



Effects of an Ergonomic Intervention for Computer Work

Final Progress Report

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ABSTRACT

Customer service work at computers is associated with elevated rates of upper body musculoskeletal disorders. This randomized controlled intervention trial evaluated the effects of a wide forearm support surface and a trackball on upper body pain severity and incident musculoskeletal disorders among 182 customer service operators at a large HMO who were randomized to receive (1) ergonomics training only, (2) training plus a trackball, (3) training plus a forearm support, or (4) training plus a trackball and forearm support. If the participant's weekly pain severity or medication usage exceeded a priori criteria an upper body physical examination was performed. Analyses using Cox proportional hazard models and linear regression models adjusted for demographic factors, baseline pain levels, and psychosocial job factors. Within 12 months post-intervention 63 participants were diagnosed with a musculoskeletal disorder in the upper extremities or the neck-shoulder region. Adjusted hazard rate ratios show a protective effect of the armboard for neck-shoulder disorders (HR = 0.49, 95% C.I. = 0.24 to 0.97). The armboard also significantly reduced neck-shoulder pain and right upper extremity pain in comparison to the control group. The findings of the trackball intervention were mixed. A return-on-investment model predicted a full return of armboard and installation costs within 2.4 months. Providing a large forearm support combined with ergonomic training is an intervention that can prevent upper body musculoskeletal disorders and reduce upper body pain associated with computer work.

SIGNIFICANT FINDINGS

The medical management of upper body pain and disorders, experienced by computer users, should consider a number of factors, including the severity of the disorder, the tasks at home and work that aggravate the symptoms, the hours of computer use per week and work-break pattern, the workstation set-up, co-morbid conditions. Our results indicate that for patients who experience upper body pain when performing computer based customer service work, physicians should consider recommending the use of a wide forearm support. Patients should be notified that the beneficial effects may take several weeks to be noticed. The lack of a consistent effect for the trackball suggests that it may be considered on a trial basis for control of hand pain, but patients should be warned that if their pain is unchanged or increases, they should try a different pointing device (e.g., different mouse, touchpad or digitizing pen). Employers should consider offering forearms supports to employees who perform computer based customer service work in order to reduce their risk of developing musculoskeletal disorders. Indeed, the return-on-investment calculations strongly support such an investment. Employers should also continue to provide employees who use computers with appropriate ergonomics training, workstations, chairs, and lighting.

TRANSLATION OF FINDINGS

Computer users experience elevated rates of musculoskeletal disorders and pain in the neck, shoulders, arms and hands that is primarily related to the number of hours using a computer, work break pattern, workstation setup, and work organizational factors. This study finds that approximately one-half of the neck-shoulder disorders can be prevented by using a wide forearm support board while working on a computer. In addition, the use of a wide forearm support board significantly reduced the pain in the neck, shoulder and right upper arm and hand.

The use of a trackball instead of a computer mouse led to a significant reduction of musculoskeletal disorders and pain in the left arm and hand but not the right arm and hand. The underlying basis for this finding is uncertain since 98% of the participants of the study used the mouse or trackball with their right hand. Eight of the 90 participants who received the trackball reported increased pain in their upper body with the use of the trackball and nine reported that the trackball was difficult to use. These mixed findings suggest that the trackball may be considered as a replacement to the mouse on a trial basis for control of hand pain, but patients should be warned that if their pain is unchanged or increases, they should try a different pointing device (e.g., different mouse, touchpad or digitizing pen).

Companies should strongly consider offering forearm boards to employees who do customer service work with a computer. Taking into account the cost of the

forearm board and the installation cost and the reasonably estimated costs of preventing workers' compensation claims for neck disorders, a cost model predicted a return-on-investment of 2.4 months.

BACKGROUND

Computer based customer service work is one of the most rapidly growing occupations in the world (Norman et al. 2004). The work involves the simultaneous use of a telephone and computer for activities such as airline reservations, banking, sales, insurance, scheduling, billing, and health related services. Musculoskeletal disorders of the upper extremities and neck are the most common occupational health problems associated with this type of work and account for the majority of work-related lost-time (Hales et al. 1994; Norman et al. 2004).

Sustained pain in the upper extremity and neck regions and specific musculoskeletal disorders, such as wrist tendonitis, epicondylitis and trapezius muscle strain, are elevated among computer users. The most consistently observed risk factors for these endpoints are increasing hours of mouse or keyboard use and sustained awkward postures, such as increasing wrist extension and keyboard above elbow height (Palmer et al., 2001; Gerr et al. 2002; Marcus et al. 2002; Kryger et al., 2003; Lassen et al. 2004). Other important risk factors include being female and work organizational factors (e.g., high work load, low job control) (Sauter et al. 1991; Faucett and Rempel 1994). The association of carpal tunnel syndrome with keyboard use is weak, but there is some evidence of increased risk with increasing hours of computer mouse use (Stevens et al. 2001; Anderson et al. 2003).

Controlled workplace studies have evaluated the effects of some interventions on upper body symptoms among computer users. Positive effects on upper body symptoms have been reported with adjustable chairs and workstations (Nelson & Silverstein 1998, Amick 2003), increased frequency of work breaks (Galinsky et al., 2000), ergonomics training (Brisson et al., 1999) and split keyboards (Tittranda et al., 1999). An intervention study of reinforced exercises found no benefit on neck pain (Kamwendo et al., 1991). These studies have been limited by lack of randomization at the subject level, small sample sizes, or lack of physical examinations.

Using arm supports when working on a computer has also been suggested as a method for preventing upper body pain and musculoskeletal disorders (Erdelyi et al. 1988; Bergqvist et al. 1995). Surprisingly, a prospective study of 632 computer users, found that use of a narrow wrist rest increased the risk of hand-arm symptoms (Marcus et al., 2002). However, the same study reported that if the keyboard was placed more than 12 cm from the edge of the desk, a position that allows the forearms to rest on the desk surface, then there was a reduced risk of hand-arm symptoms. Laboratory studies have found that forearm support can decrease shoulder muscle load and wrist deviation (Visser et al. 2000; Cook and Burgess-Limerick 2004a). Although the use of forearm support is recommended by these prospective and laboratory studies, the findings of two intervention studies of forearm supports have been mixed (Aaras et al. 2001, Cook and Burgess-Limerick 2004b). These intervention studies were limited by

small sample size, short study duration, and lack of physical examinations to confirm musculoskeletal disorders.

The purpose of this study was to determine whether two simple workstation interventions, a forearm support board and a trackball, when used by computer based customer service workers, would reduce the incidence of upper body musculoskeletal disorders and pain severity. Secondary purposes included estimating the effects of the intervention on productivity and costs.

METHODS

Study Design and Subjects

This is a one-year, randomized intervention trial with 4 treatment arms.

Employees at two customer service center sites (sites A and B) of a large HMO were eligible for participation if they performed computer based customer service work for more than 20 hours per week and did not have an active workers' compensation claim involving the neck, shoulders, or upper extremities.

Customer service operators are either registered nurses (RN) or health care specialists (HCS). The work involves answering phone calls from patient members in order to address questions, scheduling appointments, saving messages, providing health care advice, and triage. There is little use of written material; almost all information is handled on the computer.

At on-site recruitment meetings, the study was explained, and interested employees who met the initial eligibility criteria signed a consent form. These potential participants filled out a self-administered baseline questionnaire and then, on a weekly basis, completed a one page questionnaire which assessed pain severity. Employees who completed at least four weekly surveys were eligible for participation in the study. Participants were randomized to receive one of four interventions; the randomization was done by means of a computer-generated permuted-block sequence. The study protocol was approved by the Committee on Human Research of the University of California at San Francisco.

Interventions

The four workplace interventions were (1) ergonomics training, (2) forearm support board and ergonomics training, (3) trackball and ergonomics training, and (4) forearm support board, trackball and ergonomics training (Figure 1). The armboard is a wraparound, padded arm support that attaches to the top, front edge of the work surface (30.5 cm depth, 76.2 cm width, 2.5 cm height; MorencyRest, R&D Ergonomics, Freeport, ME). The armboard provides 30.5 cm of support for the forearms. The trackball (16.5 cm depth, 8.6 cm width, 4.6 cm height, with a 4 cm diameter ball; Marble Mouse, Logitech, Fremont) was installed next to the keyboard. The interventions were administered by a research associate who was trained to perform the ergonomics training and install the armboard and the trackball. The ergonomics training involved conventional recommendations (Brisson et al. 1999), which included maintaining an erect posture while sitting or standing, adjusting the chair height so that the thighs were approximately parallel to the floor, adjusting the arm support and worksurface height so that the forearms were approximately parallel to the floor, adjusting the mouse and keyboard location to minimize the reach, adjusting the monitor height so that the center of the monitor is approximately 15 degrees below the visual horizon, and a reminder to take scheduled breaks.

The computer workstations used at the sites had independently adjustable keyboard and monitor support surfaces. The workstations were typically

equipped with a conventional keyboard, computer mouse and a telephone headset. Chairs were wheeled and adjustable in height with adjustable height arm rests.

Endpoints

The baseline questionnaire collected information on demographic factors and possible co-variates, such as, medical history, medications, years at this job, years performing this work, previous occupations, hobbies, upper extremity symptoms, and psychosocial stressors. The latter was assessed by a composite measure of psychological strain (a sum index of job dissatisfaction, physical/psychosomatic strain, and sleep problems) and two continuous measures of job strain and iso-strain, all ascertained by the Job Content Questionnaire (Karasek et al. 1998). These psychosocial job factors may confound the relationship between ergonomic factors and musculoskeletal disorders among computer users (Hales et al. 1994; Bernard et al. 1994; Rugulies and Krause 2005).

The weekly survey was completed by participants at the end of either of the last two days of each work week for 52 weeks. It assessed pain, work schedule, medication used for pain, acute injury events during the week, and workplace changes during the week. Three body regions, the neck/shoulders, right elbow/forearm/wrist/hand and left elbow/forearm/wrist/hand, were assessed for

the worst pain during the preceding 7 days using a 0 to 10 point scale (0=no pain; 10=unbearable pain) (Gerr et al. 2002).

After the intervention, if subjects recorded, on the weekly survey, a pain intensity level of more than 5, or they used over-the-counter non-steroidal anti-inflammatory medications for 2 days or more for upper extremity or neck pain, that was not associated with an acute traumatic event (e.g., laceration, fall), then a physical examination of the upper extremities or neck/shoulders was performed. The examination protocol focused on the body region of pain and was performed by one physician who was blinded to intervention status. The examination protocol assessed for the presence of 40 different upper extremity and neck musculoskeletal disorders (e.g., de Quervain's tendinitis, carpal tunnel syndrome, epicondylitis, supraspinatus tendonitis, etc.) (Gerr et al., 2002). An incident disorder was defined as a disorder diagnosed on the physical examination, only if the participant did not report pain > 5 in that body region (neck/shoulder, right upper extremity, left upper extremity) on the weekly questionnaires prior to the intervention. In other words, those participants with moderate to severe pain, prior to the intervention, could not develop an incident disorder in that region. Subjects with multiple specific disorders in the same body region (neck, left upper extremity, or right upper extremity) counted as one incident case only. Subjects with incident disorders in more than one region would be counted as incident case for each region.

Approximately one month after the intervention, an unannounced visit was made to the participant at the workplace. Subjects completed a follow-up survey and the workstation was evaluated to ensure that the assigned intervention was used.

At the end of the study, or at the time of dropout, an exit questionnaire was administered to identify the reason for dropout and the participant's subjective ratings of the intervention. An open ended question asked participants to list the positive and negative aspects of their assigned intervention and to rate the effect of the intervention on their productivity. Subjects were also asked, in an open ended question, to describe what, if anything, improved their discomfort in the upper body in the past 4 weeks.

The effect of the intervention on employee productivity was also assessed by using the employer's measures of productivity. The computer system automatically records handle time per call, calls per hour, call type per hour, and time waiting for calls for each employee. The effects of interventions on productivity were based on calculating differences for these measures between the year prior to the intervention and the year post-intervention.

Data Analysis

The analysis followed an intention-to-treat approach. The study was designed to have 80 percent power to show a 50% difference in disorder risk at the two-sided 5 percent level between those who received the arm support and those who did

not or between those who received the trackball and those who did not. The incidence of neck-shoulder disorders was expected to be 35% (Gerr et al. 2002).

The Cox proportional-hazards model was used to calculate hazard ratios for the interventions with respect to incident cases for each of the three body regions. A two-sided p value of less than or equal to 0.05 was considered to indicate statistical significance. The covariates of age, gender, pre-intervention pain score, and two psychosocial variables (composite psychological strain score and iso-strain) were forced into all models to eliminate any residual confounding due to these important worker and workplace characteristics. The mean pre-intervention pain level was also forced into all models. The other 23 possible covariates were each examined in multivariate models which included the forced covariates. If the tested covariate changed the hazard ratio of an intervention by 0.05 or more it was included in the final, adjusted model.

For the analysis of the effect of interventions on pain in the three body regions, the outcome measure was the difference between the mean post-intervention pain level less the mean pre-intervention pain level. Missing weekly pain levels were replaced by the mean of the scores just prior to and following the missing data. General linear models were used to calculate the beta-coefficient and 95 percent confidence intervals for the interventions for each of the three body regions. A negative coefficient indicated that the pain declined after the intervention. The approach to inclusion of covariates was similar as that used in

the Cox proportional-hazards model; a tested covariate was retained in the final model if it changed the beta-coefficient by 0.05 or more.

RESULTS

Between June 2001 and May 2002, 269 customer service operators attended study recruitment meetings and 182 agreed and were eligible to participate in the study. The 182 participants were randomly assigned to one of the 4 intervention groups. The baseline characteristics of the participants did not significantly differ by intervention group (Table 1). Fifty-seven participants dropped out before completing the full 12 months of the study; 5 dropped out in the first 30 days and 31 dropped out in the first 6 months. The overall number of dropouts per intervention group was similar, but more participants in the trackball (N=4) and trackball and armboard intervention (N=4) groups left the study due to discomfort than in the other two groups (N=1 each). The most common reason for dropout was job change (N=21).

Over the 52 weeks of the study, 113 of the 182 participants reported upper body pain levels greater than 5 or use of pain medication for 2 or more days for upper body pain in the prior week on the weekly survey. Of these, 11 did not qualify for a physical exam because their pain was the result of a preexisting injury, not work-related, or due to an acute event. Of the remaining 102 (56%), 7 did not have a physical examination because they either refused or were not available (on leave). Of the 95 who had an examination, 77 received a specific diagnosis based on clinical signs, the other 18 had no physical examination findings. Of the 77 who received a diagnosis, 63 reported no pain >5 in the body region prior to the intervention, and therefore qualified as incident cases. Subjects could

receive more than one incident diagnoses; 39 received a diagnosis in the neck-shoulder region, 29 received diagnosis in the right upper extremity and 17 received a diagnosis in the left upper extremity. A list of the incident regional disorders and the frequency of specific diagnoses are presented in Table 2 by intervention group.

The unadjusted and adjusted effects of the interventions on incident regional disorders were examined using the Cox-proportional hazard model for the three body regions (Table 3). Because the interaction term between the interventions armboard and trackball was not significant in any of the models (p-values on interaction terms ranged from 0.10 to 0.97), the models were simplified to evaluate the independent effects of armboard and trackball, and not the effects of each treatment arm. In the final, adjusted models, protective effects were found for the armboards reducing the hazard rate of incident neck-shoulder disorders by a statistically significant factor of 2 (HR=0.49), and reducing the hazard rate of left upper extremity disorders by a factor of 3.4, although this latter effect was only marginally significant (p=0.06). The trackball intervention led to a statistically significant reduction of left upper extremity disorders by a factor of 5.26 but had no reduction effect on right upper extremity disorders.

The unadjusted and adjusted effects of the interventions on the change in pain scores for the three body regions were examined using linear regression analysis (Table 4). Again, the interaction terms for armboard and trackball was not significant (range of p values ranged from 0.33 to 0.52); therefore, the models

were simplified to evaluate just armboard and trackball effects. In the final, adjusted models, significant declines in neck/shoulder pain and right upper extremity pain were associated with the armboard intervention. The adjusted beta-coefficient for the effect of armboard on neck-shoulder pain was -0.48, indicating that the armboard intervention was associated with a mean reduction in pain of 0.48 points on the 10-point visual analog pain scale. Although the trackball intervention was also associated with reduced pain levels in both of these regions, the effects were not statistically significant. The trackball intervention was associated with a significant reduction in pain in the left upper extremity.

In order to investigate whether the effect of trackball was associated with mouse using hand, handedness was replaced by 'mouse using hand' in the final model. This change did not have any substantial effect on the adjusted model results. The adjusted models were also run using just the female participants (N= 173) in order to evaluate the effects of important female related medical conditions (e.g., oophorectomy, menopause, use of birth control pills). This analysis did not change the conclusions derived from the fully adjusted model of all participants.

On a weekly basis, subjects reported the number of days of medication used for upper body pain. This data was analyzed in a similar way to the pain scores. Those who received the armboard intervention reported a mean reduction of 0.31 days of medication usage compared to those not receiving this intervention, but the difference was not statistically significant ($p=0.08$). Those receiving the

trackball reported no difference in days of medication usage (beta coefficient: 0.08, $p=0.66$).

At the end of the study or at the time of dropout, subjects also evaluated their assigned intervention (Table 5). Subjects in the intervention groups reported decreased pain in comparison to the control group. There were no other significant differences on the subjective evaluation although it should be noted that 9 subjects reported difficulty using the trackball. Subjects were also asked, in an open ended question, to describe what, if anything, improved their discomfort in the upper body in the past 4 weeks (Table 6). The top 4 factors were the intervention, medications, stretching and rest.

The effects of the intervention on productivity were assessed separately for company tracked productivity measures and self-perceived measures. Several productivity measures are automatically tracked by the employer for each employee including the percent of work time available for a call, the average time to process a call, and the number of calls handled per hour. The change in productivity was calculated as the difference between the mean value of a productivity measure during the year post-intervention and the mean value for the year pre-intervention. Self-perceived effects on productivity were assessed at the end of the study. There were no significant differences between intervention groups for company recorded productivity measures or self-perceived measures (Table 7).

A return-on-investment (ROI) calculation for the armboard considered the retail cost of the intervention, the installation cost, and the savings associated with preventing a neck-shoulder disorder case. The retail cost of the arm support is approximately \$90 and the cost of the technician time for installation was estimated to be \$10. If the mean medical and salary replacement workers' compensation cost of an employee with a typical non-traumatic neck-shoulder disorder is approximately \$11,540 (Silverstein, 2004), and if the annual incidence of neck-shoulder disorder of 0.35 (Gerr et al., 2002) is reduced by 50% by the intervention, and if 25% of employees with disorders file a workers compensation claim (Silverstein 1997) then the ROI is 2.4 months. These calculations do not consider indirect costs, such as temporary replacement employee costs, and do not consider the benefit of reduction in symptom severity among the non-incident cases and those who do not file workers' compensation claims.

DISCUSSION

The findings of this randomized controlled trial suggest that a simple workstation modification can reduce upper body pain and prevent musculoskeletal disorders among computer users who perform customer service work. Since there was no interaction effect between armboard and trackball, the effects of each could be examined separately. The addition of a wide armboard reduced neck-shoulder and right upper extremity pain and prevented incident neck-shoulder disorders in comparison to ergonomics training alone. On average, the armboard reduced neck/shoulder pain by 0.48 on a 0 to 10 pain scale, and the standardized effect size (score change/SD of change score) was 0.31 (0.48/1.53). Overall, these findings matched the subjects' own conclusions about the effects of the armboard intervention (Table 5).

On the other hand, the effects of the trackball were mixed. The trackball significantly reduced pain and risk of musculoskeletal disorders in only the left upper extremity. This finding is unexpected since 98% of the study subjects used the mouse and trackball with the right hand. In the right upper extremity, the trackball decreased pain but increased risk of disorders, but neither trend rose to the level of statistical significance. At the conclusion of the study some subjects reported experiencing more pain when using the trackball and 8 subjects reported that the trackball was more difficult to use than the mouse (Table 5).

In two prospective studies of computer users, the use of a narrow depth wrist support (less than 7.5 cm) was associated with an increased risk of hand and arm pain and disorders (Marcus et al., 2002; Lassen et al., 2004). The armboard used in our study provided a surface with a 30 cm depth support surface, leading to less localized contact stress in comparison to a narrow depth wrist rest.

Furthermore, the support from the armboard is provided at the center of the forearms and not at the wrist, where some tissues (e.g., flexor tendons, bones and nerves) lie relatively close to the skin surface. The other possible benefit is that the use of the armboard will reduce the relative height of the keyboard above the worksurface and thereby may reduce wrist extension (Marcus et al., 2002) and shoulder muscle load (Visser et al. 2000; Cook and Burgess-Limerick 2004a).

The annual incidences of disorders in this population were higher than that of a 3-year prospective study of computer users (Gerr et al. 2002) which used similar case criteria. In our study, neck-shoulder annual incidence was 0.44, right upper extremity 0.17, and left upper extremity was 0.17. In the Gerr study the neck-shoulder 12 month incidence rate was 0.35 while the combined left and right upper extremity rate was 0.21. These differences may be due to differences in recruitment, differences in computer related tasks, differences in psychosocial factors, or differences in how the physical examination was performed. Our intervention study is more likely to have attracted symptomatic employees although we have no symptom data on the non-participants.

Several limitations should be considered when interpreting the study findings.

First, the definition of an incident case required a relatively high symptom threshold, moderate to severe regional pain (> 5) or use of pain medication for 2 or more days in one week. In these participants, the probability of a positive physical examination, identifying a specific disorder, was 81%. If a lower threshold was used to trigger the physical examinations, the number of incident cases would have increased. This may have increased the power of the study but is unlikely to have influenced the conclusions. Second, the unavailability of 7 participants [distribution by intervention group: (1) 1, (2) 3, (3) 3, and (4) 0] for a physical examination likely led to a small underestimation of incidence rates, and it is uncertain whether this loss biased the conclusions. Third, the risk benefit calculations may overestimate the cost benefit of the intervention because more employees with disorders may not file workers compensation claims than assumed in the model. On the other hand, the calculations may underestimate the actual benefits because indirect costs were not included in the calculations and typically add 2 to 4 times the amount of direct costs (Webster and Snook 1994; Leigh 1997). Finally, randomization is not always effective and residual confounding may have influenced results. However, a major strength of this study is that it investigated over 20 potentially confounding factors and controlled for several of them in the analyses. In addition, the study controlled for psychosocial job factors which have been shown to potentially confound the relationship between the physical work environment and musculoskeletal disorders (Faucett and Rempel 1994; Bongers 2002).

The medical management of upper body pain and disorders, experienced by computer users, should consider a number of factors, including the severity of the disorder, the tasks at home and work that aggravate the symptoms, the hours of computer use per week and work-break pattern, the workstation set-up, co-morbid conditions. Our results indicate that for patients who experience upper body pain when performing computer based customer service work, physicians should consider recommending the use of a wide forearm support. Patients should be notified that the beneficial effects may take several weeks to be noticed. The lack of a consistent effect for the trackball suggests that it may be considered on a trial basis for control of hand pain, but patients should be warned that if their pain is unchanged or increases, they should try a different pointing device (e.g., different mouse, touchpad or digitizing pen). Employers should consider offering forearms supports to employees who perform computer based customer service work in order to reduce their risk of developing musculoskeletal disorders. Indeed, the return-on-investment calculations strongly support such an investment. Employers should also continue to provide employees who use computers with appropriate ergonomics training, workstations, chairs, and lighting.

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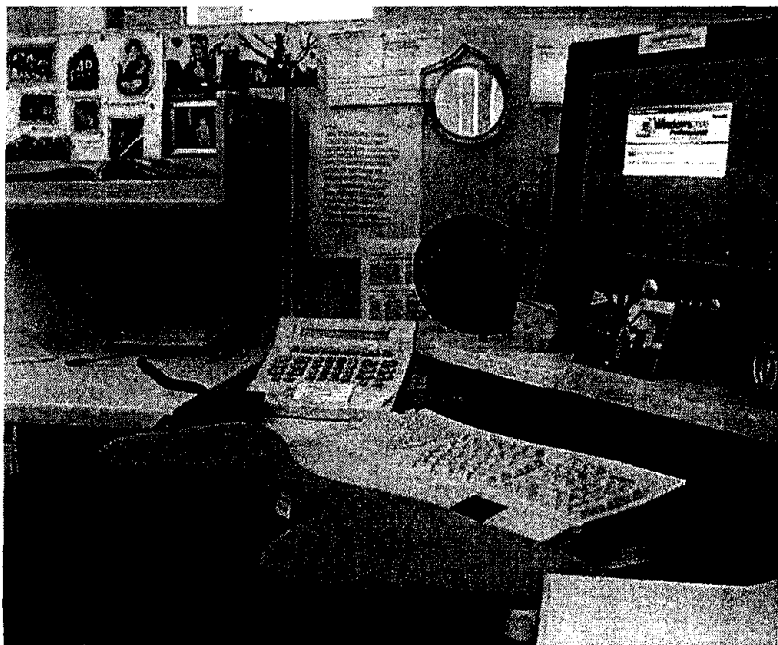
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FIGURES AND TABLES

Figure 1. The four interventions were (1) training only with no equipment changes, (2) training plus replacing the mouse with a trackball, (3) training plus adding a forearm support board, or (4) training plus forearm support board and trackball. The pictures are of a typical workstation with no equipment changes (A) and a workstation with both the armboard and trackball (B).



A



B

Table 1. Characteristics of participants by intervention group.

	Ergonomic training only	Ergonomic training & trackball	Ergonomic training & armboard	Ergonomic training & trackball & armboard	
	n=46	n=45	n=46	n=45	
	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %	Mean (SD) or %	P value ¹
Demographics					
Gender: female	94%	98%	100%	89%	0.08
Age in years	40.0 (11.6)	40.5 (12.4)	38.9 (12.1)	40.7 (12.2)	0.89
Body mass index ²	27.6 (6.20)	28.2 (6.62)	29.9 (7.69)	30.1 (8.95)	0.30
Right handed	89%	96%	89%	96%	0.45
Right handed mouse use	100%	96%	96%	100%	0.25
Single	35%	29%	43%	38%	0.54
Educational Level					0.07
High school	20%	27%	20%	36%	
Some college	33%	40%	57%	40%	
Completed college	48%	33%	24%	24%	
Ethnicity					0.25
African American	13%	18%	30%	22%	
Asian or Pacific Islander	26%	16%	13%	16%	
Hispanic	9%	16%	15%	11%	
White	52%	51%	37%	51%	
Native American	0%	0%	4%	0%	
Medical History					
Systemic comorbidity ³	24%	31%	20%	20%	0.54
Regional disorders ⁴	65%	76%	57%	62%	0.28
Low back pain ⁵	43%	47%	46%	36%	0.71
Lost work days in past year ⁶	0.36 (0.96)	2.99 (13.7)	4.22 (16.5)	0.58 (1.25)	0.25
Previous Surgery in upper body	11%	18%	9%	9%	0.49
Pregnant	0%	5%	0%	3%	0.29
Oophorectomy	9%	9%	2%	8%	0.51
Menopausal	21%	27%	17%	13%	0.38
Pain medication	59%	36%	46%	58%	0.09
Anti-Depressant medication	9%	9%	17%	4%	0.21
Current smoker	11%	16%	9%	22%	0.26
Weekly exercise ⁷	63%	58%	46%	64%	0.25
Hand intensive recreational activity (h/wk)	12.8 (8.94)	16.7 (11.2)	15.2 (16.4)	16.1 (13.5)	0.47
Aerobic activity (h/wk)	0.25 (0.92)	0.22 (1.06)	0.37 (1.34)	0.43 (1.70)	0.85

(continued on next page)

Table 1 (continued)

Workplace Factors					
Worksite A	83%	82%	83%	84%	0.99
Job Title: registered nurse	54%	42%	41%	42%	0.54
Seniority in months	20.6 (13.6)	23.2 (13.3)	21.9 (14.0)	23.9 (12.9)	0.65
Typing speed in words per minute	45.7 (11.6)	47.0 (15.7)	44.9 (11.1)	46.3 (14.8)	0.90
Work hours per week	33.0 (5.51)	32.6 (6.86)	33.7 (6.34)	33.9 (5.74)	0.76
Computer use hours per week	31.5 (5.48)	31.7 (6.81)	32.2 (7.13)	31.9 (5.71)	0.96
Total break minutes per day	53.7 (16.3)	41.7 (23.2)	47.7 (23.3)	48.7 (21.0)	0.06
Iso-strain ⁸	0.40 (0.10)	0.41 (0.09)	0.41 (0.09)	0.41 (0.10)	0.82
Composite Psychological Strain ⁹	-0.06 (0.96)	-0.04 (0.88)	0.19 (1.18)	0.10 (0.96)	0.51

¹ Chi square for categorical measures, ANOVA for continuous measures, and Bartlett's test for equal variances for psychosocial variables

² Body Mass Index = $(704.5 \times \text{weight in pounds}) / (\text{height in inches})$

³ Systemic co-morbidity is defined as a positive history of any of the following disorders: diabetes (excluding diabetes solely related to pregnancy), rheumatoid arthritis or lupus erythematodes, degenerative arthritis (osteoarthritis), low thyroid or overactive thyroid, gout, fibromyalgia

⁴ Regional disorders is defined as a positive history of any of the following disorders: neck pain, upper back pain, middle back pain, herniated cervical disk, cervical radiculopathy, muscle strain/sprain in the fingers, hands, wrists, forearms, or elbows, muscle strain/sprain in the upper arms or shoulders, rotator cuff injury, tendinitis in the shoulders, thoracic outlet syndrome, broken bones in the upper arms or shoulders, broken bones in the fingers, hands, wrists, forearms, or elbows, tendinitis in the fingers, hands, wrists, forearms, or elbows, trigger finger, carpal tunnel syndrome, ulnar neuropathy, ganglion

⁵ Low back pain is defined as a positive history of: lower back pain, herniated lumbar disk, sciatica

⁶ Lost workdays in last year due to problems in upper extremities, shoulders, or neck

⁷ Exercise at least once per week.

⁸ Iso-strain = psychological job demands / (job control and social support at work)

⁹ Composite Psychological Strain = z-score addition of job dissatisfaction score, anti-depressant medication, physical and psychosomatic strain score, sleeping problems score

Table 2. Twelve month incidence rates of regional musculoskeletal disorders by intervention group and frequencies of specific disorders within each body region.

	Ergonomic training only	Ergonomic training & trackball	Ergonomic training & armboard	Ergonomic training & trackball & armboard
	n=46	n=45	n=46	n=45
Any upper body disorder ¹	21 / 44	15 / 42	13 / 44	14 / 44
Neck/shoulder disorders	19 / 43	6 / 35	6 / 40	8 / 40
shoulder tendonitis ²	10	3	4	5
somatic pain syndrome ³	15	2	4	2
thoracic outlet syndrome	9	4	2	4
Right Upper Extremity Disorders	7 / 40	8 / 38	7 / 35	7 / 38
carpal tunnel syndrome	0	3	2	2
ulnar neuritis (elbow)	2	1	1	4
pronator syndrome	0	0	0	1
anterior interosseous nerve entrapment	0	0	0	1
posterior interosseous nerve entrapment	0	0	1	0
deQuervain's tendinitis	3	1	1	1
extensor tendinitis ⁴	1	2	3	4
flexor tendonitis ⁵	0	0	3	1
lateral epicondylitis	0	2	2	0
medial epicondylitis	3	1	4	2
Left Upper Extremity Disorders	7 / 41	3 / 40	4 / 41	3 / 43
carpal tunnel syndrome	2	2	1	0
ulnar neuritis (elbow)	3	0	1	3
anterior interosseous nerve entrapment	1	0	0	0
posterior interosseous nerve entrapment	1	0	1	0
deQuervain's tendinitis	2	1	0	0
extensor tendinitis ⁴	3	1	1	1
flexor tendonitis ⁵	2	0	1	1
lateral epicondylitis	2	1	2	1
medial epicondylitis	1	1	1	0

¹ Denominators exclude participants who reported pain greater than 5 in that body region prior to the intervention (e.g., not eligible to become an incident case). Participants may have more than one diagnosis.

² includes bicipital, subscapularis and supraspinatus tendonitis

³ shoulder pain and trapezius muscle tenderness

⁴ includes dorsal compartment 2, 3, 4, and 5 tendonitis

⁵ includes digital flexor, flexor carpi radialis and flexor carpi ulnaris tendonitis

Table 3. Unadjusted and adjusted hazard ratios evaluating the effects of interventions on incident musculoskeletal disorders by body region (N=182).

	<u>Trackball Intervention</u>			<u>Armboard Intervention</u>		
	Hazard Ratio ¹	95% CI	P Value	Hazard Ratio ¹	95% CI	P value
Neck-Shoulders Disorders						
Unadjusted Model	0.61	0.31 - 1.17	0.14	0.53	0.28 - 1.03	0.06
Adjusted Model ²	0.62	0.3 - 1.28	0.19	0.49	0.24 - 0.97	0.04
Right Upper Extremity Disorders						
Unadjusted Model	1.30	0.62 - 2.71	0.49	0.81	0.39 - 1.69	0.57
Adjusted Model ³	1.26	0.56 - 2.86	0.58	0.64	0.28 - 1.45	0.29
Left Upper Extremity Disorders						
Unadjusted Model	0.56	0.21 - 1.52	0.26	0.66	0.25 - 1.73	0.40
Adjusted Model ⁴	0.19	0.04 - 0.9	0.04	0.29	0.08 - 1.05	0.06

¹ Cox proportional hazard ratio: those without the intervention are the reference group.

² variables: trackball, armboard, pre-intervention mean neck-shoulders pain value, age, gender, composite psychological strain, iso-strain, ethnicity, pain medication, current smoker, hand intensive activity outside of work

³ variables: trackball, armboard, pre-intervention mean right upper extremity pain value, age, composite psychological strain, iso-strain, seniority, total break minutes per day, educational level, ethnicity, current smoker, hand intensive activity outside of work

⁴ variables: trackball, armboard, pre-intervention mean left upper extremity pain value, age, gender, composite psychological strain, iso-strain, job title, typing speed, body mass index, educational level, ethnicity, low back pain score, previous surgery in neck, shoulders, or upper extremities, pain medication, current smoker, weekly exercise, hand intensive activity outside of work

Table 4. Unadjusted and adjusted regression models examining the effects of interventions on change in beta-coefficient for regional pain. A negative beta-coefficient indicates a decrease in pain scores after the intervention (N=182).

	<u>Trackball Intervention</u>			<u>Armboard Intervention</u>		
	Beta-Coefficient ¹	95% CI	P Value	Beta-Coefficient ¹	95% CI	P value
Neck-Shoulders Pain						
Unadjusted Model	-0.29	-0.74 - 0.16	0.20	-0.38	-0.83 - 0.06	0.09
Adjusted Model ²	-0.27	-0.66 - 0.11	0.16	-0.48	-0.85 - -0.10	0.01
Right Upper Extremity Pain						
Unadjusted Model	-0.26	-0.74 - 0.22	0.29	-0.73	-1.21 - -0.25	0.003
Adjusted Model ³	-0.29	-0.69 - 0.12	0.17	-0.66	-1.06 - -0.25	0.002
Left Upper Extremity Pain						
Unadjusted Model	-0.23	-0.64 - 0.17	0.25	-0.28	-0.68 - 0.13	0.18
Adjusted Model ⁴	-0.35	-0.69 - -0.02	0.04	-0.30	-0.63 - 0.03	0.08

¹ regression coefficient - a negative value indicates a decline in pain after the intervention.

² variables in model: trackball, armboard, pre-intervention mean neck-shoulders pain value, age, gender, composite psychological strain, iso-strain, current smoker

³ variables in model: trackball, armboard, pre-intervention mean right upper extremity pain value, age, gender, composite psychological strain, iso-strain, educational level

⁴ variables in model: trackball, armboard, pre-intervention mean left upper extremity pain value, age, gender, composite psychological strain, iso-strain, body mass index

Table 5. Subjects' assessment of intervention at end of study or time of dropout.

	Intervention				P Value ¹
	Ergonomic training only (n=46)	Ergonomic training & trackball (n=45)	Ergonomic training & armboard (n=46)	Ergonomic training & trackball & armboard (n=45)	
Subjects' evaluation of intervention					
Decreased pain	5	14	29	20	0.001
Increased pain	1	4	1	4	0.27
Liked or helped	18	24	25	22	0.45
Did not like	2	1	1	1	0.90
Difficult to use	0	4	1	5	0.06

¹ Chi square test statistic

Table 7. Effect of intervention on company tracked measures of productivity and subjects' rating of productivity changes at end of study.

	Intervention				P Value ⁴
	Ergonomic training only (n=46)	Ergonomic training & trackball (n=45)	Ergonomic training & armboard (n=46)	Ergonomic training & trackball & armboard (n=45)	
Measured productivity changes ¹					
Change in % work time ²	-2.7 (10.3)	0.04 (8.0)	-2.3 (8.7)	-2.8 (13.7)	0.57
Change in average handle time ³	-25 (57)	-10 (51)	4 (66)	-17 (96)	0.30
Change in calls per hour	0.4 (1.3)	0.6 (1.5)	0.1 (1.7)	0.2 (2.3)	0.57
Subjects reporting improved productivity	18	27	30	27	0.31

¹ Change in productivity is the difference between employer measured mean productivity during the year post-intervention and the year prior to the intervention. Only data from 162 subjects was available for these calculations.

² Percent work time is the number of hours logged on and available for a call divided by the number of hours at work, times 100.

³ Handle time is the time (sec) it takes to completely process a call.

⁴ ANOVA for continuous measures and Chi square for categorical measures.