SPINE Volume 28, Number 24, pp 2706–2711
©2003, Lippincott Williams & Wilkins, Inc.

Effect of Office Ergonomics Intervention on Reducing Musculoskeletal Symptoms

Benjamin C. Amick III, PhD,*†‡ Michelle M. Robertson, PhD,CPE,§ Kelly DeRango, PhD,¶
Lianna Bazzani, MPH,** Anne Moore, PhD,†† Ted Rooney, MPH,** and Ron Harrist, PhD*

Study Design. Office workers invited and agreeing to participate were assigned to one of three study groups: a group receiving a highly adjustable chair with office ergonomics training, a training-only group, and a control group receiving the training at the end of the study.

Objective. To examine the effect of office ergonomics intervention in reducing musculoskeletal symptom growth over the workday and, secondarily, pain levels throughout the day.

Materials and Methods. Data collection occurred 2 months and 1 month before the intervention and 2, 6, and 12 months postintervention. During each round, a short daily symptom survey was completed at the beginning, middle, and end of the workday for 5 days during a workweek to measure total bodily pain growth over the workday. Multilevel statistical models were used to test hypotheses.

Results. The chair-with-training intervention lowered symptom growth over the workday ($P = 0.012$) after 12 months of follow-up. No evidence suggested that training alone lowered symptom growth over the workday ($P = 0.461$); however, average pain levels in both intervention groups were reduced over the workday.

Conclusion. Workers who received a highly adjustable chair and office ergonomics training had reduced symptom growth over the workday. The lack of a training-only group effect supports implementing training in conjunction with highly adjustable office furniture and equipment to reduce symptom growth. The ability to reduce symptom growth has implications for understanding how to prevent musculoskeletal injuries in knowledge workers.
[Key words: office ergonomics intervention, musculoskeletal symptom growth] **Spine 2003;28:2706–2711**

Annually, approximately 1 million people take time away from work because of repetitive motion or overexertion to treat or recover from musculoskeletal pain or functional loss.[8] With the growth of the global knowledge workforce and therefore the number of office workers at risk for musculoskeletal injuries, surprisingly little evidence exists as to whether office ergonomic interventions significantly reduce musculoskeletal injury incidence.[14,18,28] The United States Census Bureau estimates that in 1997 approximately 50% of all employed adults in the United States used a computer on the job.[26] Training and alternative input device interventions have produced mixed results.[1,7,16,21,25,27] Interventions that change comprehensive features of the office environment often do not clearly identify which environmental changes contributed to reduced symptoms or injuries.[1,5,19,23] While numerous laboratory studies have demonstrated the impact of chair features such as seat pan depth, lumbar and full back supports, adjustable seat height, and lower arm support on musculoskeletal symptoms of the back and upper and lower extremities,[4] no field interventions have focused on the role of office chairs in reducing musculoskeletal injuries.[18] A study was designed to assess how well a highly adjustable chair and office ergonomics training could affect ergonomic knowledge, postural behavior, health and productivity. This article presents health outcomes associated with the intervention.

Materials and Methods

Employees from a state department of revenue services were invited to participate in the study. These workers had access to the Internet and worked in sedentary computer-intensive jobs (requiring at least 4 hours per day working at an office computer and at least 6 hours per day sitting in an office chair). Individuals agreeing to participate were assigned to one of three study groups: a group receiving a highly adjustable chair with office ergonomics training, a training-only group and a control group receiving training at the study's end. Group assignment was intended to minimize the potential for the control group to attain ergonomic knowledge from the other two groups. Thus, group assignment was not random, but based on geographic separation by different supervisory units, floors, and buildings. The Liberty Mutual Research Institute for Safety Institutional Review Committee for Human Subjects approved the study protocol.

The study design was guided by a specific theory of change (Figure 1). It was expected training would increase office ergonomics knowledge and motivate workers to reorganize their workspace, which would then influence working postures and behaviors such as rest break patterns, choices about workstation layout, and the use of adjustability features in the office

---

*The University of Texas School of Public Health, Houston, TX; †The Institute for Work and Health, Toronto, Canada; ‡The Texas Program for Society and Health, James A. Baker III Institute for Public Policy, Rice University, Houston, TX; §Liberty Mutual Research Institute for Safety, Hopkinton, MA; ¶The Upjohn Research Institute, Kalamazoo, MI; **Health and Work Outcomes, Brunswick, ME; and ††York University, Toronto, Canada

The manuscript submitted does not contain information about medical device(s)/drug(s).

Corporate/Industry funds were received in support of this work. One or more of the author(s) has/have received or will receive benefits for personal or professional use from a commercial party related directly or indirectly to the subject of this manuscript: *e.g.*, honoraria, gifts, consultancies.

Acknowledgment date: February 28, 2003. Acceptance date: June 5, 2003.

This research was funded by grants from Steelcase, Inc. to the University of Texas, The Upjohn Research Institute, York University and Health and Work Outcomes and through the support of the Liberty Mutual Research Institute for Safety. Noe Palacios and Paul Allie of Steelcase, Inc. contributed to data collection. Arden Brink of Health and Work Outcomes designed the web-based data collection system.

Address correspondence and reprint requests to Benjamin C. Amick III, PhD, The University of Texas Health Science Center–Houston, School of Public Health, 1200 Herman Pressler, Houston, TX 77030. E-mail: bamick@sph.uth.tmc.edu

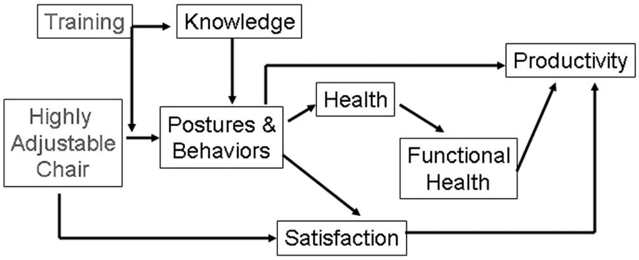

Figure 1. Theory of Change.

workstation. The training, coupled with the chair, was expected to improve postures and behaviors that reduce musculoskeletal loads and muscle fatigue and thus decrease musculoskeletal symptoms (improve health). Decreases in symptoms would result in improved job functioning and ultimately would contribute to improved productivity. The primary health hypotheses were that workers in the chair-with-training group would experience reduced musculoskeletal symptom growth over the workday compared with those in the training-only and control groups and workers in the training-only group would experience reduced musculoskeletal symptom growth over the workday compared with workers in the control group. Secondary health hypotheses were that musculoskeletal symptom levels would be lower in the chair-with-training group compared with the training-only and control groups and the training-only group would have lower average symptom levels compared with the control group.

The intervention consists of a highly adjustable chair and a one-time office ergonomic training workshop with a series of educational follow-ups conducted concurrently with the chair distribution.

The chair includes adjustable armrests in height, width, and pivot that should allow the user to support arms and reduce shoulder static muscle load, providing low-level type I muscle fibers an opportunity to rest. Chair height and armrest adjustment relative to keyboard and mouse location may help the worker achieve a neutral posture, reducing forearm extensor static muscle loading required to maintain an extended wrist against gravity and the passive and active forces of the forearm flexor musculature. A flexible back support conforms to the shape and movement of the user's back, which should allow for a range of trunk postures while maintaining the relationship of the hands to the keyboard. The chair provides adjustable firmness support in the low back combined with adjustable seat depth. The chair's gliding mechanism allows the seat to glide forward as the user reclines; this mechanism as well as the back firmness and seat depth adjustments support reclining action and should improve matching of the chair's reclining support with the upper body gravitational forces, so the worker can recline without requiring active trunk extension or feeling unstable. This is reflected in more reclining postures, more varied postures, and less static load on erector spinae, so the user can easily adjust body postures throughout the workday without causing forearm or visual range shifts potentially allowing for trunk loading variation.[9] The chair's high adjustability supports large and small frame bodies and allows for an open hip angle and comfortable floor contact for the feet.

Providing adjustable chairs alone may not be sufficient to result in an effective ergonomic intervention. Ergonomic training is necessary for workers to understand why they should adjust their chair and how to make the correct adjustments to achieve proper body postures. Furthermore, for the chair to have maximum ergonomic impact, it must be used in relation to other workstation features. Thus, additional knowledge about the entire office workstation layout was provided by a one-time, 90-minute workshop. The training goals were: improve worker understanding of office ergonomic principles, create the ability to perform ergonomic self-evaluations, and promote the adjustment and rearrangement of the office workstation layout. To achieve these goals, the following instructional objectives were defined: recognizing work-related musculoskeletal disorders and risk factors, understanding the importance of varying work postures, knowing how to rearrange the workstation to maximize the "comfort zone," recognizing and understanding visual issues, reducing visual discomfort, understanding rest breaks are necessary for healthy computing, knowing how to change work–rest patterns, being aware of the company's existing health and ergonomic programs, and knowing how to obtain ergonomic accessories through the company's programs. The workshop includes an instructional video, handouts, a PowerPoint presentation, and practice sessions including group exercises and problem solving.[22] Finally, a series of tailored educational e-mail messages were delivered postintervention at months 1 (using information from a preoperative and posttraining knowledge test), 3, and 5 (using information from the observational assessments). Two trainers conducted all the workshops and were trained by the training designer.

Data collection occurred 2 months and 1 month before the intervention and 2, 6, and 12 months postintervention. During each round, a short daily symptom survey (DSS) was completed at the beginning, middle, and end of the workday for 5 days during a workweek. Respondents rated their level of pain or discomfort on a scale from 0 (none) to 10 (extremely severe) for each of nine body areas (neck, shoulders, upper back, elbows, lower arms/wrists/hands, lower back, buttocks/thighs, knees, and lower legs/ankles/feet). The primary outcome variable was the sum of the ratings which could range from 0 (no pain in any body area) to 90 (extremely severe pain in all body areas). Pain scores were not calculated if any of the body area scores were missing. Participants not completing at least 12 symptom surveys during the first week of survey administration were asked to try completing at least that number again the following week. A longer work environment and health questionnaire (WEH) was completed just once subsequent to the week of DSS completion. Thirty different covariates and potential confounders were measured in this questionnaire (a complete list is available from the first author).

Hypothesis testing was performed by bringing into a model with covariates eleven additional terms: two dummy variables for two intervention groups (control group as referent), a variable indicating time of day (0 = beginning, 1 = middle, 2 = end), a variable indicating study phase (0 = preintervention, 1 = postintervention), and the five two-way interaction terms and two three-way interaction terms of these variables. The three-way interaction term including the chair group indicated whether symptom growth was reduced for the chair-with-training group compared with the control group. The three-way interaction involving the training-only group indicated whether symptom growth was reduced for that group relative to the control group. The difference between the chair-with-training group and the training-only group was tested by taking the difference between the two three-way interaction effects. The general model is:

Table 1. Number of Participants and Completed Symptom Surveys by Group and Measurement Period

	Measurement Period*				
Group	1	2	3	4	5
Chair & training	87 (1,258)	85 (1,247)	82 (1,160)	75 (974)	80 (1,117)
Training only	52 (728)	51 (721)	51 (702)	49 (587)	47 (641)
Control	53 (756)	53 (738)	45 (598)	46 (567)	41 (561)

* Periods 1 and 2 are pre-intervention and 3–5 are post-intervention.

$$\begin{aligned}\text{Pain}_{ij} = {} & \beta_{0ij}\text{constant} + \beta_{1j}\text{covariates} + \beta_{2j}\text{chair} \\ & + \beta_{3j}\text{training} + \beta_{4ij}\text{time of day} + \beta_{5ij}\text{intervention} \\ & + \beta_{6ij}\text{chair*time of day} + \beta_{7ij}\text{training*time of day} \\ & + \beta_{8ij}\text{intervention*time of day} + \beta_{9ij}\text{chair*intervention} \\ & + \beta_{10ij}\text{training*intervention} \\ & + \beta_{11ij}\text{chair*intervention*time of day} \\ & + \beta_{12ij}\text{training*intervention*time of day}\end{aligned}$$

where i indicates a level 1 (within-person) variable, j indicates a level 2 (between-person) variable, the constant term is equal to 1, and β_{1j}*covariates* refers to a vector of covariates.

Tenability of the model's distributional assumptions was examined through diagnostic analysis of both level one and two residuals. Level 1 residuals appeared normally distributed, but level 2 residuals were positively skewed for persons reporting greater pain levels. After fitting the model by a maximum likelihood technique, a nonparametric bootstrapping method of estimation was applied.[20] After performing 250 bootstrap sets of 350 replications each, no meaningful differences were observed between the coefficients obtained by the two estimation methods. Thus, the reported model coefficients were free of any significant bias that might have been attributed to the skewed nature of the level 2 residuals.

Covariates were considered for inclusion if they: demonstrated an association with the outcome variable, demonstrated no great correlation with other covariates already selected for inclusion, and were not evenly distributed between the study groups, either preintervention or postintervention. The first two conditions were assessed by identifying significant associations (Pearson's correlation; $P \leq 0.05$) with the symptom score and absence of a strong correlation ($r > 0.65$) with a second covariate. In cases with high intercorrelation, the covariate with the higher correlation to the outcome variable was chosen. Heterogeneity between study groups was assessed for each time-varying continuous variable using a two-level variance components model that predicted the covariate with study groups, intervention, and their interaction. A joint χ-squared statistic was used to determine if there was a significant difference between the study groups preintervention or postintervention ($P = 0.10$ for each test). Study group heterogeneity for time-invariant continuous variables was assessed by one-way analysis of variance ($P = 0.10$). Heterogeneity between study groups for dichotomous variables was determined by cross-sectional time series logistic regression modeling ($P = 0.10$, with separate tests run for preintervention and postintervention data). Finally, after placing all covariates meeting the three conditions ($n = 8$) into the multilevel model described, a stepwise backwards selection procedure was followed and those not significantly decreasing the model log likelihood ($P > 0.20$) were removed (education, gender, a count of the number of days microbreaks had been skipped in the past week, and an administrative measure of disability status were removed).

To test the secondary hypotheses, differences in average pain levels were considered separately for the beginning, middle, and the end of the day. A "difference in differences" approach was used to compare the distance between predicted levels for the intervention and control groups both preintervention and postintervention. The differences of interest were calculated as linear combinations of the standardized estimated coefficients of Equation 1. Because these linear combinations of standardized coefficients are approximately normally distributed, Wald tests were used to assess statistical significance.

All multilevel analyses were conducted using MLwiN[17]; all other analyses were done using Stata.[24]

■ Results

A workforce of 316 persons was invited to participate and 219 completed electronic informed consent (69.3% participation rate). After excluding 11 part-time employees and 15 with incomplete DSS data, 192 persons at baseline provided enough data for use in analysis (87 in the chair-with-training, 52 in the training-only, and 53 in the control group). At 12 months postintervention, 168 persons completed the questionnaire (88% retention; Table 1). Participants were predominantly white (92%), the average age was 47.5 years and the average time

Table 2. Distribution of Covariates By Pre- and Post-Intervention and Group

		Intervention		Group Intervention		
	Overall	Pre	Post	Chair/ Training	Training	Control
Time spent in office chair	3.36	3.39	3.35	3.39	3.26	3.42
Repetitive hand/wrist activity	3.69	3.73	3.66	3.82	3.26	3.92
General (poor) health	2.47	2.55	2.44	2.37	2.48	2.62
Job level	3.26	3.24	3.27	3.34	3.49	2.89

Table 3. Multi-Level Models Including and Excluding the Main Effect Parameters

Variable	Model 1 (Std. Error)	Model 2 (Std. Error)
Time spent in office chair	0.150 (0.11)^{ns}	0.15 (0.11)^{ns}
Repetitive hand/wrist activity	0.38 (0.07)*	0.38 (0.07)*
General (poor) health	0.99 (0.14)*	0.99 (0.14)*
Job level	−1.12 (0.25)*	−1.22 (0.25)*
Chair-and-training group	0.45 (1.29)^{ns}	−0.04 (1.30)^{ns}
Training-only group	0.25 (1.43)^{ns}	0.40 (1.44)^{ns}
Intervention phase	0.85 (0.25)*	0.56 (0.32)^{ns}
Chair*intervention	−2.27 (0.27)*	−1.54 (0.40)*
Training*intervention	−1.314 (0.30)*	−1.56 (0.45)*
Time of day	3.35 (0.15)*	3.21 (0.20)*
Time of day*intervention	−1.19 (0.13)*	−0.88 (0.25)*
Chair*time of day	−1.58 (0.16)*	−1.13 (0.24)*
Training*time of day	−1.06 (0.18)*	−1.22 (0.27)*
Chair*intervention*time of day	–	−0.78 (0.31)*
Training* intervention*time of day	–	0.26 (0.35)^{ns}
Intercept term	4.91 (1.37)	5.05 (1.38)
Level 1 variance	27.93 (0.39)	27.89 (0.39)
Level 2 variance	51.56 (5.30)	51.56 (5.30)
−2 ln(likelihood)	66850.48	66837.02
Difference in −2 ln(likelihoods) = 13.46*		

* = $p < 0.05$

ns = $p > 0.05$

The multi-level regression equation represented in Model 1 does not include the variables necessary to test the primary hypothesis. The Chair-Intervention-Time of Day variable in Model 2 and the Training-Intervention-Time of Day variable allow the testing of the primary hypothesis related to the Chair-with-Training group and the Training-Only group respectively. Additionally, the decrease in log likelihood between Model 1 and Model 2 tests the significance of adding the primary hypothesis variables to the multi-level regression model.

spent in an office chair and computing was 5 to 6 hours per day.

Of the 30 potential confounders analyzed, Table 2 shows the four that met all criteria for final inclusion in the model: time spent in office chair during a typical day in the past week (0 = less than an hour and 5 = nine or more hours), repetitiveness of hand/wrist activity (0 = no repetitiveness and 6 = highly repetitive), general health (1 = excellent and 5 = poor), and job level (1 = low or entry level and 5 = high or senior level). Data on job level were obtained from company administrative data.

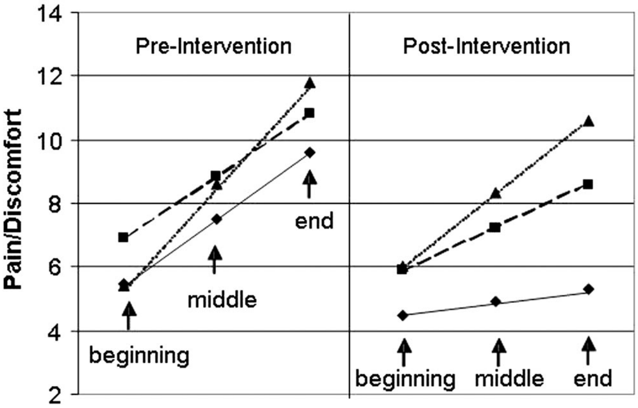

Figure 2. Bodily pain at the beginning, middle, and end of the day before and after treatment. Predicted model includes study population mean levels for time in office chair, repetitive hand/wrist activity, general health, and job level as indicated in Table 2. ◆, chair and training; ■ , training only; ▲, control.

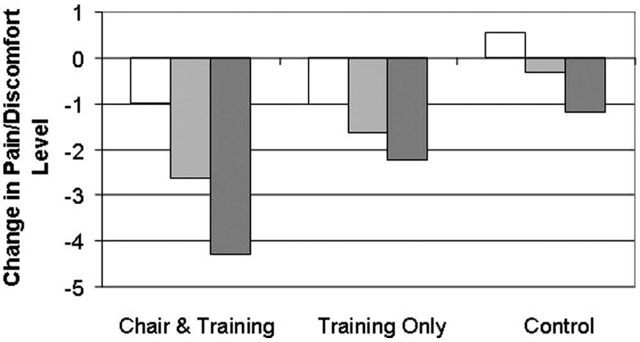

Figure 3. Changes in bodily pain levels after treatment. Changes in pain levels are calculated from the predicted model values at the beginning (☐), middle (▨), and end (▦) of the day.

Table 3 shows the multilevel model results including the regression coefficients, betas (β), and their standard errors. Model 2 shows the chair-with-training group experienced a statistically significant reduction in symptoms postintervention compared with the control group (βchair*intervention* time of day = 0.78; z = 2.502; $P = 0.461$). However, the training only group did not experience a similar reduction (βtraining* intervention* time of day = 0.26; z = 0.737; $P = 0.461$) compared with the control group. The differences in log likelihoods of models 1 and 2 (13.46; $P = 0.001$) indicate the hypothesized intervention effects significantly improve model fit. The predicted intervention results based on estimates in Table 3 are depicted in Figure 2. The chair-with-training group experiences a reduction in growth of symptoms over the day compared with either the control or the training only groups. The difference between the chair-with-training and training-only groups was statistically significant (function result = 1.044; $\chi^2_{(1)} = 11.508$; $P < 0.001$). Separate analyses of the 3-, 6-, and 12-month postintervention data indicate the coefficient for the three-way interaction term "chair* intervention* time of day" became larger and increasingly significant with time. Finally, the body area that experienced the greatest reduction in symptom growth was explored. The neck and shoulder experienced the largest reduction, followed by the upper back and lower back (data not shown). However, the sample sizes are not large enough to conduct anatomic site-specific analyses.

As a secondary hypothesis, postintervention differences in the average pain levels between the chair-with-training, training-only, and control groups were examined. Using the predictive model to obtain estimated pain levels at each time of day, the beginning of the day decrease in pain from preintervention to postintervention averaged 0.98 points for the chair-with-training group, 1.0 point for the training-only group, and −0.56 points for the control group (indicating a slight pain increase). Further, the end of the day decrease in pain from preintervention to postintervention averaged 4.3, 2.2, and 1.2

points for the chair-with-training, training-only, and control groups, respectively. These changes in pain level are depicted in Figure 3. Both the beginning ($\beta \mathit{chair*intervention} = -1.539$, $\chi^2_{(1)} = 15.207$, $P < 0.001$) and end of day ($\beta \mathit{chair*intervention} + 2\beta \mathit{chair*intervention*time\ of\ day} = -3.106$, $\chi^2_{(1)} = 52.363$, $P < 0.001$) differences are significant for the chair-with-training compared to the control group. The training-only group difference is significant at the beginning ($\beta \mathit{training*intervention} = -1.560$, $\chi^2_{(1)} = 12.199$, $P < 0.001$), and at the end of the day as well ($\beta \mathit{training*intervention} + 2\beta \mathit{training*intervention*time\ of\ day} = -1.038$, $\chi^2_{(1)} = 4.600$, $P = 0.032$).

■ Discussion

In this office ergonomics intervention study, workers who received a chair and office ergonomics training had reduced growth of pain and discomfort over the work day compared with workers who received only training, or compared with a control group. No significant reduction in symptom growth over the workday for the training-only group compared with the control group was observed. In economic analyses of the intervention published elsewhere,[11] the chair-with-training intervention is associated with productivity improvements of $354 per worker per day and has a benefit-to-cost ratio of 22:1. The analyses reported here coupled with the economic analysis suggests a highly adjustable chair and office ergonomics training reduces musculoskeletal symptom growth and improves productivity.

One of the challenges of conducting well-designed office ergonomic intervention studies is that interventions often involve multiple workstation components augmented with training.[2,5,14] Business's goal is to develop the best solution for each worker so multicomponent interventions are desired. This approach makes it challenging to disentangle which component contributed to the reported effects. A second challenge is getting employers to support well-designed long-term field experiments. For example, Ghahramani conducted a post-only analysis of managers receiving new office chairs compared with managers who did not.[13] While the study demonstrated a short-term effect 2 weeks postintervention, the threats to validity of nonrandomized posttreatment-only designs are substantial enough to limit the finding's usefulness.[10] The present study is the first to demonstrate in a field setting the impacts of a highly adjustable chair and ergonomic training intervention on musculoskeletal symptom growth.

A large and growing body of evidence supports the use of symptom severity and functional status measures as primary outcomes in studies of musculoskeletal conditions.[15] For example, an international working group of low back pain investigators arrived at this conclusion for studies of back disorders.[12] The drawback of symptom measures is that they are clinically nonspecific. That is, a wide range of conditions can give rise to pain and to functional limitation. A physical examination might provide additional specificity, especially when coupled with an anatomic-specific pain diagram like the one used in this study. However, clinical procedures such as radiography can be nonspecific and insensitive.[6] In addition, clinical exams in broad-based work-site interventions not targeting injured workers are most likely to encounter only early manifestations of musculoskeletal disorders. In this early setting, the physical examination is often negative and would fail to resolve the clinical syndromes unambiguously. For these reasons a symptom pain scale was chosen.

The results here suggest that unless workers are provided with the appropriate tools to easily implement knowledge obtained through training, the full benefits of training will not be achieved. However, from a cognitive and behavioral perspective, training worked. Pretraining and posttraining knowledge tests indicate ergonomic knowledge was increased as was intent to change office workstation set-ups.[22] Postural risks were lower postintervention in both the chair-with-training and training-only groups, and arrangement of workstation features was improved.[22] Furthermore, the training-only group had lower average pain levels compared to the control group at the beginning and the end of the day.

The observed chair group effect might be attributed to worker perceptions of the chair's value ("Hawthorne effect"). To address this, it must be demonstrated that the workers in the group receiving the chair have improved postures and decreased static muscle loads relative to the group receiving the training only. Currently, muscle loading changes are being studied at a second employer site.

There are several study limitations. Lack of randomization could result in unmeasured group differences that might explain the symptom growth differences. However, a range of covariates was measured and only a few were statistically different between groups. Furthermore, no group differences were found in supervisory unit level policies and practices that could support or inhibit ergonomic behaviors.[3] The decision not to randomize was intended to reduce the risk of contamination between groups. However, future work would benefit from a randomized design. Another design issue is the absence of a chair-only group. While from a research design perspective this additional group creates the opportunity to examine the unique contribution of the chair, it was considered inappropriate to provide workers with a highly adjustable chair and not teach them why and how to adjust it and also provide some basic office ergonomics training in how to use the chair to maximize the use of their workstations.

Nonparticipation or loss to follow-up could affect the ability to make unbiased conclusions.[3] Those lost to follow-up after intervention tended to have experienced more pain than their peers. For example, the eight persons who only submitted preintervention questionnaires had average beginning, middle, and end of day pain scores of 10.9, 16.0, and 16.2 relative to their peers' preintervention scores of 5.6, 8.6, and 11. Within the control group, the 14 people who did not participate in the final round of surveys had average preintervention scores of 8.3, 13.0, and 13.8 compared with their peers' average preintervention scores of 5.9, 10.2, and 13.0. The greater loss to follow-up among the controls would likely result in an underestimation of the intervention's effects.

In summary, this research contributes to a small literature suggesting office interventions can reduce symptoms, injuries, and sick days. The office ergonomic intervention of a highly adjustable chair coupled with ergonomic training should increase ergonomic knowledge and skills, reduce musculoskeletal loads and strains, and allow users to maximize health and productivity. This research has immediate implications for office employers and employees. Future research should try to replicate these results in randomized trials.

■ Key Points

- With an increasing population of knowledge-workers, there is a need to design and evaluate office ergonomic interventions.
- A highly adjustable chair coupled with office ergonomics training reduced musculoskeletal symptom growth over the workday.
- Office ergonomic interventions that rely exclusively on training may not affect musculoskeletal symptom growth, especially when office ergonomic equipment is limited in adjustability. However, training did result in modest reductions in average pain levels.

References

1. Aaras A, Ro O, Thoresen M. Can a more neutral position of the forearm when operating a computer mouse reduce the pain level for visual display unit operators? A prospective epidemiological intervention study. International *J Hum Computer Interaction* 1999;11:79–94.
2. Aaras A, Horgen G, Bjorset H, et al. Musculoskeletal, visual and psychosocial stress in VDU operators before and after multidisciplinary ergonomic interventions. A 6 years prospective study—Part II. *Appl Ergon* 2001;32: 559–557.
3. Amick BC III, Robertson MM, DeRango K, et al. *An overview of a longitudinal quasi-experimental field study to evaluate the effect of an office ergonomics training and a new chair on quality of work life, health and productivity*. Proceedings of the 6th International Scientific Conference on Work with Display Units. Berchtesgaden, Germany: ERGONOMIC Institut für Arbeit-und Sozialforschung Forschungsgesellschaft mbH; 2002:365–367.
4. ANSI/HFES Standard100–1988. *Draft Revised Standard for Human Factors Engineering of Computer Workstations*. Santa Monica, CA: Human Factors and Ergonomics Society; March 31, 2002.
5. Bayeh AD, Smith MJ. Effect of physical ergonomics on VDT workers' health: A longitudinal intervention field study in a service organization. *Int J Hum Computer Interaction* 1999;11(2):109–135.
6. Boden SD, Davis, DO, Dina TS, et al. Abnormal magnetic-resonance scans of the lumbar spine in asymptomatic subjects: A prospective investigation. *J Bone Joint Surg Am* 2000;72(3):403–408.
7. Brisson C, Montreuil S, Punnett L. Effects of an ergonomic training program on workers with video display units. *Scand J Work Environ Health* 1999; 25(3):255–263.
8. Injuries, Illnesses, Fatalities [US Dept. of Labor, Bureau of Labor Statistics website]. Washington, D.C. US Department of Labor Bureau of Labor Statistics, 1999. Available at: http://www.bls.gov/iif/home.htm. Accessed February 14, 2003.
9. Bush T, Hubbard R. *An Evaluation of Postural Motions, Chair Motions and Contact in Four Office Seats*. Proceedings of the Human Factors and Ergonomics Society 43rd Annual Meeting. Houston, TX; 1999.
10. Shadish WR, Cook TD, Campbell DT. *Experimental and Quasi-Experimental Designs for Generalized Causal Inference*. Boston: Houghton Mifflin Compan; 2002.
11. DeRango K, Amick BC III, Robertson MM, et al. The productivity consequences of office ergonomics training and an ergonomically designed chair. Proceedings of the 6th International Scientific Conference on Work with Display Units. Berchtesgaden, Germany: ERGONOMIC Institut für Arbeit-und Sozialforschung Forschungsgesellschaft mbH; 2002;368–370.
12. Deyo RA, Battie M, Beurskens AJ, et al. Outcome measures for low back pain research. A proposal for standardized use. *Spine* 1998;23(18):2003–2013.
13. Ghahramani, B. Significant improvements from providing ergonomic furniture to AT&T corporate managers. In: Kumar S, ed. *Advances in Industrial Ergonomics and Safety IV*. London: Taylor and Francis; 1992.
14. Karsh B, Moro FBP, Smith MJ. The efficacy of workplace ergonomic interventions to control musculoskeletal disorders: a critical examination of the peer-reviewed literature. *Theoret Issues Ergonomic Sci* 2001;2(1):23–96.
15. Katz JN, Stock SR, Evanoff BA, et al. Classification criteria and severity assessment in work-associated upper extremity disorders: methods matter. *Am J Ind Med* 2000;38(4):369–372.
16. Kukkonen R, Luopajarvi T, Riihimaki V. Prevention of fatigue amongst data entry operators. In: Kvalseth TO, ed. *Ergonomics of Workstation Design*. London: Butterworth & Co; 1993.
17. MLwiN [software]. Version 1.10. London: Multilevel Models Project Institute of Education, 2001.
18. National Research Council, Institute of Medicine. *Musculoskeletal Disorders and the Workplace: Low Back and Upper Extremities*. Washington DC: National Academy Press; 2001.
19. Nelson N, Silverstein BA. Workplace changes associated with a Reduction in Musculoskeletal Symptoms in Office Workers. *J Hum Factors Ergonomics Soc* 1998;40(2):337–350.
20. Rasbash J, Browne W, Goldstein H, et al. *A User's Guide to MLwiN*. London: University of London; 2000.
21. Rempel D, Serina E, Kleinenberg BJ, et al. The effect of keyboard keyswitch make force on applied force and finger flexor activity. *Ergonomics* 1997; 40(8):800–808.
22. Robertson MM, Amick BC III, DeRango K, et al. The impact of an office ergonomics training on worker knowledge, behavior and musculoskeletal risk. Proceedings of the 6th International Scientific Conference on Work with Display Units. Berchtesgaden, Germany: ERGONOMIC Institut für Arbeit-und Sozialforschung Forschungsgesellschaft mbH; 2002;376–378.
23. Rudakewych M, Valent-Weitz L, Hedge A. *Effects of an ergonomic intervention on musculoskeletal discomfort among office workers*. Proceedings of the 45th Human Factors and Ergonomics Society Annual Meeting. Santa Monica, CA; 2001;1:791–795.
24. Stata [software]. Release 7.0. College Station, TX: Stata Corporation; 2001.
25. Tittiranonda PS, Burastero S, Rempel D. Risk factors for musculoskeletal disorders among computer users. *Occupational Med STAR* 1999;14:17–38.
26. US Census Bureau. Computer use in the United States. *Curr Population Rep* 1999:20–52.
27. Verbeek J. The use of adjustable furniture: Evaluation of an instruction program for office workers. *Appl Ergon* 1991;22(3):179–184.
28. Westgaard, RH, Winkel, J. Ergonomic intervention research for improved musculoskeletal health: A critical review. *Int J Industrial Ergonomics* 1997; 20:463–469.