9	.	.
Work-relatedness	61.0	.	.	54.8	.	.

Among employees with a productivity loss of 10–20% at baseline, the reduction in magnitude of productivity loss was more prominent in the intervention than the control group both at 8 and 12 weeks (table 2). At 12 weeks, the proportion of productivity loss was also lower in the intervention than the control group. If the baseline productivity loss was >20%, there were no significant differences between the study groups in productivity loss during the follow-up.

The improvement of productivity at 12 weeks was significantly better in the intervention than the control group in the subsample of subjects with: (i) no keying at work but exposure to other physical work load factors (P=0.033), (ii) low job demands (P=0.036), (iii) no sickness absence due to UED before the study (P=0.043), and (iv) low fear-avoidance beliefs (P=0.033). The improvement did not differ between the intervention and control groups in those with low or high job control.

Among those who had been on sick leave for any reason during 4 weeks preceding the follow-up at 12 weeks, there was no difference in the change of productivity between the intervention and control groups. Among those who had not been on sick leave, improvement in productivity at 12 weeks was higher in the intervention compared with the control group (6.5 versus 2.4%, P=0.033).

There was no difference between the control and intervention groups in pain intensity at 12 weeks (mean 2.6 versus 2.9) or pain interference with work (mean 2.4 versus 2.5).

Discussion

The results of this study show that an early ergonomic intervention in addition to adequate medical care help to reduce work-related productivity loss associated with UED compared to medical care on its own. The fact that the difference between the control and intervention groups was largest at 12 weeks after enrolment, suggests that the result is based on the actual impact of the intervention rather than the subjects' satisfaction with the additional attention received from the occupational health service. Many of the new aids or tools recommended by the occupational physiotherapists were not received until later during the course of the study. This may explain why the difference between the study groups was found only at 12 weeks.

A possible explanation for the improved productivity is that the intervention managed to modify the employees' adverse workstyles, which have been shown to be a risk factor for upper-extremity pain and functional limitations (24, 25). Contact with the physician and physiotherapist might also have promoted a better understanding of the nature and consequences of the disorder at the workplace. Consequently, the employee and the supervisor were able to adjust the work requirements to meet better the restrictions during recovery. The physiotherapist's practical suggestions supported the implementation of these changes.

Although the intervention appeared to have beneficial effects on productivity, no difference in pain intensity was found between the two groups at 12 weeks. Therefore, pain relief does not explain the results. This is in accordance with an earlier intervention study that

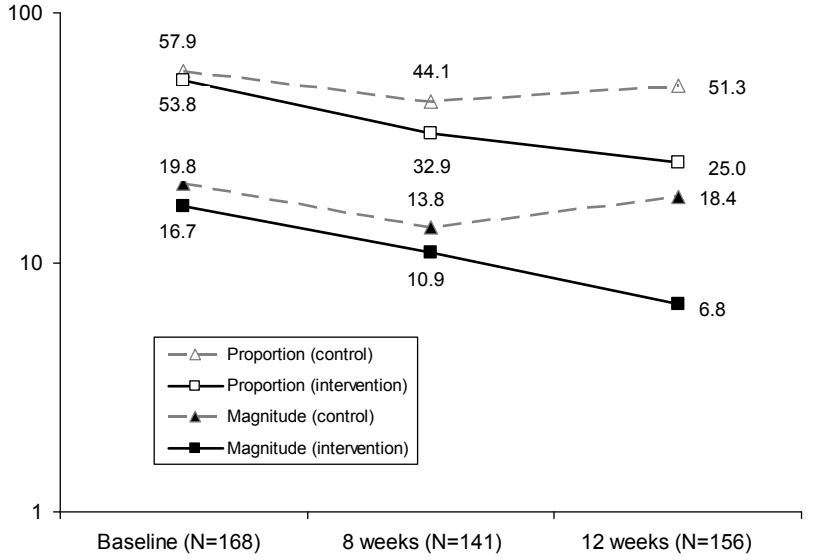

Figure 2. Proportion and magnitude of productivity loss (in logarithmic scale) at baseline, 8 and 12 weeks after intervention in the control and intervention groups.

Table 2. Differences in productivity loss between the control and intervention groups.

	Characteristic																			
	Subjects with no productivity loss at baseline				Subjects with 10–20% productivity loss at baseline						Subjects with >20% productivity loss at baseline						All subjects			
	Sample (N) [a]	Proportion [b] (%)	Magnitude [b]		Sample (N) [a]	Magnitude [b] at baseline		Proportion [b] (%)	Change in magnitude [b] from baseline [c]		Sample (N) [a]	Magnitude [b] at baseline		Proportion [b] (%)	Change in magnitude [b] from baseline [c]		Sample (N) [a]	Proportion [b] (%)	Magnitude [b]	
			Mean	SD		Mean	SD		Mean	SD		Mean	SD		Mean	SD			Mean	SD
8 weeks																				
Control	30	30.0	8.1	17.3	15	16.3	4.7	53.3	-8.1	36.2	23	44.0	9.7	56.5	29.5	17.4	68	44.1	13.8	22.2
Intervention	32	15.6	3.7	11.5	22	16.0	4.7	36.4	8.5	12.2	19	49.1	20.1	57.9	22.1	35.6	73	32.9	10.9	21.2
P-value [d]		0.17	0.24					0.30	0.05					0.92	0.38			0.17	0.42	
12 weeks																				
Control	32	37.5	12.8	24.3	17	16.2	4.7	52.9	-3.8	26.4	27	45.5	12.1	66.7	21.3	25.8	76	51.3	18.4	25.7
Intervention	37	10.8	1.6	4.9	23	16.2	4.7	21.7	12.8	8.1	20	48.1	20.0	55.0	27.8	29.1	80	25.0	6.8	17.4
P-value [d]		0.009	0.007					0.04	0.007					0.41	0.42			0.001	0.001	
8 and 12 weeks (repeated measure analysis)																				
Control	97	21.7	6.7	17.6	51	15.5	4.9	70.5	-3.6	24.5	80	46.1	12.8	76.3	15.7	21.5	228	51.8	17.9	23.9
Intervention	108	8.3	1.6	7.0	69	16.4	4.6	53.6	7.0	9.8	60	48.5	19.5	71.7	16.3	28.5	237	37.6	11.6	20.6
P-value [d]		0.006	0.010					0.089	0.007					0.87	0.94			0.021	0.013	

[a] Sample for repeated measure analysis shows the number of observations.
[b] Of productivity loss.
[c] A positive value of change shows a higher productivity loss at baseline and a negative value shows a higher productivity loss at follow-up.
[d] Significance tests at 8 or 12 weeks were assessed by chi-square or t test. For repeated measure analysis, P-values were assessed by generalized estimating equation and controlled for age, gender, physical work load factors, fear-avoidance beliefs, and follow-up time.

objectively improved workstyle behavior, but showed no effect on arm/wrist/hand pain (26, 27). Because the difference in productivity at 12 weeks was seen also in the subgroup with no sickness absence during the follow-up, the results cannot be explained by the intervening impact of sickness absenteeism.

A substantial effect of the intervention was seen among those employees with no or only mild productivity loss at baseline. The other subgroup analyses showed that those with less fear-avoidance beliefs, more physical load factors at work, or low job demands benefitted more from the intervention. This suggests that the impact of the intervention on productivity could be mediated by a reduction in physical load factors. If the condition caused more functional impairment (productivity loss was >20% at baseline or there was previous

sick leave due to UED), the intervention was not effective. When the disability caused by UED is too severe, it seems that ergonomic interventions have less effect on restoring normal performance at work.

The major strength of our study was its randomized controlled design. The intervention and control groups were comparable without any other significant differences than the intervention itself. Lifting at work and specific shoulder disorders were, however, somewhat more prevalent in the control group, whereas the proportion of elevated scores in fear-avoidance beliefs was higher in the intervention group. The subgroup analyses in this study showed that those employees who were exposed to lifting, forceful gripping or elevated arm postures or who had less fear-avoidance beliefs benefitted from the intervention more than those who had less physical exposures at work or more fear-avoidance beliefs. Therefore, these differences at baseline might have diluted the benefits of the intervention. Another fact that might have led to the same effect was the method to replace productivity data at 12 weeks with those at 8 weeks. This may have overestimated the remaining productivity loss at 12 weeks among those 8 subjects in the intervention group with missing data.

Because there are no objective measures for productivity in most occupations, the generally accepted method is to use self-assessed productivity as we did in our study. The challenges related to measuring productivity have been discussed earlier (28). In previous intervention studies among employees with symptoms in the upper extremities and neck region, both objective (12, 13) and self-assessed productivity (13) have been measured. Compared to these studies, the strength of our study was that the disorders were medically verified using standardized diagnostic criteria, whereas a weakness was that no objective measurement of productivity could be used.

Another strength of the study was that its subjects were actively working people from three companies with varying exposure to work-related factors. Mainly validated questions were used to collect information on all background variables. The ergonomic intervention reached almost all of the subjects in the intervention group and the intervention process included more than 400 suggested improvements.

The major weakness of our study was its small size. This has led to the described imbalances in the randomization. However, despite the small number of participants, the results support the positive effects of an early ergonomic intervention. As the intervention had two parts (ie, physician telephone contact and physiotherapist workplace visit), we do not really know if both aspects were crucial for the effect or if one or the other would suffice. Therefore, more research is needed to clarify the essential parts of the intervention but also to verify the results in different occupational settings.

Due to the incomplete information at baseline and loss to follow-up, some selection may have occurred. Regarding primary selection, the occupational health services staff were asked to recommend study participation to all potentially eligible subjects, but we have no information as to whether this was the case. Neither do we know how many subjects declined participation. After being examined at the Finnish Institute of Occupational Health, none declined. We further analyzed whether those lost to follow-up, allocated initially to the intervention or control groups, differed with respect to baseline variables. We found that the drop-outs and those with incomplete data in the intervention group reported a higher exposure to lifting and had higher levels of pain intensity and interference with work, leisure time, and sleep than those in the control group. On the other hand, the drop-outs initially in the intervention group reported less productivity loss and fear-avoidance beliefs. If selection bias due to non-participation affected our results, it seems, however, unlikely that it caused significant overestimation in the observed difference.

Our study shows that an ergonomic intervention together with adequate medical care can help improve on-the-job productivity associated with UED. Compared to regular practices in the Finnish occupational health services, the intervention during this study was initiated at an earlier stage of the UED process. Physician telephone contacts and occupational physiotherapists visits to the workplace are usually applied only in case of more chronic musculoskeletal disorders. Our study adds to the scarce evidence on the effectiveness of ergonomic interventions. The results also encourage occupational health personnel to interact early with supervisors and make worksite visits where UED is the main complaint of the employee.

Acknowledgements

The Coordinating Ethics Committee at Helsinki University Hospital approved the study, which was supported by the Work Environment Fund and the Academy of Finland. We acknowledge Dr Martti Rechardt for examining the subjects and collecting the data.

References

1. Shiri R, Varonen H, Heliövaara M, Viikari-Juntura E. Hand dominance in upper extremity musculoskeletal disorders. J Rheumatol 2007;34(5):1076–82.

2. Punnett L, Wegman DH. Work-related musculoskeletal disorders: the epidemiologic evidence and the debate. J Electromyogr Kinesiol. 2004;14(1):13–23.

3. van Rijn RM, Huisstede BM, Koes BW, Burdorf A. Associations between work-related factors and the carpal tunnel syndrome – a systematic review. Scand J Work Environ Health 2009;35(1):19–36.

4. Silverstein B, Viikari-Juntura E, Kalat J. Use of a prevention index to identify industries at high risk for work-related musculoskeletal disorders of the neck, back, and upper extremity in Washington state, 1990-1998. Am J Ind Med. 2002;41(3):149–69.

5. Hagberg M, Tornqvist EW, Toomingas A. Self-reported reduced productivity due to musculoskeletal symptoms: associations with workplace and individual factors among white-collar computer users. J Occup Rehabil. 2002;12(3):151–62.

6. Lötters F, Meerding WJ, Burdorf A. Reduced productivity after sickness absence due to musculoskeletal disorders and its relation to health outcomes. Scand J Work Environ Health. 2005;31(5):367–74.

7. van den Heuvel SG, Ijmker S, Blatter BM, de Korte EM. Loss of productivity due to neck/shoulder symptoms and hand/arm symptoms: results from the PROMO-study. J Occup Rehabil. 2007;17(3):370–82.

8. Hagberg M, Vilhemsson R, Tornqvist EW, Toomingas A. Incidence of self-reported reduced productivity owing to musculoskeletal symptoms: association with workplace and individual factors among computer users. Ergonomics. 2007;50(11):1820–34.

9. Boström M, Dellve L, Thomée S, Hagberg M. Risk factors for generally reduced productivity—a prospective cohort study of young adults with neck or upper-extremity musculoskeletal symptoms. Scand J Work Environ Health. 2008;34(2):120–32.

10. Martimo KP, Shiri R, Miranda H, Ketola R, Varonen H, Viikari-Juntura E. Self-reported productivity loss among workers with upper extremity disorders. Scand J Work Environ Health. 2009;35(4):301–8.

11. Boocock MG, McNair PJ, Larmer PJ, Armstrong B, Collier J, Simmonds M, et al. Interventions for the prevention and management of neck/upper extremity musculoskeletal conditions: a systematic review. Occup Environ Med. 2007;64(5):291–303.

12. van den Heuvel SG, de Looze MP, Hildebrandt VH, Thé KH. Effects of software programs stimulating regular breaks and exercises on work-related neck and upper-limb disorders. Scand J Work Environ Health. 2003;29(2):106–16.

13. Rempel DM, Krause N, Goldberg R, Benner D, Hudes M, Goldner GU. A randomised controlled trial evaluating the effects of two workstation interventions on upper body pain and incident musculoskeletal disorders among computer operators. Occup Environ Med. 2006;63(5):300–6.

14. Burton AK, Kendall NA, Pearce BG, Birrell LN, Bainbridge LC. Management of work-relevant upper limb disorders: a review. Occup Med (Lond). 2009;59(1):44–52.

15. Feuerstein M, Harrington CB. Secondary prevention of work-related upper extremity disorders: recommendations from the Annapolis conference. J Occup Rehabil. 2006;16(3):401–9.

16. Sluiter JK, Rest KM, Frings-Dresen MH. Criteria document for evaluating the work-relatedness of upper-extremity musculoskeletal disorders. Scand J Work Environ Health. 2001;27 suppl 1:1–102.

17. Karasek R, Brisson C, Kawakami N, Houtman I, Bongers P, Amick B. The Job Content Questionnaire (JCQ): an instrument for internationally comparative assessments of psychosocial job characteristics. J Occup Health Psychol. 1998;3(4):322–55.

18. Waddell G, Newton M, Henderson I, Somerville D, Main CJ. A Fear-Avoidance Beliefs Questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability. Pain. 1993;52(2):157–68.

19. Estlander AM. Kivun psykologia [Psychology of pain]. In: Estlander AM, editor. Kipupotilaan psykologinen tutkimus [Psychological assessment of a patient with pain]. Helsinki: WSOY; 2003.

20. Varonen H, Viikari-Juntura E, Pasternack I, Ketola R, Malmivaara A, Rahkonen E, et al. Repetitive strain injuries of the hand and forearm. Helsinki: Finnish Medical Society Duodecim; 2007 [cited 20 October 2009].Current Care Summary. Available from: http://www.kaypahoito.fi/web/kh/suositukset/naytaartikkeli/tunnus/ccs00033.

21. Brouwer WB, Koopmanschap MA, Rutten FF. Productivity losses without absence: measurement validation and empirical evidence. Health Policy. 1999;48(1):13–27.

22. Hoeijenbos M, Bekkering T, Lamers L, Hendriks E, van Tulder M, Koopmanschap M. Cost-effectiveness of an active implementation strategy for the Dutch physiotherapy guideline for low back pain. Health Policy. 2005;75(1):85–98.

23. Hanley JA, Negassa A, Edwardes MD, Forrester JE. Statistical analysis of correlated data using generalized estimating equations: an orientation. Am J Epidemiol. 2003;157(4):364–75.

24. Nicholas RA, Feuerstein M, Suchday S. Workstyle and upper-extremity symptoms: a biobehavioral perspective. J Occup Environ Med. 2005;47(4):352–61.

25. Meijer EM, Sluiter JK, Frings-Dresen MH. Is workstyle a mediating factor for pain in the upper extremity over time? J Occup Rehabil. 2008;18(3):262–6.

26. Bernaards CM, Ariens GA, Knol DL, Hildebrandt VH. The effectiveness of a work style intervention and a lifestyle physical activity intervention on the recovery from neck and upper limb symptoms in computer workers. Pain. 2007;132(1–2):142–53.

27. Bernaards CM, Ariens GA, Simons M, Knol DL, Hildebrandt VH. Improving work style behavior in computer workers with neck and upper limb symptoms. J Occup Rehabil. 2008;18(1):87–101.

28. Mattke S, Balakrishnan A, Bergamo G, Newberry SJ. A review of methods to measure health-related productivity loss. Am J Manag Care. 2007;13(4):211–7.

Received for publication: 9 July 2009