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An Ergonomic Education and Evaluation Program for Apprentice Carpenters

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Eighteen new apprentice carpenters received sixteen hours of ergonomics awareness education as a part of their regular apprenticeship training during 1994 and 1995. An equal number of apprentices received no training but served as controls. The training took place in the Southwest Ohio District Council of Carpenters's Joint Apprenticeship and Training School. The curriculum was designed to be "learner-centered." Instruction included short lectures presented by a journeyman carpenter and emphasized participatory activities in the school's carpentry shop. Ongoing program evaluation assessed trainees' reactions to the content and structure of the curriculum and its influence on their behavior. Trainees and controls completed brief quizzes on ergonomic knowledge. Hands-on exercises enabled trainees to apply recently acquired ergonomic knowledge in the school's carpentry shop. Trainees scored significantly higher on one-half of the post-session quizzes and the comprehensive test. Trainees preferred participatory teaching methods, especially those using redesigned tools (93%) and evaluating ergonomic risks (86%); and they supported continued safety and health education during apprentice training. The authors conclude that apprenticeship programs should provide regular "learner-centered" occupational safety and health education that includes ergonomics, and these programs should be integrated with their shop-based manual arts instruction. Am. J. Ind. Med. 32:641–646, 1997. *© 1997 Wiley-Liss, Inc.*

KEY WORDS: carpenters; ergonomics awareness; work-related musculoskeletal disorders; construction ergonomics; evaluation; curriculum

INTRODUCTION

Construction workers labor in a constantly changing social and physical environment. The job site is constantly changing as members of each craft complete their tasks and move to the next site or unemployment line. Workers in each craft are exposed to multiple ergonomic risk factors, such as awkward working postures, material handling, soft tissue contact stressors, varying outdoor temperatures, noise, and whole-body and/or segmental vibration. The frequency and duration of exposure to various stressors may also be increasing due to economic and technological changes in the industry [Sobel, 199].

General contractors' use of subcontractors to reduce construction costs has increased. Subcontractors competitively bid for work on a construction project and this has resulted in their ‘‘tendency to specialize in whatever they are able to estimate more accurately, do quickly, and afford specialized tools for'' [Reckman, 1979]. Carpenters working for a specialty subcontractor work on specific structural components, such as ceiling systems, walls, or flooring. This division of labor often extends into the subcontractor's workforce where workers further specialize in some aspect of the specialty, such as ‘‘shooting wires'' for ceiling systems or ‘‘hanging'' sheets of drywall. This specialization requires carpenters to perform more routine or repetitive tasks.

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Studies show that carpenters' work can result in increased back, neck and shoulder problems and traumatic knee disease [Damlund et al., 1986; Tola et al., 1988; Thun et al., 1987]. Work-related musculoskeletal disorders (WMD) have been associated with the use of tools, such as overhead bolt pistols, carpet knee-kickers, and straight-handled claw hammers [Wos et al., 1992; Bhattacharya et al., 1986; Knowlton and Gilbert, 1983]. Schneider and Susi [1994] have described carpenters' potential ergonomic risks when building concrete forms and scaffolds, installing drywall and ceiling systems, laying carpet and other flooring materials, and doing interior trim and finish work.

In Ohio, for example, WMDs accounted for 38% of the compensable injuries and illnesses of workers employed by special trades contractors (SIC 17) in 1989 [Ohio Bureau of Workers' Compensation]. Sprain/strain injuries in Washington State during 1989–1992 accounted for 30% of all union carpenters' compensation claims, or 10.5 claims per 200,000 union-hours worked [Lipscomb et al., 1996]

In recent years, construction union and contractor representatives have begun to apply traditional ergonomic methods to identifying and controlling WMD risk factors. These methods include the design of tools, equipment, and materials, modifying work practices and organization, implementing administrative controls, and providing education and training [Center to Protect Workers' Rights, 1994; Coleman and Narayan, 1995].

Worker education and training play a key role in all occupational health and safety control strategies and have been used to address ergonomic hazards and prevent WMDs [Kilbom, 1988; Parenmark et al., 1988; Dortch and Trombly, 1990; Keyserling et al., 1993]. Educational programs can improve worker understanding and identification of WMD risk factors and inform workers of available methods to reduce risk. The empowerment education model has been proposed for use in worker health and safety training and education. According to Wallerstein and Weinger [1992], empowerment education ''is participatory, based on real-life experiences, incorporates dialogue between and among educators and workers, critically analyzes the organizational and system-wide causes of problems, and has the goals of worker action and empowerment.'' Empowerment-based teaching methods include increasing students' active participation in the process and a curriculum that addresses the potential technological, economic, and social barriers to change.

BACKGROUND

Unionized journey carpenters are members of the United Brotherhood of Carpenters and Joiners (UBC). Before achieving journey status, carpenters must serve a 4-year apprenticeship. During their apprenticeship carpenters work full-time for a contractor and attend quarterly classes. In the Cincinnati area, apprentices are enrolled in the Southwest Ohio District Council of Carpenters' Joint Apprenticeship and Training Program. This program is jointly administered by contractor and union representatives. Apprentices attend classes one week (40 hours) of every quarter-year to learn the theory and practice of the carpenter's trade. The school curriculum includes both academic and manual arts instruction taught by union journeymen carpenters. Academic classes include mathematics, blueprint reading, building specification and code, and construction technology. During each quarter, apprentices develop their manual skills working on small-scale building projects related to a carpentry subspecialty, such as installing drywall or ceiling systems.

In 1991, the NIOSH-sponsored Cumulative Trauma Disorders in Carpenters multi-disciplinary project conducted the following activities: a survey of working carpenters' musculoskeletal symptoms with a medical follow-up of reported symptoms, [Atterbury et al., 1996; Lemaster et al., 1995] and an ergonomic evaluation of journeymen and apprentice carpenters' jobs [Bhattacharya et al., 1997]. During the third and fourth years of the project, an ergonomic awareness education program was developed and provided to first-year carpenters during their apprenticeship training.

An ergonomics awareness education program was developed for Cincinnati-area apprentice carpenters. The objectives of the program were to (1) to increase apprentices' knowledge of carpenters' WMDs and construction ergonomics; (2) to prepare apprentices to identify potential WMD risks; and (3) to motivate apprentices to act to prevent WMDs. This report describes the content and organization of the curriculum, the results of the program evaluation, and recommendation for program implementation.

METHODS

The ergonomic awareness project began with new carpenter apprentices. Apprentices were divided into two groups: those receiving the training ($n = 18$) and those not receiving training ($n = 19$). Members of the training group received a total of 16 hr of ergonomics awareness education during the four quarters of apprentice training. Both groups completed the same knowledge-based tests. In addition, training group apprentices completed four class evaluations and one final program evaluation.

The apprenticeship school's lead instructor, a journeyman carpenter, agreed to serve as the primary ergonomics awareness instructor. Before each class, a ''learner-centered'' ergonomics awareness curriculum was developed by study investigators and the school's instructor [Luskin et al., 1992]. The instructor received a four-hour overview of the ergonomic issues related to each class before presenting the curriculum. Instruction took place in the classroom and in the carpentry shop. Each class focused on one of the following muscle/joint groups—the back, the neck and shoulders, the hands and wrists, and the elbows and knees. Basic information presented for each group included anatomy, physiology and biomechanics, recognized and suspected WMDs, WMD risk factors for carpentry, and WMD prevention tactics and strategies. These topics were introduced by the school's instructor during short informal lectures and discussions in the classroom. Audiovisual materials, including photographic slides and video tapes, were used to complement lectures. Each apprentice received a copy of the United Brotherhood of Carpenters' Ergonomics for Carpenters Training Manual to use as a reference in the classroom. Other classroom activities included discussions, hands-on demonstrations, and small group problem-solving activities.

After the first class, hands-on activities were integrated into the small scale building projects apprentices completed in the carpentry shop. The hands-on activities reinforced classroom presentations and provided apprentices with an opportunity to apply new knowledge. These activities included evaluating tools and equipment designed to reduce musculoskeletal stress, completing carpentry tasks using different work methods, and performing ergonomic job-task evaluations. The curriculum emphasized active learning methods, such as hands-on exercises (45%), demonstrations and group discussions (20%), interactive lectures (25%) and written quizzes (10%).

RESULTS

The program evaluated apprentices' assessment of the content and structure of the curriculum, knowledge gained, and the influence of the program on their behavior. Trainees completed a quiz following each of the four ergonomics awareness classes they took during the year and a final comprehensive test three months after their last ergonomics awareness class. Test questions were true/false and multiple choice. Apprentices serving as controls completed these same tests and mean scores were compared using analysis of variance tests. Members of the training group scored significantly higher than controls on the quizzes following the first and fourth ergonomic instruction and the comprehensive test (Table I).

Trainees completed a written evaluation following each ergonomics awareness class and filled out a final course evaluation. Evaluation questions addressed apprentices' attitudes concerning the curriculum's content, methods of instruction, lesson application to work, and recommendations for future ergonomics education and training. Most apprentices approved of the types of information presented in the classroom. The apprentices found information on CTDs associated with carpentry, ergonomic tool evaluation, and evaluating ergonomic hazards equally useful (86%) and also considered physiology (79%) and CTD risk factors (71%) highly useful. Trainees consistently preferred participatory teaching methods over traditional classroom instruction (Table II). They especially preferred the applied learning methods, with 93% rating ''tools/equipment demonstrations'' and 86% rating ''evaluating job risks'' as the most useful teaching methods. By contrast, less than half (43%) found listening to lectures useful.

As stated earlier, each 3-month period, apprentices attended the ergonomics instruction for approximately 4 hr (10% of instruction time), and most (71%) stated that the course took time away from the usual apprenticeship training agenda. Despite this concern, Table III shows that 71% of apprentices supported setting aside at least 2 hr during each week, i.e., 8 hr/year, for apprenticeship training for safety and health education, including ergonomics.

In the final course evaluation, apprentices were given a list of construction hazards and job-related injuries and illnesses and asked to rank them by severity. Ergonomic hazards were ranked more serious than traditional safety

TABLE I. Trainees Versus Controls Test Scores

	Trainee mean score		Control mean score		
Quiz	**%**	**n**	**%**	**n**	***P***
Post-class #1	85	19	68	7[a]	0.02
Post-class #2	80	19	75	8[a]	≥0.05
Post-class #3	58	19	51	10[a]	≥0.05
Post-class #4	86	18	74	18	0.05
Comprehensive	77	15	67	19	0.02

[a] Quiz only given to one control class.

TABLE II. Preferred Teaching Methods

Method	More useful (%)
Demonstrating tools/equipment.	93
Evaluating job risks in the shop.	86
Classroom discussions.	79
Evaluating and using tools in the shop.	71
Taking quizzes.	50
Listening to lectures.	43

TABLE III. Trainee Support for Ergonomic Education

Question	Agree (%)
Teach ergonomics in regular construction safety training programs.	100
Teach apprentices about the ''by-stander'' hazards they may be exposed to working around other trades.	100
Teach apprentices about safety hazards and toxic chemicals.	93
Ergonomics instruction interfered with apprenticeship training.	71
Teach at least 2 hr of safety and health information during each week of apprenticeship training.	71

hazards, such as working at heights and using power tools, but less serious than toxic exposures (chemical and dust) and working around ‘‘unsafe’’ co-workers. In terms of severity, apprentices ranked cumulative trauma disorders above all other occupational diseases or illnesses, such as lung disease, skin rash, and heat stress, but below injuries, such as cuts and bruises, broken bones and dislocations.

Health and safety education programs rarely evaluate how training has influenced trainees’ behavior in the workplace. This ergonomics awareness program attempted to identify the program’s impact on apprentice behavior in two ways. First, apprentices were asked to answer questions on the final course evaluation related to the program’s impact on their work practices. More than one-half of apprentices (57%) reported using information they received in the ergonomics awareness training on a construction job site. In addition, 43% of the trainees said they had changed the way they work because of the course.

During the fourth and last ergonomics awareness class, trainees prepared ergonomic ‘‘action plans’’ by selecting two ergonomic problems they encountered on the job and that they believed could be eliminated or improved within 6 months [Brown and Nguyen-Scott, 1992]. Each plan included the actions that the trainee believed were necessary to realize their goal, actions others needed to take, and possible barriers to success. The problems the 18 trainees identified included: lack of appropriate tools ($n = 7$), poor planning on the job site ($n = 4$), problems with material handling methods ($n = 5$), repetitive work ($n = 5$), and three each for poor tool design, awkward postures, and poor housekeeping. Overall 30 problems were identified. Fourteen trainees remained in the program. When asked to describe the outcome of their action plans 3–6 months later, six (43%) reported success in changing at least one problem they had targeted in their action plan.

DISCUSSION

The results of this study show increased knowledge of trainee carpenters related to ergonomics and WMDs and significant support for continued ergonomic education during apprentice training. In addition, the training group showed the ability to apply information received in the course, and they showed an interest and capability in identifying and abating ergonomic hazards at work. Trainee responses to course evaluations showed that apprentices preferred active learner centered teaching methods, especially those using hands-on demonstrations and exercises in the carpentry shop, over traditional classroom instruction. The evaluations also demonstrate apprentices’ strong support for health and safety education during their apprenticeship. Most apprentices reported using information from the course in their work and some reported a more significant influence. Finally, almost one-half (43%) of the remaining 14 apprentices who developed an ergonomics ‘‘action plan’’ reported they had successfully abated at least one identified ergonomic problem.

The curriculum was written during the year training was provided rather than before training was initiated. This proved beneficial for two reasons. First, it simplified the integration of active ergonomic instruction into the regular apprenticeship curriculum, as the apprenticeship school did not complete its quarterly curriculum in advance. Second, and more importantly, feedback from the apprentice instructor and the trainees was used to improve the next lesson plan. This feedback was obtained during discussions with apprentices and the instructor, and in the evaluations apprentices completed after each quarterly ergonomic awareness class. For example, all problem-solving activities for the first ergonomics awareness instruction occurred in the classroom. Conversations with individual apprentices and responses on the first program evaluation revealed dissatisfaction with the increased time they spent in the classroom. Subsequently, most ergonomics instruction was shifted to the carpentry shop, with some exercises integrated into their manual skills projects. The stepwise development of the ergonomics curriculum made it easier to modify the program, based on the concerns and observations of the trainees, the instructor, and members of the project.

Limitations

Several limitations of the study include presenting four hours of ergonomics education during each 40-hr class, using apprentices participating in other aspects of the Carpenters’ project as controls, and the failure to administer all the quizzes to controls.

Skilled workers in the building and construction trades are recognized as having a distinct occupational culture characterized by the positive control they exert over their job tasks. This work autonomy is related to the skills learned while serving their apprenticeship, their tool ownership, and the ‘‘portability’’ of their skill. In the apprenticeship process, an apprentice acquires and improves his or her carpentry skills. In the Cincinnati area, an apprentice spends four weeks each year in the apprenticeship school during their 4-year apprenticeship. The remaining time is spent working with experienced journey-status carpenters or not working due to a layoff. Acquiring job skills is important, but not the only learning taking place during the apprenticeship. Apprentices also learn ‘‘the way in which work should and should not be done, the beliefs of the occupation, and the existing attitudes concerning how workers should behave, dress, and communicate.’’ [Riemer, 1982]. Apprentices’ principal interactions are with the journey-status carpenters. The study team saw the apprenticeship school as a practical environment to initiate an ergonomics intervention in the industry. The study presumed that the apprentices’ deference toward their instructor would help to ensure their support for ergonomics awareness education.

The controls may have received some ergonomics information just by taking the quizzes and participating in other aspects of the Carpenters' project [Atterbury et al., 1996; Bhattacharya et al., 1997]. Consequently, this ergonomics information that controls received may have reduced the ability to detect the true training benefit, thereby understating it.

Making Changes

Apprentices in the ergonomic awareness program repeatedly denied that they could play a major role as ergonomic innovators in their work organizations, including introducing redesigned (''unusual'') tools or non-traditional work methods at a job site. Several apprentices said they would like to use a curved-handled hammer, but did not want to face the ridicule they anticipated. Another apprentice described the negative reaction of co-workers when she wore knee pads on the job. During group discussions most apprentices agreed that they could not suggest to a co-worker or contractor that two people should carry a sheet of ½-inch 4 ft × 12 feet drywall weighing approximately 80 lb.

Apprentices also identified their employers as barriers to ergonomic innovation in the industry. During the third class, only 22% of trainees ($n = 18$) believed that contractors would adopt ergonomic interventions without a legal requirement. Although trainees recognized the utility of a drywall lift for certain jobs, they did not believe that their employers would purchase the equipment. During group discussions many apprentices said that they would be labeled a troublemaker or malcontent, possibly jeopardizing their employment and standing within their work community, if they lobbied for ergonomics intervention. This emphasized the importance of reaching experienced journey carpenters.

Although several apprentices carried out their action plans, expecting them to serve as the main conduit for ergonomic oriented innovation on the job site or within their occupational community is unrealistic. While apprentices may lack the knowledge, skill, and social standing of experienced journey-status craft workers, and can be laid off or fired without cause by a contractor-employer, training enabled 43% to make changes.

RECOMMENDATIONS

Historically, occupational health problems, including work-related musculoskeletal disorders, have received much less government, contractor, and union interest than acute or fatal injuries. Now is the time to integrate occupational disease and illness education, including ergonomic awareness programs, with traditional safety or injury prevention programs offered in the industry. The emphasis that an education and training program gives to each of these hazards could be determined by the workers' activities, including their potential ''by-stander'' exposure to the hazards generated during the work of other trades. Apprenticeship training programs should introduce the hazards of a Trade's ''subspecialty,'' such as drywall installation or concrete form building. When the apprentice or journey-status carpenter begins work in a new subspecialty, the contractor should provide specific information about the hazards associated with the materials, equipment, and work practices the contractor uses, and all precautions that should be observed by the worker.

Apprenticeship programs should provide regular occupational health and safety education for all apprentices. The occupational health and safety curriculum should be task-oriented and describe all hazards associated with the manual arts instruction. Health and safety education should not be confined to theoretical concepts presented in a classroom. A unique opportunity exists in apprenticeship programs for apprentices to practice hazard recognition and prevention while completing construction projects in the school shops (Appendix A).

Finally, apprentices should not be expected to lead job health and safety innovation in their trade. Injury and illness prevention education includes information that many experienced journey-status construction workers will consider foreign or impractical. Apprentices may not be able to explain fully the need to replace traditional technologies, work practices, or work organization used in the industry. Construction safety and health education and training should be developed to improve simultaneously the capability of all stakeholders to recognize potential hazards and act to prevent their occurrence. In addition to better apprentice training, another step would be improving the traditional construction ''tailgate'' or ''toolbox'' safety meeting, such that presentations engage the participants, provide information relevant to the job site, and encourage discussion about the potential hazards and the means to prevent injuries and illnesses [Baker et al., 1992].

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APPENDIX A. Apprentice Carpenters Ergonomics Awareness Education

Apprentices should work in two-person crews and screw-off (fasten) a 4 ft × 8 ft sheet of drywall to the ceiling the following ways:

A. Lift and hold the drywall in place with your hands and fasten it to the ceiling.
B. Lift and hold the drywall in place using the panel hoist and fasten it to the ceiling.

After fastening both sheets of drywall answer the following questions.

1. Use the following scale to show your neck and shoulder effort when you fastened drywall to the ceiling using the panel lift and *not* using the panel hoist.

Neck Effort: Using Panel Hoist	Neck Effort: *Not* Using Panel Hoist
Maximum	Maximum
10 Very, very strong (almost max)	10 Very, very strong (almost max)
9	9
8	8
7 Very strong	7 Very strong
6	6
5 Strong (heavy)	5 Strong (heavy)
4 Somewhat strong	4 Somewhat strong
3 Moderate	3 Moderate
2 Weak (light)	2 Weak (light)
1 Very weak	1 Very weak
0.5 Very, very weak	0.5 Very, very weak
0 Nothing at all	0 Nothing at all

Shoulder Effort: Using Panel Hoist	Shoulder Effort: *Not* Using Panel Hoist
Maximum	Maximum
10 Very, very strong (almost max)	10 Very, very strong (almost max)
9	9
8	8
7 Very strong	7 Very strong
6	6
5 Strong (heavy)	5 Strong (heavy)
4 Somewhat strong	4 Somewhat strong
3 Moderate	3 Moderate
2 Weak (light)	2 Weak (light)
1 Very weak	1 Very weak
0.5 Very, very weak	0.5 Very, very weak
0 Nothing at all	0 Nothing at all

2. It was easier to lift the drywall to the ceiling using by
   a. hand
   b. hoist

3. It was easier to screw-off (fasten) the drywall to the ceiling
   a. when holding it by hand
   b. using the panel hoist

4. Yes/No
   As a working carpenter I would recommend using the lift when installing drywall to the ceiling.

5. Briefly explain why you would or would not recommend using a panel hoist.

6. Yes/No
   If I were a contractor I would buy panel hoists for my carpenters to use.

7. Briefly explain why you would or would not purchase panel hoists as a contractor.