Health and Performance Consequences of Office Ergonomic Interventions Among Computer Workers

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Abstract. An investigation of the effects of office ergonomics interventions on musculoskeletal health and group performance among computer knowledge workers was conducted. A flexible workspace and office ergonomics training program were designed and created. It was hypothesized that the training and workplace intervention would allow the worker to more effectively use their workspace through increased office ergonomics knowledge and skills. Following the intervention, there was a significant decrease in self-reported musculoskeletal disorders for the experimental group who had a workplace change and received ergonomic training relative to a workplace change-only group and a control group. Business process efficiency analyses revealed that both the workspace and training interventions significantly contributed to reductions in the time required to complete the business processes that were tracked.

Keywords: office ergonomics intervention, performance, musculoskeletal discomfort.

1 Introduction

Organizations in today's world are seeking ways to effectively use office workspaces to enhance individual and group performance and to reduce psychological and physical stress among computer workers, specifically knowledge workers [1,2,3]. As the dependence on computer use increases, concerns have been raised over the potential for an escalation in the incidence of computer-related Work-related Musculoskeletal Discomfort WMSDs. Computer work has been identified as a risk factor for WMSDs in the working age population [4,5]. Several intervention strategies, such as workplace design changes, ergonomics training programs, work reorganization, adoption of new technologies, and workplace change communication programs [3,2,6] may be employed to create workspaces for office knowledge workers. Each of these strategies may have varying effects on employee perceptions of job and workplace satisfaction, stress, performance, and well-being. Field and laboratory research suggests that ergonomics training, workspace and workstation design can prevent or reduce musculoskeletal injuries in an office environment [7,8,9,10,11,12,13,14]. Systemically designed office ergonomics interventions

M.J. Dainoff (Ed.): Ergonomics and Health Aspects, HCII 2007, LNCS 4566, pp. 135–143, 2007.

contribute not only to enhanced worker health and well-being, but also to organizational effectiveness. When a successful office ergonomics intervention program is implemented, one of the many results is an increased ability for the worker to change his/her work environment, leading to enhanced individual effectiveness and the prevention of WMSDs and injuries [8,12,3].

Several studies have demonstrated that giving people more control over decisions affecting their work can enhance physical health and performance [15]. This concept of environmental control has been expanded to include enhancing workers' control over their physical work environment [11,16].

The study aim was to investigate the effects of an office ergonomics workplace and training intervention on self-reported musculoskeletal discomfort, and group performance and business process efficiency. It was hypothesized that the training and workplace design together would allow the worker to effectively use their workplace through increased office ergonomics knowledge and skills. Moreover, these intervention effects would be expected to translate into behavioral changes, for example: re-arranging workspaces, adjusting furniture and accessories, changing computing work habits, thus leading to a reduction in musculoskeletal discomfort and an increase in environmental satisfaction. Three hypotheses were tested in this study: Hypothesis 1: Self-reported musculoskeletal discomfort will be reduced as a function of increased workspace flexibility; Hypothesis 2: The greatest reduction in self-reported musculoskeletal discomfort will occur as a result of both workspace flexibility and ergonomic training. Hypothesis 3: Group performance and business process efficiency will be enhanced as a function of increased workspace flexibility and training.

2 Methods

2.1 Setting and Participants

The new flexible office work environment was created for approximately 750 employees within a large corporate office building (housing about 1750 employees), for a large U.S. management-consulting firm. Approximately 500 employees engaged in identical work, but remaining in traditional office workspaces on other floors of the building, served as the control group. These employees were classified as knowledge workers who used a computer 4+ hours a day. 1135 participants took part in the study. The sample demographics regarding job level consisted of: Partner, (4%); Associate Partner (4%); Manager (29%); Consultant/Specialist (37%); Analyst (24%); and Assistant (1%).

2.2 Study Design

The study design was a quasi-experimental field study design. The experimental interventions consisted of: 1) a new flexible office space with adjustable workstations and a flexible overall facility layout and 2) office ergonomics training regarding the use of the space that supports employee control over how the overall space is used. There were three treatment conditions: 1) "Control" group consisting of employees

who did not receive a new workspace or training; 2) "Workstation-only" (WS) employees who received the new experimental, flexible workspace, and 3) "Workstation + training" (WS + T) employees who received the new workspace and office ergonomics training.

Employees were randomly selected to participate in the training, however participation was limited to employees on two out of the four building floors to minimize unwanted cross contamination or voluntary sharing of the training materials and ergonomic knowledge with other employees. Data were collected simultaneously from all three groups once prior to the office ergonomics intervention, and twice (3 and 6 months) following the interventions.

2.3 Office Workplace Intervention

There were three defined goals of the new workplace intervention project, which were: 1) Create a new concept for work environments that enables higher worker effectiveness, 2) Provide ergonomically designed workspaces that enhance employees' health and well-being, and support employees' needs, 3) Increase communication and collaboration among individuals, groups and departments, and 4) Create operational efficiencies through business process effectiveness. The new workplace was architecturally designed to create a sense of openness and to provide natural lighting throughout the workspace. Design issues related to auditory and visual privacy were addressed by installing white noise and moveable partitions. Overall, the layout of the individual workstations was a soft "U" shape and each workstation had adjustable storage and paper management tools. Each workstation consisted of a highly adjustable chair.

2.4 Office Ergonomics Training Intervention

We used an instructional design model, which is based on a systems approach, to create the office ergonomics training. This instructional model consists of five processes: 1) Analysis, 2) Design, 3) Development, 4) Implementation, and 5) Evaluation [16]. In the analysis phase we collaborated with, and interviewed, the company's corporate safety and facilities managers to identify existing related office health and ergonomics training programs and to determine if workers had been previously trained.

Using the results from training needs analysis, we customized the design of the training program to support the organizational culture, and the existing health and ergonomics programs and policies. The goals of the training were defined as: 1) to understand office ergonomic principles, 2) to perform ergonomic self-evaluation of workspace, 3) to adjust and rearrange one's own workspace and 4) to understand how to utilize the various workspaces designed to support individual and group work. Overall, the training was designed to incorporate active adult learning models, which allow for a high level of interaction among the trainers and trainees. Several media were used to deliver the training, including group exercises and break-outs. Developed training materials included: a facilitators handbook and a computer ergonomic guidelines ("Ergo-Guidelines") handout with recommendations and

solutions. Specifically designed e-mail messages provided feedback to the trainees on the results of the knowledge tests, which also served as reminders of office ergonomics principles.

Training effectiveness was evaluated by a training evaluation framework [17]: 1) Baseline Assessment, prior to training, 2) Trainee reaction, 3) Learning, 4) Behavioral changes, and 5) Organizational results (productivity). Results of the second and last training evaluation levels: learning (ergonomic knowledge) and organizational results (self-reported musculoskeletal health, group performance and business process efficiency) will be presented here.

2.5 Instruments

Three methods of data collection were employed: 1) Work Environment electronic surveys, 2) Ergonomic knowledge tests, and 3) Business Process Analysis (BPA). The Work Environment survey contains 10 sections to measure office environment design issues, individual and group performance, and work-related musculoskeletal discomfort. The scales used were adapted from previous office environment studies [18,19,2] where earlier factor analyses revealed these variables. Self-reported musculoskeletal symptoms were determined based on the standardized discomfort questionnaire using a 5-point Likert-type scale [20].

2.6 Business Process Analysis (BPA)

A series of Business Process Analyses (BPA's) data collection efforts were conducted which included interviews with several internal working groups prior and subsequent to the intervention. The purpose of using the BPA approach was to measure the process step time, resources, and the overall elapsed time of repeatable business process. Two internal groups and three business processes (Global financial Reporting (GFR), Project Scheduling and salary administration/performance review) were identified as part of the experimental groups. For the control group, the Quarterly Financial Reporting process was used. To collect BPA data from internal groups, the research team interviewed participants using a general business process-mapping model. Table 1 lists the specific data gathered from each group and for each process.

Table 1. BPA Data Collection Measurements

Measurement	*Description*
Process Time	The amount of time that is required to complete a process step.
Resources	The individuals (internal or external) involved in the completion and decision making required to complete each process step.
Supporting Technology	The tools, templates and technology used to complete each process step.
Elapsed Process Time	The overall amount of time required to complete a process cycle.

3 Results

3.1 Response Rates

For those who participated (n=642), 68% completed all three Work Environment surveys. Data were gathered from all three groups once before, and twice after, the office ergonomics intervention of workspace change and training.

3.2 Learning: Office Ergonomic Knowledge

Results of the pre/post knowledge test revealed a significant 32% increase in overall office ergonomics knowledge ($p<.01$). Significant increases were also observed in the categories of: 1) improvement of body posture 2) the use of ergonomic workstation, chair features and ergonomic accessories and 3) awareness of company ergonomic practices and resources (all at $p<.01$).

3.3 Organizational Results: Individual Self-reported Musculoskeletal Discomfort

Preliminary analyses of the surveys for all groups revealed that, in response to a yes/no survey item regarding experiencing overall work-related WMSDs, there was no significant change observed over time for the control group ($p>.05$). The WS-only group exhibited a moderate 14.1% reduction in reported WMSDs from Time 1 (pre-intervention) to Time 2 (post-intervention; 3 mos. ($p=.10$); however, from Time 2 to Time 3 (post-intervention; 6 mos.), an increase of 18.9% in WMSDs was noted. A significant reduction (47.6%) in overall work-related musculoskeletal discomforts from Time 1 pre-intervention to Time 2 post-intervention (<.01) was revealed for the WS+T group, with a further reduction reported from Time 2 post-intervention to Time 3 post-intervention (23.4%). Post-intervention differences for both the WS-only and WS+T groups were significant compared to the control group ($p<.05$). A significant reduction in the overall rated body discomfort (collapsed across 8 body parts) was found for both the WS-only and WS+T groups over time, compared to the control group ($p<.05$). Similarly, significant reductions in upper limb and lower limb rated body discomforts (collapsed across 6 and 2 body parts, respectively) were observed over time for both the WS-only and WS+T groups compared to the control group. A significant difference between the WS-only and WS+T groups for Time 3 was revealed only for the lower limb rated discomfort.

3.4 Organizational Results: Business Process Efficiency

Table 2 presents the preliminary BPA results based on data gathered from the control group and the experimental groups. For the control group, the Quarterly Financial Reporting process was unchanged in both time and quality. It was observed for this group that at both the pre-move and post move levels, the overall amount of elapsed process time of 123 hours or approximately 15 days remained unchanged. This reflects the amount of time required by the Finance Specialist to complete a quarterly finance report. For the experimental group (workstation only and workstation + training), at the pre-move level, the overall amount of elapsed process time measured

was 38.92 hours or approximately 5 days. This reflects the amount of time required by the Finance Manager and Specialist to complete a monthly finance report. However, at the post-move, the overall amount of elapsed time decreased by 4.28% for a measurement of 37.25 hours or just over 4 days. For the experimental group 2, (workstation only and workstation + training), at the pre move level, the overall amount of elapsed process time measured was 8.25 hours or just over 1 day. This reflects the amount of time required by the HR Specialist to staff an employee on a customer project. However, at the post-move level, the overall amount of elapsed time decreased by 15.15% for a measurement of 7 hours or just less than one day. For the experimental group 3 (workstation-only and workstation + training), at the pre-move level, the overall amount of elapsed process time measured was 397.73 hours or approximately 50 days. This reflects the amount of time required by the HR Specialist to complete both the salary administration and performance review process tasks. However, at the post-move level, the overall amount of elapsed time decreased by 4.52% for a measurement of 379.73 hours or just over 47 days. In addition, to further determine whether changes in process time existed following the redesign of the workspace and training, the research team gathered information about the number of times per calendar year the business process was completed, as well as the number of group members (at the pre-move and post move levels) involved in the process. Each group member also rated the overall quality of the process output.

Table 2. BPA Results by Group

	Control Group	*Experimental Group*	*Experimental Group*	*Experimental Group*
Pre-Move Elapsed Process Time	123	38.92 hrs.	8.25 hrs.	397.73 hrs.
Post Move Elapsed Process Time	123	37.25 hrs.	7.0 hrs	379.73 hrs.
%Time Reduction	0%	4.28%	15%	4.52%
Post Move Process Output Rating	5	4	4	4
Process Completed	4 x per year	12x per year	30 x per day	2 x per year

3.5 Analyses of the Effects of the Experimental Workspace and Training on Business Process Efficiency

The effects of the treatment condition on business process efficiency (time to complete a process) was performed. A regression analysis was completed to examine the effects of the two aspects of the treatment. The results indicated that both aspects contributed to reductions in the time required to complete the business processes. Table 3 shows the treatment group and the overall process time saved. The sizes of

the effects of the two aspects of the treatment were roughly equivalent to each other. That is, the experimental group conditions (workspace only and workspace + training) each contributed equivalent amounts of effects in the improvements to process efficiency [Beta = 2.68, p<.05, (WS + T) and Beta = 2.49, p<.05, (WS only) R2=.226, F+ 4.68, p< .05]. The two treatment conditions together accounted for roughly 23% of the total variance in the time-savings across the four processes. Reduction in process cycle time was calculated across all four processes that were measured. Percentage of reduction is pre-treatment process time versus post-treatment process time.

Table 3. Treatment Group and Process time

Treatment Group	*Reduction in Process Cycle Time*
Control	.46%
Experimental Workspace	5.62%
Experimental Workspace + Training	10.55%

4 Conclusions

The study results indicated that trained participants reported that the office ergonomics training was beneficial and that they could apply the information to their work environment. There was an observed increase for the WS+T participants in office ergonomics knowledge and skills in the categories of body postures, ergonomic design features and corporate resources from pre- to post-knowledge test after the training. Trainees exhibited a large, significant increase in knowledge in the categories of body postures, ergonomic design features and corporate resources. Through training, these employees were encouraged to use corporate resources to achieve an ergonomic fit with their new workstations. Participants also gained a high sense of knowledge and awareness of where to go and who to contact concerning the use of their company's corporate resources pertaining to ergonomic and facility adjustments and changes.

The finding that the WS+T group exhibited significant decreases in overall discomfort compared to the control group suggests that training provides employees with the knowledge necessary to use their workstations in a more ergonomic and healthy way. The observation that the WS-only group reported a greater decrease in overall body, upper and lower discomforts relative to the control group suggests that providing ergonomic furniture alone may be beneficial. These results are consistent with the earlier findings of Green and Briggs [21] and Verbeek [22]. The continued reduction of WMSDs over time for the WS+T group suggests that providing ergonomic skills, in the form of training, allows individuals to make appropriate workstation changes, thus reducing the musculoskeletal risks and discomfort associated with computer work.

Results of the business processes analyses revealed the impact that the workspace and training had on reducing the process cycle time. The group that received only the new workspace saw a moderate reduction (5.5%) in process cycle time. Those participants that received the ergonomic training and the new workspace experienced

a rather large reduction in their process cycle time of 10.5%. Interestingly, it appears that these effects are additive; that is, the effects of the training add on to process time reductions, on top of the positive effects of the work environment. Moreover, these study results suggest that the flexible workspace and training were significant predictors of process cycle time reductions. This finding supports the notion that workspace design and training can have positive effects on quantitative measures of organizational output.

Overall, it appears that due to the knowledge gained following the office ergonomics training and workplace design change, knowledge workers were able to appropriately change and adjust their workstation and chair setup as well as use the workplace facility more ergonomically and effectively. These results suggest that the provision of ergonomic skills, in the form of training, allows individuals to make appropriate workstation changes, thus reducing musculoskeletal risks and discomfort associated with computer work and improved organizational effectiveness.

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