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Evaluative research and methods development for the assessment of training effectiveness in occupational respiratory protection

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Agricultural workers face a variety of respiratory hazards in the daily conduct of their work. In the absence of engineering controls workers must depend on respirators to protect them from the deleterious health effects of chemical, biological, and particulate exposures. Respirators are not failsafe, however, and their effective use requires that the wearer adhere to a wide range of prescribed practices with respect to respirator selection, maintenance, fit-testing, and routine operation. Training is therefore an important component of any respiratory protection program, and workers who have not been adequately instructed in the essentials of respirator use remain at serious risk. It is equally important that the training be systematically evaluated to assure that it provides workers with the necessary knowledge and skills for optimal protection. The present paper reports on the results of an effort to evaluate the respiratory protection course given by the National Institute for Occupational Safety and Health (NIOSH).

Methods

The 4-d "Occupational Respiratory Protection" course is offered four times a year to the general public as part of the NIOSH continuing education curriculum. Topics covered include hazard assessment and respirator selection, inspection procedures, standard operating characteristics, qualitative and quantitative fit-testing, and respirator maintenance (including disassembly, cleaning and disinfection, reassembly, and examination for leaks). As a first step to the course evaluation, external consultants having expertise in both adult learning measurement techniques and occupational health were asked to audit a scheduled course presentation to familiarize themselves with the material. Their observations were then reviewed with the course instructors to reach consensus on the major course objectives in terms of the essential skills and knowledge necessary for effective respirator usage. A battery of test items, performance checklists, and exercises were then developed to measure achievement levels relative to the stated course objectives. Each performance task was designed to be short, to be administered individually, to provide immediate and corrective reinforcing feedback and knowledge of results, and to serve as a point for subsequent small group discussions. In addition to measuring factual knowledge and information, instruments were also developed to measure procedural skills (eg, properly inspecting and donning a respirator) and decision-making abilities by means of test questions, simulation exercises, and problem sets. The specific instruments and their purpose were (i) the Respirator Components Matching Test — measures basic knowledge about the component parts of different types of respirators; (ii) the Respirator Wearer Performance Audit Checklist — measures basic skills about monitoring and evaluating respirator programs; (iii) a set of four multiple-choice tests administered on successive days of the course to monitor knowledge gained over time regarding facts relevant to respirator usage and respirator selection decision logic; (iv) the Respirator Training Record Checklist — measures skills related to the quantitative fitting of respirators; (v) the Respirator Qualitative Fit-Test Checklist — measures ability to perform properly a qualitative fit-test; (vi) the Respirator SOP Program Exercise — measures knowledge about how to develop a standard operating procedure (SOP) for a company's respiratory protection program; (vii) the Respirator Inspection Record — measures knowledge and ability to inspect various types of respirators; and (viii) the Demographic Questionnaire — collects information about the individual's age, job title, level of experience in working with respirators, and similar details. Once developed, all of the evaluation instruments were reviewed by the course instructors for technical accuracy and relevance to course objectives. Following the technical review and final edit, the individual tests were then administered to a class of 33 individuals attending a regularly scheduled "Occupational Respiratory Protection" course. For purposes of our present discussion, we will focus only on the administration of the multiple-choice tests and the Respirator Components Matching Test. On the first day of the course all of the attendees were asked to make up a

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four-digit personal identification number, known only to them. This personal identification number was to be used on each test to permit cross-tabulating of test performance. This procedure allowed for pre- and posttraining comparisons of individual performance while still maintaining anonymity.

At the beginning of class on days 1 through 3, a five-item multiple-choice test measuring factual knowledge about various aspects of respirator usage and decision logic in respirator selection was administered to all of the attendees. The tests covered information to be presented later in the day so that inexperienced trainees could not be expected to have prior knowledge about the material. Since the difficulty of the course content increased over successive days, the multiple choice tests also became increasingly difficult over days 1 through 3.

At the conclusion of the course on day 4, a 15-item comprehensive multiple-choice test covering the same material was given to all of the attendees. This procedure allowed for a comparison of individual performance before and after the training.

The Respirator Components Matching Test, measuring the ability to locate and identify the essential components of different types of respirators, was administered on days 2 and 4. As with the multiple-choice tests, this procedure allowed for a comparison of individual performance before and after the training.

Results and discussion

Complete demographic information was collected for 31 of the 33 trainees. The trainees' average age was 37.6 (SD 10.5) years. Twenty (64.5%) of the trainees were men. Trainees' experience in their present position ranged from less than 1 year (25.8% of the sample) to more than 20 years (12.9%). Approximately 19% of the sample reported one to three years' experience and 23% four to six years' experience. All of the trainees had some post high-school education but 25.8% had no college degree. An AA degree was held by 16.1%, a bachelor of science by 38.7%, and a master's by 19.4% of the sample. Forty-eight percent of the trainees were from organizations with more than 1000 workers. Approximately 32% of the trainees represented organizations with 250—999 workers, and 16% represented organizations with ≤50 workers. One-third of the trainees took the course to receive NIOSH certification. Approximately 32% were employed as industrial hygienists, 19% as safety professionals, 16% as environmental health and safety technicians, 6.5% as managers, and 26% in other jobs, including construction, manufacturing, sales, marketing, biology, and nursing. Approximately 66% of the trainees reported job responsibilities related to an occupational respiratory protection program.

The course participants indicated the degree to which they had received previous training in, and routinely performed, job-related occupational respiratory protection duties. The results are shown in table 1. The trainees were also asked to rate their degree of expertise with respect to course content, and how much prior training they had received related to the course. These results are shown in table 2. Each trainee evaluated the validity and utility of each test as soon as it had been completed. Table 3 presents these evaluative data for the second Respirator Component Matching Test and the Comprehensive Multiple-Choice Test. The results reported are typical for all of the other measures.

Item analyses and reliability checks were completed for each test. The lengths and reliability values of the tests are shown in table 4. The three five-item and

Table 1. Percentage of trainees with prior training and with routine job performance related to respirators.

Task or performance	Special training	Routinely perform
Occupational respiratory protection	29.2	70.6
Respirator inspection	5.0	75.0
Respirator maintenance	5.9	70.6
Worker respirator training	9.5	76.2
Personally wearing a respirator	11.8	58.8

Table 2. Trainees' self-reported rating of expertise and prior training in course content (frequency percent).

	Little			Much		Mean rating	SD
	1	2	3	4	5		
Expertise	31.3	15.6	46.9	6.3	0.0	2.28	0.99
Training	28.1	37.5	28.1	3.1	0.0	2.0	0.92

Table 3. Percentage of trainees' agreeing with statements about test validity, relevance, and utility.

Content	Matching test 2	Comprehensive Multiple-Choice Test
Adequately covered content	96.9	96.3
Worthwhile learning experience	78.2	96.3
Learned something new	31.3	59.2
Took too long to complete	3.1	7.4
Liked working the test	75.0	88.9
Test too difficult	3.1	7.4
Questions fair and accurate	93.8	96.3
Test useful for company	84.8	65.4
Instructor expert in content	90.3	92.4
Opportunity to review test	84.4	88.5

Table 4. Test lengths and estimated reliability coefficients (Cronbach's alpha). (MT1 = matching test 1, MT2 = matching test 2, MCT1 = Multiple-choice test 1, MCT2 = Multiple-choice test 2, MCT3 = Multiple-choice test 3, MCT4 = Comprehensive Multiple-Choice Test, and CMCT = composite (30-item) multiple-choice test)

	MT1	MT2	MCT1	MCT2	MCT3	MCT4	CMCT
Number of items	5	5	5	5	5	15	30
Reliability estimate	0.79	0.36	0.55	0.42	0.62	0.56	0.78

Table 5. Means and standard deviations (percent) by groups across tests. (MT1 = matching test 1, MT2 = matching test 2, MCT1 = multiple-choice test 1, MCT2 = multiple choice test 2, MCT3 = multiple-choice test 3, MCT4 = Comprehensive Multiple-Choice Test, CMCT = composite (30-item) multiple-choice test)

Group	Test mean score	SD
Experienced (N = 17)		
MT1	87.9	11.2
MT2	93.0	5.1
MCT1	72.9	27.3
MCT2	56.5	26.7
MCT3	45.9	37.3
MCT4	79.6	15.7
CMCT	69.1	18.1
Inexperienced (N = 15)		
MT1	86.4	8.7
MT2	92.3	4.1
MCT1	58.7	26.7
MCT2	44.0	25.3
MCT3	49.3	22.5
MCT4	72.4	13.1
CMCT	61.6	13.4

one comprehensive 15-item multiple-choice test data were pooled and considered one test. These analyses revealed that 56.7% of the multiple-choice test question scores were significantly ($P \leq 0.05$) positively correlated with the composite-test total score, that there were no negative discriminating questions, and that the reliability of the overall composite multiple-choice test was 0.78. The reliability estimates of the two matching tests were 0.79 and 0.36, respectively. All of the matching-test question scores significantly ($P \leq 0.05$) positively correlated with their respective total test scores. On the basis of the information presented in tables 1 and 2, the trainees were classified into two levels (experienced and inexperienced) with respect to the course content. Table 5 lists the mean scores and standard deviations for these two groups on the two matching tests, each of the four multiple-choice tests, and the composite 30-item multiple-choice test.

No statistically significant differences ($P \leq 0.05$) were found between the mean scores of the experienced and inexperienced groups on any of these tests. Matching test 1 was found to predict significantly the test scores of matching test 2 (degree of freedom = 1, 28; $F = 5.51$; $P \leq 0.026$).

In conclusion, most of the persons in this sample were responsible for aspects of occupational respiratory protection and had relatively little prior formal training in this area. The trainees achieved a mean score of 76.3% on the Comprehensive Multiple Choice Test, which measures a combination of factual knowledge and decision logic involved in selecting respirators for specific contaminants. The tests are reliable, short, and are teaching devices, as well as performance measures useful for documenting the achievement of course objectives. The trainees reported that they liked and learned from taking the tests. Most of the trainees felt that the tests would be useful for teaching other workers at their companies.