

Effect of an Ergonomics Intervention on Workstations of Microscope Workers

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KEY WORDS

- ergonomics
- microscope
- occupational therapy
- work

OBJECTIVE. This study evaluated the effect of an occupational therapy ergonomics intervention on the workstation design and body positioning of microscope workers at a fiber optics facility.

METHOD. The study was quasi-experimental. Fifty-one microscope workers were assigned to one of three groups: control, education only, and education training. Their workstation design and body positioning were assessed before and after intervention.

RESULTS. Workers who participated in a client-centered, participatory, and onsite ergonomics program demonstrated improved workstation design and improved body positioning compared with both a control group ($p = .000$) and an education-only group ($p = .001$). These results were supported through analysis of covariance and effect size calculations. Workers who received only educational handouts also demonstrated improved body positioning and workstation design when compared with the control group ($p = .001$).

CONCLUSION. Researchers concluded that participation, client-centered training, context, and feedback represented critical components of ergonomics training.

Darragh, A. R., Harrison, H., & Kenny, S. (2008). Effect of an ergonomics intervention on workstations of microscope workers. *American Journal of Occupational Therapy*, 62, 61–69.

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Ergonomics has become an area of practice for many occupational therapists and is identified as an emerging area of practice by the American Occupational Therapy Association (Brachtesende, 2005). Simply put, ergonomics is the adaptation or fitting of work responsibilities and environments to the abilities of the worker (Cohen, Gjessing, Fine, Bernard, & McGlothlin, 1997). The goal of the occupational therapist in ergonomics is to prevent or reduce exposure to risk factors associated with musculoskeletal disorders (MSDs; Droeze & Jonsson, 2005). It is an important and appropriate practice area for occupational therapists who offer knowledge and training in the physiology and psychology of human engagement in occupation and the interaction of the worker's cognitive, physical, and psychological capacity with the demands of work (Clinger, Dodson, Maltchev, & Page, 2007).

The authors of this study integrated principles of health education and ergonomics with occupational therapy practice to design a comprehensive ergonomics program that reflected central themes of occupational therapy practice, including client-centered practice, client collaboration throughout the intervention process, and participation in context (AOTA, 2002). As recommended by Butler (1997), they integrated three domains of learning (cognitive, affective, and psychomotor) into their prevention program to facilitate learning. This integration included providing health-related knowledge (cognitive domain); considering and including the emotions, values, and attitudes of the participants toward health behaviors and behavior change (affective domain); and facilitating motor skills through performance and application (psychomotor domain; Butler, 1997).

Evidence also suggests that the participatory ergonomics approach is an effective technique for effecting behavioral change (Fischer, 1998; Hagg, 2003; Haslam, 2002; Hignett, Wilson, & Morris, 2005; Koningsveld, Dul, Van Rhijn, & Vink, 2005). This approach allows the active acquisition of knowledge and skills and reflects the client-centered, participatory nature of occupational therapy practice (AOTA, 2002). As the name suggests, participatory ergonomics involves the worker in the implementation of ergonomics principles in the work environment (Nagamachi, 1995). In addition, participatory ergonomics is the recommended intervention for reducing MSDs among workers performing manual work duties (Carrivick, Lee, & Yau, 2001; Straker, Burgess-Limerick, Pollock, & Egeskov, 2004; Stubbs, 2002).

As early as the 1970s, demonstration and training were seen as superior methods of safety intervention. Leslie and Adams (1973) compared different methods of instruction delivery with punch press operators and found that the most significant decrease in accidents occurred in the group that received formal training and demonstrations as opposed to just oral instruction or a slide show. More recent studies of participatory ergonomics interventions also have demonstrated behavior change; for example, 53% of dentists involved in a participatory program reported implementing all or nearly all of the changes recommended (Droeze & Jonsson, 2005). Another study of participatory ergonomics in Australia revealed that hospital cleaners experienced a decrease in injury rate, injury duration, and injury cost after being involved in a participatory ergonomics program (Carrivick, 2002; Carrivick et al., 2001; Carrivick, Lee, Yau, & Stevenson, 2005).

Results from Furth, Holm, and James (1994), however, showed a low degree of follow-through on ergonomic recommendations, perhaps because the training was performed in a clinic, whereas participants in the present study practiced recommendations at their actual workstation, thereby applying ergonomic principles in context. This approach is in accordance with studies by Schwartz (1989) and McCauley (1990), which found positive results relating to ergonomic practices and decreased injury incidence in employees who were given the chance to apply and practice ergonomic adaptations to actual work tasks.

Ergonomics programs that consider context, practice, and feedback promote generalization of learning and behavior change. A successful ergonomics program therefore must be specific to the individual, his or her environment, and the job performed (A. L. Cohen et al., 1997). Numerous ergonomics studies have demonstrated that ergonomics interventions emphasizing on-the-job education and training provide people with important practice opportunities and result in

greater carryover (Leslie & Adams, 1973; McCauley, 1990; Schwartz, 1989). Ergonomics interventions that combined education with practice found improvement among groundskeepers, custodians, clerks, and grocery workers (Christopher & Sehna, 1993; Hultman, Nordin, & Ortengen, 1984; McCauley, 1990; Schwartz, 1989). Komaki, Barwick, and Scott (1978) found an increased use of ergonomically effective techniques when weekly, personal feedback was provided. Tiraboschi, Weiss, and Blayney (2002) found 86% of administrative assistants who received personalized feedback and one-to-one instruction in ergonomics demonstrated at least one behavior change relating to instruction. Brandenburg and Mirka (2005) studied volunteers in a laboratory setting and found that after an ergonomic training program, people who received positive reinforcement as they were performing tasks had a more positive view of the program, a factor that has application in the motivation of the worker to make behavioral changes.

Microscope Workers at Risk

Work-related MSDs account for approximately one-third of all injuries involving days away from work (National Safety Council, 2006; Straker et al., 2004). These injuries include injuries to the upper extremities, neck, and back and often are referred to as *cumulative trauma disorders* (Droeze & Jonsson, 2005). According to the National Safety Council (2006), musculoskeletal injuries result in a median of 10 lost workdays, more than the median of 8 lost workdays for all injuries. Finally, cumulative trauma disorders cost approximately \$15,275 per injury in medical and indemnity costs (National Safety Council, 2006). The Centers for Disease Control and Prevention (CDC; 1997) reported that workers using microscopes are at risk of injury to the upper extremities, neck, and back because of the nature of their work. Microscope and laboratory workers stand for prolonged periods of time, perform tasks with awkward posturing, look downward while performing eye-straining tasks for prolonged periods of time, and carry out fine manipulation activities that require the use of flexor and extensor muscles of the fingers and wrist. The potential for injury is compounded by the increase in time workers spend at their workstations (Cohen et al., 1997; Drake & Ferraro, 1997). The likelihood of being exposed to one or more risk factors, such as repetition and awkward positioning, is high; this exposure is amplified because of the amount of time spent in these activities.

Despite these risk factors, few studies have examined the prevalence of musculoskeletal injuries among microscope workers. In one survey of 82 cytotechnologists (microscope workers), who spend the majority of their workday looking

through a microscope, 61.5% reported neck symptoms, 56.4% reported hand and wrist symptoms, and 42.3% reported lower back symptoms (Kalavar & Hunting, 1996). In a more recent study, a survey of 244 cytotechnologists revealed that 85% experienced musculoskeletal symptoms and approximately one-third reported neurological symptoms, such as numbness and tingling of fingers (Thompson, Mason, & Dukes, 2003). In addition to musculoskeletal symptoms, microscope work may affect vision, including eyestrain and visual changes (Soderberg, 1983). Microscopes have evolved over the years with improvements to increase illumination, visual field, and positioning, yet musculoskeletal symptoms persist (Hinsch, 1997; "Microscopes," 2006). Thompson and colleagues (2003) reported that of the 34.4% of cytotechnologists who were employed by companies with ergonomics programs, only half had received an assessment of their workstation. This demonstrates the need for education and training regarding the use of ergonomically designed equipment or the modification of existing microscopes, because older technologies may persist on site.

Researchers drew on the work on the aforementioned scientists to design an occupational therapy prevention program grounded in participation, client centeredness, and health education that included elements of feedback, one-to-one training, context, and practice. The purpose of this study was to evaluate the effectiveness of this occupational therapy intervention in (1) improving employee body positioning and body mechanics at a microscope workstation and (2) improving workstation ergonomic design. Two hypotheses were proposed:

1. Participants in the intervention (education–training) program would demonstrate a significantly greater improvement in body positioning and workstation design than participants in the control and education-only groups, as measured by the Laboratory Assessment Checklist (Occupational Safety and Health Administration [OSHA], 2001), after the program.

2. There would be no significant difference in body positioning and workstation design between the control and education-only groups after the intervention period.

Method

Participants

A convenience sample of 92 microscope operators was obtained from a fiber optics technology production facility. They were recruited through announcements, flyers, and word of mouth within the facility. To be included in the study, participants had to be full-time, first-shift production workers who spent at least 1 hr per day at a microscope

workstation. Potential participants were excluded from the study if they had received prior ergonomics training, were unable to complete both the pretests and the posttests, and were unable to fully participate in the research protocol. The study was approved through the Sacred Heart University Institutional Review Board, and written consent was obtained from all participants. Individual results and participants' identities were kept confidential through the use of a numbering system that correlated each participant to his or her location and assigned research group. On completion of the study, researchers provided all participants with the occupational therapy intervention.

Instrumentation

The primary outcome measure used in this study was the Laboratory Assessment Checklist (OSHA, 2001). The link to this checklist is no longer available; however, many of the items on this checklist can be found in the Laboratory Self-Assessment Checklist (CDC, 2007).

The Laboratory Assessment Checklist is an evaluation of the worker and the microscope work area. The first four sections are observational assessments of the worker and workstation; they were performed by the two occupational therapy graduate students who led the design and implementation of the training protocol. These sections address both worker positioning and workstation design. The "General Workstation" section focuses on questions pertaining to the observed worker–workstation fit. The section on microscopes concerns the worker–microscope fit and microscope work area. The section on laboratory chairs notes whether a chair is present and how the worker is positioned when using it. The section on standing workstations addresses worker position in addition to contact stressors. Finally, the section on work habits is a worker self-report section covering basic worker behaviors and characteristics such as frequency of breaks, body position change, and eyestrain.

In addition to the outcome measure, a self-administered Employee Comfort Survey (Anderson, 1995) was completed by the participants. This assessment asks workers to rate their comfort on a scale ranging from 0 to 10, by body part, using a visual representation of the human body as a guide. In addition, the assessment collects information on the employees' perceptions of morale, difficulty of work, and how well their needs are being met. This instrument was used not as an outcome measure but as a method for understanding the various symptoms or discomforts the participants may have been experiencing. It also served as a vehicle for discussion of common symptoms and experiences within the workplace environment during the training sessions. No psychometric properties were available for these instruments.

Procedures

Investigators used a quasi-experimental, pretest–posttest comparison group design, with random assignment of work group to intervention group. The primary independent variable was the ergonomic intervention, with three levels. The primary dependent variable was the workers' positioning and workstation design. After identifying the eligible participants, researchers assigned participants to one of three groups depending on their designated "cell" (the work area to which specifically assigned employees report each day). In other words, researchers randomly assigned one of the three research conditions to each cell.

Production Cells

The facility uses a lean manufacturing approach to production. In keeping with this method, employees working on microscopes are cross-trained to different cells and report to different cells depending on the needs of the business. Each cell is responsible for the inspection and assembly of a different product, although similar equipment may be found in each area and the biomechanical expectations are essentially the same, as determined by the environment, health, and safety (EHS) manager and confirmed by the research team through observation, task analysis, and job description analysis. Because they were cross-trained and moved through different cells, all microscope employees experienced similar exposure to ergonomic risk factors. Supervisors also were cross-trained to move among cells. At any one time within the facility, at least three microscope cells were being used. During this study, however, workers were assigned to a specific cell, and they reported to this cell each day for the duration of the study. The decision to randomly assign intervention to cell as opposed to participant was to avoid cross-contamination of groups, thereby reducing the chance of misclassification. In addition, members of the research team believed that they could facilitate learning, participation, and peer support with members of one cell proceeding through the training together. Cell members were not specifically instructed not to discuss the intervention with the other cells. The members of the cells had different lunch and break times, which restricted their contact; of course, the employees knew each other and could have communicated.

The control group, Group 1, did not receive any intervention; however, the group members completed both the Laboratory Assessment Checklist and the Employee Comfort Survey. No education or feedback regarding the assessments or how the workers appeared at their workstations was given to these participants. Group 2 received the same assessments, in addition to an educational handout; however, neither the education nor the results of the assessments were discussed.

Members of Group 3 completed both assessments, supplemented by the educational handout given to Group 2 and a 1-hr occupational therapy training session with a lecture, a slide show of the educational handout, and modeling and practice of ergonomic principles focusing on body positioning and workstation design for microscope users at individual workstations. Groups 2 and 3 were provided with the handouts the day after the pretest assessments. In addition, Group 3 participated in the 1-hr training and one-to-one training the day after the pretest assessments.

Intervention

Participants in Group 2 (the education-only group) received an educational handout created by the research team. The handout consisted of a hard copy of a slide show presentation and included topics such as an ergonomics overview, laboratory workstation risk factors (e.g., awkward postures, repetitive movements, eyestrain), symptoms of repetitive strain injuries (e.g., pain, discomfort, fatigue), goals of ergonomics programs (e.g., worker positioning, workstation redesign, work process modification), and guidelines to follow for injury prevention (e.g., rest breaks, environmental modification, worker positioning). This handout was created to provide participants with the health-related knowledge they required, thereby addressing the cognitive domain of learning.

Participants in Group 3 (education–training) received the previously mentioned handout in addition to a 1-hr training and a "hands-on" workstation redesign session. The 1-hr training included the visual slide show presentation of the educational handout, a question-and-answer session, and a discussion of the results of assessments. The session content was driven by the results of the Laboratory Assessment Checklist and the Employee Comfort Survey. During the question-and-answer session, participants had the opportunity to clarify the concepts presented in the slide show and were able to relate the results of their personal assessments to the training content. The assessments, both the checklist and the body comfort survey, allowed participants to voice their opinions and thoughts about their workstations and the degree to which they thought change was necessary. This assessment addressed the affective domain of learning and was critical to the facilitation of behavior change. Study participants worked with the research team to solve individual and group problems and to make recommendations for personal and peer workstation improvement. Discussions were facilitated by, not directed by, the researchers. The goal of the discussion was to allow the participants to begin to recognize the relevance of the content of the ergonomics presentation and to begin to apply it to their own work and to the results of their own assessments.

Immediately after the group training, the participants returned to their workstations for the “hands-on” workstation redesign session. The goal of this session was to help them apply the concepts and solutions generated during the 1-hr training session to themselves, their work, and their workstations and then to practice using their revised workstations. Because this part of the intervention was hands-on and individualized, it was the most time consuming. The researchers first provided everyone with a demonstration of how to adjust a workstation, using the information covered in the 1-hr training. Participants were then divided into smaller groups on the basis of their location within the cell. While in the smaller groups, participants had the opportunity to work one-to-one with researchers for approximately 7 to 10 min at their workstations to make the modifications and practice using them. The researchers used the results of the Laboratory Assessment Checklist to guide any modifications that were made.

Workers participated in this process by examining the checklist and problem-solving changes with the researchers and peers. Participants also analyzed and adjusted the workstations of their coworkers to facilitate natural supports and psychomotor learning. The participants received feedback about the changes they made both from the researchers and from their peers. According to Butler (1997), any successful prevention program must include both educational measures and the promotion of skills with the long-term goals of health, productivity, behavior change, and learning. Therefore, recommendations were made to the EHS manager at the workplace on how to continue to effectively train workers and how to begin a comprehensive ergonomics program for all staff.

Participants in Group 1 (control) received no intervention.

Two weeks after the pretest administration for each group, researchers readministered the Laboratory Assessment Checklist to all participants and noted any changes that had been made in positioning and workstation design. The researchers assessed the same participants they had assessed at pretest and assessed the same number of participants in each cell. All participants were retested at their workstations during their shift. In addition to the checklist scores, researchers looked for the incorporation of low- or no-cost adaptation recommendations that had been made during the education–training session.

Participation was supported and encouraged by facility management at the site. The EHS manager assisted with recruitment and logistics of the study. He requested and received a copy of the training protocol to integrate with existing facility protocols. Finally, he attended the poststudy training for members of the control and education groups. The EHS manager had support from the operations manager and the facilities manager for this study. The operations

manager and facilities manager assisted with organizing space and ensuring employees could participate in the study during their shift. They also verbally supported the project in meetings and on the floor.

After all data were compiled, comparisons were made among the three groups to determine whether the education–training intervention affected microscope workers, as evidenced through observation and documentation of proper body positioning and workstation design.

Statistical Analysis

On completion of data collection, results of the Laboratory Assessment Checklist pretest and posttest from the three groups were analyzed using the SPSS version 11.0 computer statistical analysis program (SPSS, Inc., Chicago, IL). To evaluate the change in body position and workstation design after the intervention, the total number of “correct” answers on the Laboratory Assessment Checklist was used to calculate mean scores for all groups before and after intervention. To account for variability, the standard deviation and standard error of measurement of pretest and posttest scores were calculated for each group. A one-way analysis of variance (ANOVA) was conducted to determine whether significant differences were found across treatment groups in relation to demographic characteristics, injury or illness status, or perceived work comfort. Analysis of covariance (ANCOVA) was used to measure the differences among group means. This technique has the ability to reduce the error variance in the outcome measure and allows the measurement of group differences (Ott, 1993). This type of analysis was used to determine whether the mean scores differed before and after intervention and whether the groups differed in the degree to which the mean score on the Laboratory Assessment Checklist improved. Statistical significance was established a priori at $p < .05$. To assess the magnitude of the change in scores, within and between group effect sizes also were calculated, using Cohen’s d and the distribution overlap (Cohen, 1988; Valentine & Cooper, 2003).

Results

Fifty-one of the 92 participants met the inclusion criteria. The sample included male and female workers between 21 and 55. Of this total, 7 participants withdrew because of job relocation or for personal reasons. The randomization process resulted in 24 participants in Group 3, which received the education–training intervention; 16 participants in Group 2, which received education only; and 11 participants in Group 1, the control group. ANOVA on the demographic data revealed no statistically significant differences between groups ($p \leq .05$).

The mean scores for all groups on the Laboratory Assessment Checklist were analyzed (Table 1). A higher score indicates a more ergonomically sound workstation, with a maximum score of 33. To assess the degree to which participants improved their workstations, no “passing” or “failing” grades were assigned; rather, the data were examined on a continuous scale. Before the study, all groups obtained mean scores between 15.25 and 17.81 (see Table 1). A one-way ANOVA revealed no statistically significant difference between the pretest values across groups ($p < .05$). The posttest mean scores revealed improvements for the education group (Group 2) and the education–training group (Group 3). The control group, however, experienced a decrease in score (Group 1).

We performed an ANCOVA (1) to evaluate our hypothesis that the education–training intervention group would demonstrate a significantly greater improvement in body positioning and workstation design compared with the education-only and control groups and the hypothesis that no difference would be found between education-only and control groups and (2) to examine the differences among all three groups (Ott, 1993). The results of the pretest scores were entered as the covariate to reduce the likelihood of error variance and to increase the power of the analysis. Statistically significant differences were found between all groups ($p < .05$; exact p values reported in Table 2). Group 3 had the highest mean score, and this score was statistically significantly higher than that of Groups 1 and 2 ($p = .000$ and $p = .001$, respectively). Group 2, whose members received educational handouts only, also demonstrated an improvement in mean score. This posttest score was statistically significantly higher than the mean score of the control group, Group 1 ($p = .002$). These findings support the hypothesis that the education–training group would improve to a greater degree than the education-only and the control groups. Contrary to expectations, however, the education-only group demonstrated a statistically significant difference in mean score (higher) than that of the control group. This finding fails to support our second hypothesis.

To investigate the practical effects of the education-only and education–training interventions, researchers also calculated effect sizes for the groups to determine the magnitude

Table 1. Pretest and Posttest Scores on the Laboratory Assessment Checklist (Occupational Safety and Health Administration, 2001)

Group	<i>n</i> (<i>N</i> = 51)	Pretest		Posttest	
		<i>M</i>	(<i>SD</i>)	<i>M</i>	(<i>SD</i>)
1 (control)	11	17.81	(3.28)	15.63	(2.87)
2 (education only)	16	17.00	(3.70)	21.30	(4.66)
3 (education–training)	24	15.25	(3.11)	25.65	(4.00)

Table 2. Between-Group Analysis of Covariance of Mean Scores on the Laboratory Assessment Checklist (Occupational Safety and Health Administration, 2001)

Comparison	<i>M</i>		<i>F</i>	<i>p</i>
	Posttest (Group 1)	Posttest (Group 2)		
Group 1 vs. Group 2 (control vs. education only)	15.63 (Group 1)	21.30 (Group 2)	10.67	.002
Group 1 vs. Group 3 (control vs. education–training)	15.63 (Group 1)	25.65 (Group 3)	53.25	.000
Group 2 vs. Group 3 (education only vs. education–training)	21.30 (Group 2)	25.65 (Group 3)	11.66	.001

of the effect of the interventions using Cohen’s d (Cohen, 1988). First, researchers examined the magnitude of the change within Groups 1, 2, and 3 from pretest to posttest (Cohen, 1988; Dunlap, Cortina, Vaslow, & Burke, 1996; Table 3). The magnitude of the change from pretest to posttest in Group 2 was $d = 1.02$, a large effect according to Cohen’s guidelines (Cohen, 1988). The same calculations for Group 3 also revealed a large effect size ($d = 2.09$). Interestingly, the control group effect size—a medium effect size of .71—was found in the opposite direction (mean score declined after “intervention”).

Researchers also considered effect size between groups and reported both d and the distribution overlap (Cohen, 1988; Valentine & Cooper, 2003). The distribution overlap expresses what percentage of scores in the group with a lower mean are surpassed by the average score of the group with a higher mean score; it also indicates what the percentile standing of one group’s mean score is relative to another’s mean score (Carson, n.d.; Valentine & Cooper, 2003). This measure is perhaps more useful than reporting only the broad guidelines of small, medium, and large effect sizes (Cohen, 1988).

In the current study, the mean score of Group 3 was at the 84th percentile relative to Group 2, and the percentage of nonoverlap between the group distributions was 55% (see Table 4). This result gives us a sense of how substantial the difference is in group performance. The magnitude of the difference between the posttest scores of Group 1 and Group 3 was $d = 2.7$, another large effect size. In this case, more than 81% of the scores in the distribution of Group 3 did not overlap with Group 1, and the percentile standing of Group 3 was more than 98% relative to Group 2 (Carson, n.d.).

Table 3. Within-Group Effect Size Calculations for All Groups

Group	Pre-Mean	Post-Mean	Cronbach’s <i>d</i>
1	17.81 (3.28)	15.63 (2.87)	0.71
2	17.00 (3.70)	21.30 (4.66)	1.02
3	15.25 (3.11)	25.65 (4.00)	2.09

Between Groups 1 and 2, the effect size is again substantial at $d = 1.47$; approximately 71% of the scores were not overlapping, and the percentile standing of Group 2 was 93% relative to Group 1.

Discussion

The evaluation of occupational therapy methods in prevention programs—specifically, ergonomics—is essential not only for promoting the entry of practitioners into this area of practice but also for improving ergonomics interventions and reducing or preventing MSDs. This study represents one of a handful of studies examining this population—and one of the few examining these specific methods in the context of occupational therapy practice. This intervention was grounded in principles of occupational therapy practice and supported by theories and models of learning and ergonomics training.

The results of this study indicate the strength of an occupational therapy approach in promoting environmental modification (workstation redesign) and behavioral change (body positioning). The researchers were able to incorporate employee and environmental risk assessment, educational training seminars, and evaluation and redesign of employee workstations and body positioning into a client-centered and contextual intervention. This inclusive intervention enabled workers to acquire knowledge about ergonomic principles and to apply that knowledge through opportunities to practice their new skills on their own workstation design and on the workstation of a peer. Finally, the intervention was efficient, requiring a 1-hr training sessions and approximately 7 to 10 min to train each employee.

As recommended by Butler (1997), the intervention provided to Group 3 incorporated the cognitive, affective, and psychomotor domains of learning. Participants received educational handouts as well as a presentation and verbal instruction in a classroom setting. In this way, the cognitive domain was incorporated into training as participants received information delivered through an instructive method relating to ergonomic principles and practices. Because all information directly related to the health of microscope workers, and all participants were microscope workers, it appealed to the participants' personal interest as

well. In addition, discussions regarding the assessments allowed researchers to keep the training employee centered, thereby including specific views of the participants about changing their workstations and behaviors. Finally, these discussions occurred among peers, so group members had the opportunity to reflect on and discuss how their own views differed or were similar to their peers. Thus, the affective domain of learning was incorporated into training. Last, the psychomotor domain of learning was incorporated into training. After the educational presentation, all participants were brought to their workstation, where they received one-to-one training in ergonomics and then applied that training to themselves and to a peer. As they engaged in this process, they were given feedback by, and provided feedback to, the researchers and the other workers in their cell.

The most compelling finding of this study was that of the three groups analyzed, the group that received the education–training intervention (Group 3) obtained the highest mean score on the Laboratory Assessment Checklist posttest and demonstrated a large effect size and substantial percentage of no overlap compared with both the education-only and the control groups. This finding implies that of the three groups, members of the education–training group improved their workstation design and body positioning most significantly. Participants in this group experienced a large change in their scores pretest to posttest and relative to the other groups. The intervention designed for this study was grounded both in the literature and in the philosophies of occupational therapy, ergonomics, and health education. The central themes of the intervention included an emphasis on client centeredness, environmental adaptation, task analysis, feedback, and participation, in addition to peer support and involvement and multimodal learning. These emphases appear to have had a substantial impact on the participants in their work environment, without excessive time requirements.

The magnitude of the change in mean scores on the Laboratory Assessment Checklist in the intervention group compared with the other groups was substantial. Note, however, that the education-only group also experienced a large change in effect size from pretest to posttest. In addition, the ANCOVA revealed that this group differed significantly from the control participants—an unexpected result. Researchers hypothesized that no difference would be seen between these groups given that the education-only participants received only limited information, from the cognitive domain only, and no feedback, practice, or participatory training. Although they did not improve to the degree the intervention group did, this finding still lends some support to providing written information to employees as a way to encourage behavior change. We should be cautious, how-

Table 4. Between-Group Effect Size Calculations (Includes Percentage of Nonoverlap and Percentile Standing)

Groups	d	Percentile Standing	% Nonoverlap
1–2	1.47	93	71
1–3	2.88	98	81
2–3	1.00	84	55

ever, because our findings may not represent true behavioral responses to written information because the participants knew that they were going to be assessed and may have made an extra effort to improve their workstation and positioning. Some misclassification also may have occurred if, in fact, members of the education-only cell sought assistance from coworkers from the education–training cell regarding the intervention. In addition, it is not known for how long these behaviors continued after this study.

Interestingly, the members of the control group experienced a decline in score after the 2-week period. Several possible explanations exist for this finding. One possibility is the tool itself. Variability in body positioning could have led to differences in the observed assessments, although the likelihood that all posttest observations of body positioning resulted in lower scores is unlikely. A more likely possibility is that the investigators evaluated the participants more critically, perhaps because of greater familiarity with the test items or familiarity with some of the observations made in different cells.

Limitations

Several limitations of this study could provide alternative explanations for the results. The study was not blinded, leaving the possibility for investigator bias. Given that the same investigators analyzed workstations and provided the training, the intervention group scores were vulnerable to inflation. The study also is vulnerable to participant bias, in that participants may have behaved differently because they knew they were being studied and, in particular, what was being evaluated. In other words, members of the education group may have been more likely to implement changes and attend to their positioning, accounting for some of their improvement. Educational interventions, therefore, may not be as effective as the results of this study might indicate. Finally, the participants in each cell may have spoken with members of other cells outside of work about the interventions they were receiving, resulting in some misclassification. This possibility could account for the improvements seen in the education group.

Of concern is that the mean scores in the control group dropped. It is possible that this outcome was related to the reliability of the workstation checklist. However, it also is possible that members of the control group attempted to change their workstations in the absence of professional assistance, resulting in workstation design and body positioning that were poorer than before. All participants received the study intervention after completion of the posttests to ensure that all employees were treated equally. Finally, some

uncertainty exists about external validity, that is, about whether results can be generalized across other populations, occupations, and settings.

Recommendations for Future Research

Future research should include additional follow-up assessments to determine the effects of occupational therapy and ergonomic interventions on employee behavior over time. In the current study, long-term follow-up was not possible, primarily because of massive layoffs that occurred in the fiber optics industry as a whole during the year after this study. In addition to examining the effects of occupational therapy intervention on behavior, studies should examine the effects of such intervention on the long-term health and productivity of workers. In general, more studies must be conducted to demonstrate the effectiveness of this type of client-centered, contextual, and participatory intervention. Moreover, in addition to studying the effects of intervention on work-related illness and injury, studies are needed to examine the effects of occupational therapy intervention on the promotion of optimal employee health, job satisfaction, and well-being. Finally, cost analyses of these interventions are critical to promoting the investment of employee time in such trainings. ▲

Acknowledgments

This study was done in partial fulfillment of the requirements for the degree of master of science in occupational therapy from Sacred Heart University, Fairfield, CT, for authors Harrison and Kenny.

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