ORIGINAL ARTICLE

A randomised controlled trial evaluating the effects of two workstation interventions on upper body pain and incident musculoskeletal disorders among computer operators

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Background: Call centre work with computers is associated with increased rates of upper body pain and musculoskeletal disorders.

Methods: This one year, randomised 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 call centre operators at a large healthcare company. Participants were randomised 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. Outcome measures were weekly pain severity scores and diagnosis of incident musculoskeletal disorder in the upper extremities or the neck/shoulder region based on physical examination performed by a physician blinded to intervention. Analyses using Cox proportional hazard models and linear regression models adjusted for demographic factors, baseline pain levels, and psychosocial job factors.

Results: Post-intervention, 63 participants were diagnosed with one or more incident musculoskeletal disorders. Hazard rate ratios showed a protective effect of the armboard for neck/shoulder disorders (HR = 0.49, 95% CI 0.24 to 0.97) after adjusting for baseline pain levels and demographic and psychosocial factors. The armboard also significantly reduced neck/shoulder pain ($p = 0.01$) and right upper extremity pain ($p = 0.002$) in comparison to the control group. A return-on-investment model predicted a full return of armboard and installation costs within 10.6 months.

Conclusion: Providing a large forearm support combined with ergonomic training is an effective intervention to prevent upper body musculoskeletal disorders and reduce upper body pain associated with computer work among call centre employees.

Computer based customer service work or call centre work is one of the most rapidly growing occupations in the world.[1] 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 problem associated with this type of work and account for the majority of work related lost time.[1 2]

Sustained pain in the upper extremity and neck regions and specific musculoskeletal disorders, such as wrist tendonitis, epicondylitis, and trapezius muscle strain are higher among computer users. The most consistently observed risk factors are increasing hours of mouse or keyboard use and sustained awkward postures, such as increasing wrist extension and keyboard above elbow height.[3–7] Other important risk factors include being female and work organisational factors (for example, high work load, low job control).[8 9] 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.[10 11]

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,[12 13] increased frequency of work breaks,[14] ergonomics training,[15] and split keyboards.[16] An intervention study of reinforced exercises found no benefit for neck pain.[17]

Using arm supports when working on a computer has also been suggested as a method for preventing upper body pain and musculoskeletal disorders.[18 19] Surprisingly, a prospective study of 632 computer users found that the use of a narrow wrist rest increased the risk of hand/arm symptoms.[5] 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. The findings of two small intervention studies of forearm supports have been mixed.[20 21] These intervention studies were limited by short study duration and lack of physical examinations to confirm musculoskeletal disorders.

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

METHODS

Study design and subjects

This was a one year, randomised intervention trial with four treatment arms. Employees at two customer service centre sites (sites A and B) of a large healthcare company 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 or healthcare specialists. The work involves answering phone calls from patient members in order to address questions, schedule appointments, save messages, provide healthcare 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 randomised to receive one of four interventions; the randomisation was done by means of a computer generated permuted-block sequence and administered by a research associate. The study protocol was approved by the Committees on Human Research of the University of California at San Francisco and Kaiser Permanente Northern California.

Interventions

The four workplace interventions were (1) ergonomics training, (2) trackball and ergonomics training, (3) forearm support board and ergonomics training, and (4) forearm support board, trackball, and ergonomics training (fig 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, USA). The trackball (16.5 cm depth, 8.6 cm width, 4.6 cm height, with a 4 cm diameter ball; Marble Mouse, Logitech, Fremont, CA, USA) was installed next to the keyboard. The interventions were administered by a trained research associate. The ergonomics training involved conventional recommendations,[15] which included maintaining an erect posture while sitting, 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 minimise the reach, adjusting the monitor height so that the centre 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 and were typically equipped with a conventional keyboard, computer mouse, and a telephone headset. Use of wrist rests at this workplace was optional. Subjects who were assigned to use the forearm support board could not continue to use a wrist rest due to the design of the forearm support. Subjects not receiving the forearm support were allowed to continue using a wrist rest if they desired. Chairs were adjustable in height with adjustable height arm rests.

Outcome measures

The baseline questionnaire collected information on demographic factors and possible covariates, such as medical history, exercise, hobbies, and psychosocial stressors.

The weekly survey was completed by participants at the end of each work week for 52 weeks. It assessed work schedule, medication use for pain, and acute injury events 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 seven days using a 0 to 10 point scale (0 = no pain; 10 = unbearable pain).[4]

After the intervention, if subjects recorded on the weekly survey a pain intensity level of more than 5, or they used medications for two days or more for upper extremity or neck pain that was not associated with an acute traumatic event (for example, 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 upper extremity and neck musculoskeletal disorders (for example, de Quervain's tendinitis, carpal tunnel syndrome, epicondylitis, supraspinatus tendonitis, and so on).[4] 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 questionnaire before the intervention.

Approximately one month after the intervention, an unannounced visit was made to the participant at the workplace 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. The effect of the intervention on employee productivity was also assessed using the employer tracked measures of productivity.

Potential covariates

The effects of 28 possible covariates were examined during data analysis. The covariates tested were age, gender,

Figure 1 Examples of two of the workstation interventions: (A) no equipment changes; (B) forearm support board and trackball.

pre-intervention pain score, three psychosocial variables (see below), work site, job title, seniority, body mass index (704.5 × weight in pounds/height in inches), handedness, marital status, education level, ethnicity, pregnancy status, history of oopherectomy, menopausal, pain medication usage, antidepressant medication usage, systemic comorbidity score, regional disorders score, low back pain (history of lower back pain, herniated lumbar disk, or sciatica), lost work days in past year due to upper body musculoskeletal problems, previous surgery on upper extremities, smoking status, exercise at least once per week, hours per week of hand intensive activity outside of work, and hours per week of aerobic activity.

The three psychosocial variables were the composite psychological strain (a z score addition of the scores for job dissatisfaction, antidepressant medication usage, physical-psychosomatic strain, and sleep problems), job strain ratio (psychological job demands/decision latitude), and iso-strain (psychological job demands/(job control plus total support at work)).[22] The measures were ascertained by the Job Content Questionnaire[23] which includes scales on psychological demands (five items), decision latitude (six items for skill discretion and three items for decision authority), supervisor support (four items), and coworker support (four items).

Systemic comorbidity was defined as a positive history of any of the following disorders: diabetes (excluding diabetes solely related to pregnancy), rheumatoid arthritis or lupus erythmatodes, degenerative arthritis (osteoarthritis), low thyroid or overactive thyroid, gout, or fibromyalgia. Regional disorders were 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, or ganglion.

Data analysis

The analysis followed an intention to treat approach. The study was designed to have 80% power to show a 50% difference in disorder risk at the two-sided 5% 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%.[4]

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. If the interaction term between the interventions armboard and trackball was not significant in the model, the model was simplified to evaluate the independent effects of armboard and trackball, and not the effects of each treatment arm. The covariates of age, gender, pre-intervention pain score, composite psychological strain score, and iso-strain were forced into all models to reduce confounding due to these factors. 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 the intervention variable (for example, trackball or armboard) by 0.05 or more it was included in the final, adjusted model.

For the analysis of the effect of intervention 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 scores were replaced by the mean of the scores just before and after the missing data. General linear models were used to calculate the beta coefficient and 95% 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 of the intervention variable 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 four 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. 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 two 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 pre-existing injury, not work related, or due to an acute event. Of the remaining 102, seven did not have a physical examination because they either refused or were on leave. Of the 95 who had an examination, 77 received a specific diagnosis; the other 18 had no physical examination findings. Of the 77 who received a diagnosis, 63 reported no pain >5 in the body region before 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. The frequencies of incident disorders by intervention group are presented in table 2.

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, 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 armboard reducing the hazard rate of incident neck/shoulder disorders to $HR = 0.49$ (95% CI 0.24 to 0.97); that is, the armboard reduced the risk of incident neck-shoulder disorder by approximately half. The hazard rate was recalculated after including the seven participants who did not have a physical examination as incident cases; the effect of the armboard was essentially unchanged ($HR = 0.52$, 95% CI 0.28 to 0.98).

The armboard reduced the hazard rate of left upper extremity disorders to $HR = 0.29$ (95% CI 0.08 to 1.05), although the effect was only marginally significant ($p = 0.06$). The trackball intervention led to a statistically significant reduction of left upper extremity disorders ($HR = 0.19$, 95% CI 0.04 to 0.90) 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 were not significant; therefore, the models were simplified to evaluate just armboard and trackball effects. In the final, adjusted

Table 1 Characteristics of participants by intervention group

	Ergonomic training only	Ergonomic training and 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*
Demographics					
Gender: female	94%	98%	100%	89%	0.08
Age (years)	40.0 (11.6)	40.5 (12.4)	38.9 (12.1)	40.7 (12.2)	0.89
Body mass index	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	24%	31%	20%	20%	0.54
Regional disorders	65%	76%	57%	62%	0.28
Low pack pain	43%	47%	46%	36%	0.71
Lost work days in past year	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
Oopherectomy	9%	9%	2%	8%	0.51
Menopausal	21%	27%	17%	13%	0.38
Pain medication	59%	36%	46%	58%	0.09
Antidepressant medication	9%	9%	17%	4%	0.21
Current smoker	11%	16%	9%	22%	0.26
Weekly exercise	63%	58%	46%	64%	0.25
Hand intensive recreational activity (hours/week)	12.8 (8.94)	16.7 (11.2)	15.2 (16.4)	16.1 (13.5)	0.47
Aerobic activity (hours/week)	0.25 (0.92)	0.22 (1.06)	0.37 (1.34)	0.43 (1.70)	0.85
Pre-intervention upper body pain scores†					
Neck/shoulder pain	2.1 (2.2)	2.9 (2.8)	2.6 (2.8)	2.0 (2.4)	0.28
Right upper extremity pain	2.0 (2.4)	2.1 (2.6)	2.7 (3.1)	2.4 (2.8)	0.52
Left upper extremity pain	1.4 (2.2)	1.6 (2.3)	1.9 (2.8)	1.0 (1.9)	0.28
Neck/shoulder pain >5	7%	22%	13%	11%	0.16
Right upper extremity pain >5	13%	16%	24%	16%	0.53
Left upper extremity pain >5	11%	11%	11%	4%	0.64
Mean post-intervention upper body pain scores					
Neck/shoulder pain	1.8 (1.9)	2.2 (2.2)	1.8 (2.1)	1.1 (1.3)	
Right upper extremity pain	1.9 (2.1)	1.9 (1.8)	1.7 (2.2)	1.3 (1.8)	
Left upper extremity pain	1.4 (1.8)	1.0 (1.3)	1.3 (2.1)	0.8 (1.6)	
Workplace factors					
Worksite A	83%	82%	83%	84%	0.99
Job title: registered nurse	54%	42%	41%	42%	0.54
Seniority (months)	20.6 (13.6)	23.2 (13.3)	21.9 (14.0)	23.9 (12.9)	0.65
Typing speed (words/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/week)	31.5 (5.48)	31.7 (6.81)	32.2 (7.13)	31.9 (5.71)	0.96
Total break (minutes/day)	53.7 (16.3)	41.7 (23.2)	47.7 (23.3)	48.7 (21.0)	0.06
Iso-strain	0.40 (0.10)	0.41 (0.09)	0.41 (0.09)	0.41 (0.10)	0.82
Composite Psychological Strain	−0.06 (0.96)	−0.04 (0.88)	0.19 (1.18)	0.10 (0.96)	0.51

*χ^2 for categorical measures, ANOVA for continuous measures, and Bartlett's test for equal variances for psychosocial variables.
†Pain score scale from 0 = no pain to 10 = unbearable pain.

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 (95% CI −0.85 to −0.10), indicating that the armboard intervention was associated with a mean reduction in pain of 0.48 points on the 0 to 10 point 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.

On a weekly basis, subjects reported the number of days of medication used for upper body pain. These data were analysed 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 only marginally significant ($p = 0.08$). Those receiving the trackball reported no difference in days of medication usage ($p = 0.66$).

At the end of the study or at the time of dropout, subjects 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 nine subjects reported difficulty using the trackball. Subjects were also asked, in an open ended

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*	21/44	15/42	13/44	14/44
Neck/shoulder disorders	19/43	6/35	6/40	8/40
Shoulder tendonitis†	10	3	4	5
Somatic pain syndrome‡	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
de Quervain's tendinitis	3	1	1	1
Extensor tendinitis¶	1	2	3	4
Flexor tendonitis**	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
de Quervain's tendinitis	2	1	0	0
Extensor tendinitis§	3	1	1	1
Flexor tendonitis**	2	0	1	1
Lateral epicondylitis	2	1	2	1
Medial epicondylitis	1	1	1	0

*Denominators exclude participants who reported pain greater than 5 in that body region before the intervention (for example, not eligible to become an incident case). Participants may have more than one diagnosis.
†Includes bicipital, subscapularis and supraspinatus tendonitis.
‡Shoulder pain and trapezius muscle tenderness.
§Neurogenic thoracic outlet syndrome based on a positive Wright's or EAST test. Of the 19 subjects with positive findings, 15 were also diagnosed with shoulder tendonitis or somatic pain syndrome.
¶Includes dorsal compartment 2, 3, 4, and 5 tendonitis.
**Includes digital flexor, flexor carpi radialis, and flexor carpi ulnaris tendonitis.

question, to describe what, if anything, improved their discomfort in the upper body in the past four weeks. The top four 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 (table 5). 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. There were no significant differences between intervention groups for company tracked productivity measures or self-perceived measures.

A return on investment (ROI) calculation for the armboard considered the estimated retail cost of the intervention plus installation ($75) and the savings associated with preventing neck/shoulder disorder cases.[24] The actual annual incidence in 2004 of workers' compensation claims accepted for neck/

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

	Trackball intervention			Armboard intervention		
	Hazard ratio*	95% CI	p Value	Hazard ratio*	95% CI	p Value
Neck/shoulder disorders						
Unadjusted model	0.61	0.31–1.17	0.14	0.53	0.28–1.03	0.06
Adjusted model†	0.62	0.30–1.28	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‡	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§	0.19	0.04–0.90	0.04	0.29	0.08–1.05	0.06

*Cox proportional hazard ratio: those without the intervention are the reference group.
†Variables: trackball, armboard, pre-intervention mean neck/shoulder pain value, age, gender, composite psychological strain, iso-strain, ethnicity, pain medication, current smoker, hand intensive activity outside of work.
‡Variables: trackball, armboard, pre-intervention mean right upper extremity pain value, age, composite psychological strain, iso-strain, seniority, total break minutes/day, educational level, ethnicity, current smoker, hand intensive activity outside of work.
§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)).

	Trackball intervention			Armboard intervention		
	Beta coefficient	95% CI	p Value	Beta coefficient	95% CI	p Value
Neck/shoulder pain						
Unadjusted model	−0.29	−0.74–0.16	0.20	−0.38	−0.83–0.06	0.09
Adjusted model *	−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†	−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‡	−0.35	−0.69–−0.02	0.04	−0.30	−0.63–0.03	0.08

*Variables in model: trackball, armboard, pre-intervention mean neck/shoulders pain value, age, gender, composite psychological strain, iso-strain, current smoker.
†Variables in model: trackball, armboard, pre-intervention mean right upper extremity pain value, age, gender, composite psychological strain, iso-strain, educational level.
‡Variables in model: trackball, armboard, pre-intervention mean left upper extremity pain value, age, gender, composite psychological strain, iso-strain, body mass index.

shoulder disorders among customer service operators at the company studied was 0.0144. The discrepancy between case incidence from the study and accepted workers' compensation claims is not unusual.[25] If the mean medical and salary replacement workers' compensation cost of an employee with a typical non-traumatic neck/shoulder disorder is $11,540,[26] and if the annual incidence of neck/shoulder disorders is reduced by 49% by the intervention, then the ROI is 10.6 months. These calculations do not consider indirect costs, such as temporary replacement employee costs, and the benefits of symptom improvement in the non-incident cases and those who do not file workers' compensation claims or whose claims are not accepted.[27 28]

DISCUSSION

The findings of this randomised 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 to support the forearms 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 standardised effect size was 0.31 (score change/SD of change score = 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 incident musculoskeletal disorders in only the left upper extremity. This finding is unexpected because 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; however, neither trend rose to the level of statistical significance. These findings are difficult to explain. It is possible that use of the trackball allowed participants to perform more mousing with the right hand and, therefore, perform less keyboard work with the left hand. At the conclusion of the study, some subjects reported experiencing more pain when using the trackball and nine 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.[5 7]

Table 5 Subject ratings of interventions and effects of interventions on company measures of productivity*

	Intervention				
	Ergonomic training only (n = 46)	Ergonomic training + trackball (n = 45)	Ergonomic training + armboard (n = 46)	Ergonomic training + trackball + armboard (n = 45)	p Value†
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
Measured productivity changes‡					
Change in % work time§	−2.7 (10.3)	0.04 (8.0)	−2.3 (8.7)	−2.8 (13.7)	0.57
Change in average handle time¶	−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

*Subjects assessed their intervention at end of study or time of dropout.
†ANOVA for continuous measures and χ^2 for categorical measures.
‡Change in productivity is the difference between employer measured mean productivity during the year post-intervention and the year before the intervention. Only data from 162 subjects were available for these calculations.
§% work time is the number of hours logged on and available for a call divided by the number of hours at work × 100.
¶Handle time is the time (seconds) it takes to completely process a call.

The armboard used in our study provided a surface with a 30.5 cm depth of support surface, leading to less localised contact stress in comparison to a narrow depth wrist rest. Furthermore, the support from the armboard is provided at the centre of the forearms and not at the wrist, where some tissues (for example, flexor tendons, bones, nerves) lie relatively close to the skin surface. Another 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.[5] Finally, the support may also reduce shoulder muscle load.[29 30]

Several limitations should be considered when interpreting the study findings. Firstly, the unavailability of seven participants for a physical examination may have biased the findings. The hazard model for incident neck/shoulder disorders was repeated including these seven participants as incident cases and the conclusions regarding the armboard were unchanged. Secondly, randomisation 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, if a confounding effect was present, controlled for it in the final analyses. Another strength of this study is that it measured and took into account the role of psychosocial job factors which have previously been shown to potentially confound the relation between the physical work environment and musculoskeletal disorders.[9 31–33]

The 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, and comorbid conditions. Our results indicate that employees who experience upper body pain when performing computer based customer service work may benefit from the use of a wide forearm support. However, they should be notified that a beneficial effect, if it occurs, 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 if the pain is unchanged or increases, a different pointing device should be tried (for example, different mouse, touchpad, or digitising pen). Employers should consider offering forearm supports to employees who perform computer based customer service work in order to reduce the risk of developing musculoskeletal disorders. Indeed, the ROI calculations 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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