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Methodological Issues for Intervention Research in Occupational Health and Safety

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This article presents a brief summary of the nature and extent of intervention research being conducted in the area of occupational safety and health. Articles were classified either as engineering, administrative, or behavioral, according to the type(s) of interventions that were evaluated. Findings suggest that many of the intervention studies conducted lacked a theoretical basis, used small samples, and tested interventions lacking the intensity to cause the desired change. Most study designs were either nonexperimental or quasi-experimental. Recommendations for conducting future research are presented. © 1996 Wiley-Liss, Inc.*

KEY WORDS: intervention research, occupational safety, occupational health, methodology, literature review

INTRODUCTION

During the past 40 years, knowledge of the causes of work-related disease and disability has grown dramatically [Levy and Wegman, 1988; Rom, 1992]. However, research on the application of this knowledge and on ways to evaluate occupational health and safety interventions has been sparse. This gap now needs to be filled. Both the growing concern for public health outcomes and the increased interested in the cost-effectiveness of intervention options are setting the stage for a closer look at how intervention research is conducted in the occupational health and safety field.

METHODS

In an effort to identify the nature and extent of intervention research already being conducted in this area, we reviewed the existing published scientific literature [Goldenhar and Schulte, 1994]. Using a number of keywords to identify relevant articles, we examined three computerized databases: NIOSHTIC (a database that includes scientific articles and reports generated at NIOSH), PSYCH-ABSTRACTS, and the WILSON SOCIAL SCIENCE INDEX. We garnered and reviewed 34 articles published between 1988 and 1993. The review was not meant to be exhaustive but rather was intended to identify representative articles presenting intervention research across the spectrum of industrial categories, including agriculture, construction, manufacturing, mining, service, and health care.

Next, based on the focus of the intervention in the study, we classified the articles into three categories: engineering, administrative, or behavioral.

ENGINEERING INTERVENTIONS

Engineering interventions are engineered or physical manipulations of sources for occupational hazards or routes of exposure to them. Researchers have used engineering-based interventions to address many occupational health and safety issues, including ergonomics injuries: adjusting keyboards and erecting barriers for grocery express-stand workers [Orgel et al., 1992]; designing a mechanical support system for construction workers [Wos et al., 1992]; modifying patients' toilets and showers to lessen the patient-lifting risk for nursing home personnel [Garg et al., 1992]; sick building syndrome [Menzies et al., 1993; Tam-

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blyn et al., 1992]; and various occupationally related exposures, including chemicals [Kercher and Mortimer, 1987]; bodily fluids [Hamer, 1992]; soaps, [Kolari et al., 1989]; contaminated needles [Sellick et al., 1991]; noise [Fairfax, 1989]; heat [White et al., 1991], and nicotine [Ghosh et al., 1991].

ADMINISTRATIVE INTERVENTIONS

Administrative interventions are management initiatives that modify a worker's work process or work exposure, or both [McGlothlin, 1988]. Some examples would be introduction of work practices, such as job rotation [Kolari et al., 1989], slower line speed, and better work/rest scheduling, as well as monitoring work areas, invoking standard operating procedures and job enlargement. Training is often classified as an administrative intervention [Harrison, 1989; LaMontagne et al., 1992; Michaels et al., 1992; Hugentobler et al., 1990].

BEHAVIORAL INTERVENTIONS

Behavioral interventions attempt to influence workers' and employers' attitudes, knowledge, beliefs, or behaviors with respect to work-related hazards or disease. Behavioral strategies targeting occupational health and safety typically include implementing informational or educational campaigns, training workers to wear personal protective equipment [Ewigman et al., 1990; Silverstein et al., 1988] and behavior modification techniques such as feedback and incentives, all aimed at encouraging health and safety-related behavior [Videman et al., 1989; Versloot et al., 1991; Kamwendo and Linton, 1991; Hilyer et al., 1990; Ferguson et al., 1989; Porru et al., 1993; Saarela et al., 1989). Worksite smoking cessation programs are typically classified as behavioral interventions as well. Although these programs are targeted at changing individual health behavior, another goal is to reduce nonsmoking coworkers' exposure to second-hand smoke.

The broad methodologic topic areas covered in analyzing these articles include (1) the theoretical bases for studies, (2) characteristics of interventions, (3) study designs, (4) subject selection, (5) measurement issues, and (6) analyses. Each of these areas is discussed below.

THEORETICAL BASIS FOR THE STUDIES

Most of the intervention studies we reviewed were not theory driven, although some were. Specifically, researchers did not provide any description of the possible causal processes involved between the intervention and the expected or desired outcome. Rather, the research took more of a "try it and see" strategy based on the researcher's own intuition and experience [Campbell, 1986]. Although clearly the development of engineering controls is based on engineering theory or principles, their implementation in the field was typically not evaluated from a theoretical perspective.

Lack of theory-driven research limits our understanding of how an intervention works, which intervening or mediating variables are important, and what interactions may take place between the study subjects and the setting characteristics. As Mark Lipsey [1993] notes, theory-based research has the greatest potential to support inferences about new and successful interventions. Such research also provides a conceptual framework for refining and improving existing hazard control methods as well as helping researchers design studies that provide more interpretable and generalizable results.

INTERVENTION CHARACTERISTICS

Most of the studies reviewed suffered from one or more of these issues: short duration of intervention exposure, limited exposure to intervention (reduced frequency), and lack of power or intensity of intervention to make a difference. These issues are discussed in detail in other articles in the Journal.

The National Institute for Occupational Safety and Health (NIOSH) recommended control implementation hierarchy states that with respect to eliminating or reducing worker exposure to hazards, engineering controls are preferred and should be used as the first line of defense, followed by administrative controls, and finally behavioral controls, including the use of personal protective equipment) [NIOSH, 1988; OTA, 1985]. However, it is likely that implementing only one of the three types of control intervention strategies is less effective than targeting multiple levels [Cohen, 1987; Vojtecky, 1988; Sloan, 1987]. Thus, combining behavioral procedures with existing engineering controls may improve worker protection, while engineering controls alone are unlikely to prevent the development of work-related diseases and subsequent mortality because they cannot address all factors responsible for worker health and safety [Vojtecky, 1988].

Even the most innovative engineering controls will be ineffective if workers do not know how to use them or have some reason to avoid using them [Cohen, 1987]. For example, rollover protection devices are often misused or not used by farmers. In fact, it is possible that implementation of some types of engineering controls without worker involvement may actually create worker resistance. Focusing on worker behavior while excluding other technical and organizational variables is probably similarly unproductive [Sloan, 1987]. In the studies reviewed, the interventions were typically designed to address only one of the levels of the hierarchy, with several exceptions [Garg and Owen, 1992; Sellick et al., 1991; Fairfax, 1989].

Finally, it is important to target interventions to address specific problems and specific audiences. One way to accomplish this is through a health surveillance program that can be used (1) to identify individual cases of occupational illness or injury; (2) to target the research appropriately from these data; and (3) to monitor subsequent trends of occupational illness or injury in the populations being followed [Baker and Matte, 1992].

STUDY DESIGNS

Traditionally, intervention study designs have been categorized as experimental with randomly assigned treatment and control groups, quasi-experimental with nonrandomly assigned treatment group and control group, and nonexperimental with only a treatment group and no control group [Cook and Campbell, 1979]. Epidemiologic studies (e.g., cross-sectional, case-control, cohort, and clinical trials) can also be included within the categories described. In our review, nonexperimental designs with no control group or quasi-experimental designs without random assignment were typically the methods of choice.

Although the study designs for research should be as similar as possible to a true scientific experiment [Fisher, 1935; Feinstein, 1977; Lilienfeld and Lilienfeld, 1980], it often is not feasible when conducting (occupational health) field research [Kish, 1987]. Nonexperimental research designs are not useful for causal inference and a quasi-experiment with nonrandom comparison groups or with longitudinal data collection to determine intervention effects over time would be the next best choice [Kish, 1987; Cook and Campbell, 1979]. If nonexperimental procedures are the only alternative, researchers should acknowledge the limitations for inferring cause and they should discuss possible rival explanations for their findings and acknowledge factors that could not be excluded by the study design [Kerlinger, 1986; Cook and Campbell, 1979].

Even when randomization is used, questions remain: who will get the intervention and who will not? Will treatments found to be beneficial ultimately be made available to nonintervention or control groups? If an intervention proves to be beneficial, withholding it from recipients in need is an important ethical issue. However, if the effectiveness of an intervention is unknown, this issue is less powerful. One solution is to compare several interventions of equal or similar desirability but of unknown effectiveness across groups, not withholding at least some form of an intervention from any one group [Cook and Campbell, 1979].

Finally, replication is used to confirm study results or suggest that more research is needed [Kish, 1987, p. 52]. If the results are similar across situations, this adds stronger confirmation than would have been achieved using a single site. If the results are not confirmed, this gives some "healthy skepticism" to research that might have been claimed a success. However, failure to replicate results may also be due to other unique and unmeasured organizational variables.

SUBJECT SELECTION AND NUMBER

Two important issues related to sampling are how should subjects be selected (randomly select? volunteers?) and how many subjects should be selected? When recruitment was discussed in the studies reviewed, subjects had most often volunteered to participate. In most occupational intervention studies, employees were recruited as volunteer participants. As such, they can drop out of the study at any time. This method of recruitment almost certainly results in selection bias. Are the volunteers different from nonvolunteers? Are nondropouts different from dropouts? This bias could clearly affect the interpretation and generalizability of the findings. Ways of addressing the dropout issue include determining if the rate of attrition is equal in all groups, or ascertaining why participants dropped-out, or using pre-test information to determine if the subjects remaining in the groups are similar. For ethical reasons, volunteer recruitment is likely to remain the prominent method of obtaining subjects for field-based occupational intervention projects.

Researchers must also determine how many subjects are necessary to detect a post-intervention difference if there is one. This is an issue of having enough statistical power in the design [Cook and Campbell, 1979]. If adequate power is unattainable, the researchers should discuss this as a study limitation. Clearly, larger sample sizes are preferable for reducing sampling error and, therefore, increasing the accuracy of the calculated statistics. Some of the sample sizes in the studies reviewed were small; others were large. None of the studies discussed the issue of statistical power.

MEASUREMENT INSTRUMENTS

The studies reviewed used either objective or subjective measures to answer the specific research questions. Very few psychosocial variables were included. Most importantly, the issues of reliability and validity were not discussed. Including information on reliability and validity of the instruments is critical. Without it, new researchers will have to "reinvent the wheel" and cross-study comparisons will not be possible.

Researchers must design reliable and valid tools to measure outcomes appropriately. For example, if an investigator develops a program to increase employees' use of protective equipment against lead, actual use of protective equipment should be measured directly either by observation or self-report, to determine whether the intervention was effective in increasing use. Measuring blood lead levels alone might not be appropriate for the stated research task

(although it might shed light on whether the equipment itself was useful in protecting worker health).

ANALYSIS

In the studies reviewed, descriptive statistics, including lists, frequencies, and percentages, were typically used to describe findings from the engineering or administrative studies. For example, sound level meter and dosimetry readings [Fairfax, 1989], as well as charted mean heart rate and body temperatures [White et al., 1991] were measured and reported. In addition, regression techniques, multiple group differences using ANOVA and ANCOVA, and change scores have been used to detect differences before and after a behavioral intervention. As this area of research progresses, a number of analytic issues need to be addressed.

One method would be to collect more qualitative data to identify underlying factors related to behavioral and organizational change. The distinction typically made between quantitative and qualitative approaches is that while quantitative data show patterns of distribution and association, qualitative data are useful for showing process and meaning behind those identified associations. The two traditions do, however, have a common goal which is to improve the human condition. In our review, some authors who collected qualitative data stated that they were able to obtain a greater understanding of the problems and needs of the worksite, as well as guidance for developing and evaluating the interventions [Hugentobler et al., 1992]. There is a current belief that combining qualitative and quantitative methods would be ideal for advancing research agendas [Steckler, 1992].

Finally, at least one nonmethodological issue is often overlooked in intervention research—cost considerations, which can limit intervention, population, and location choices [Rossi and Freeman, 1993; Patrick and Erickson, 1993]. Issues such as cost-effectiveness, cost-utility, and cost-benefit analyses allow researchers to compare both the costs and the benefits of implementing no intervention, of implementing different types of interventions, or of addressing different problems altogether. Determining the total program cost, both direct and indirect, should be included in the economic analysis and should include items such as personnel, equipment, space, lost time from work, and travel. One likely reason why cost analyses are typically not conducted is that it is very difficult to convert all costs and all benefits into the same measurement terms. However, methods for dealing with cost issues do exist and need to be more widely used.

CONCLUSION

It is true that more occupational health and safety intervention research focusing on preventing illness and injury needs to be conducted. It should be an integral part of a large-scale research agenda that uses a variety of intervention types and conducts research in various industries and occupations. Conducting this type of research is difficult and time-consuming; however, without increasing the number and methodological rigor of these studies, it will be difficult to identify effective intervention methods and confidently encourage their use.

One way to proceed is to conduct this research using interdisciplinary teams which include scientists and practitioners trained as epidemiologists, health behaviorists, industrial hygienists, sociologists, clinicians, statisticians, economists, organizational theorists, and engineers, to name a few. Many individuals involved in the traditional occupational health disciplines have no theoretical foundation about behavioral change and organizational dynamics and thus tend to neglect organizational variables, process issues, and conflicting interests that people may have when attempting to change behavior or organizational policies. By using a more interdisciplinary approach, a stronger foundation will be developed for conducting intervention research in occupational health and safety.

Finally, as key stakeholders in the research outcomes, representatives from labor and management need to be included in research planning and implementation. Some researchers promote the use of approaches, such as "Action Research" and "Participatory Action Research," which include management, supervisors, workers, unions, and researchers to effectively encourage change in an occupational setting [Hugentobler et al., 1992; Israel et al., 1992]. Where unions exist, their involvement can greatly contribute to intervention success or failure. The principles of Action Research and Participatory Action Research have been applied to some occupational interventions, although there are few published studies evaluating the effectiveness of such approaches.

Related to Action Research and Participatory Action research, are principles such as employee empowerment [Widfeldt et al., 1992] and total quality management (TQM) [Deming, 1986]. These models may affect the overall climate for conducting intervention research. In the past, worksite research usually involved a researcher approaching a company and imposing a study on the workers and on the working environment. This model may be inappropriate for companies attempting to incorporate the TQM and empowerment goal of enhanced employee participation. Rather, researchers will be successful in conducting studies only if they include both labor and management in the planning of the study, in selecting the interventions, as well as in recruiting and selecting subjects. The research will be valuable and usable only when investigators have insight into the interests and motivations of others in the system and into the roles that they consciously or inadvertently play [Weiss, 1993].

REFERENCES

Baker EL, Matte TP (1992): Surveillance of occupational illness and injury. In Halperin W, Baker EL (eds): "Public Health Surveillance." New York: Van Nostrand Reinhold, pp 178–194.

Campbell DT (1986): Relabeling internal and external validity for applied social scientists. In Trochym WMK (ed): "Advances in Quasi-experiment Designs and Analysis. New Directions for Program Evaluation." No. 31. San Francisco: Jossey-Bass.

Cohen A (1987): Perspectives on protective behaviors and workplace hazards. In Weinstein ND (ed): "Taking Care: Understanding and Encouraging Self-protective Behavior." Cambridge: Cambridge University Press, pp 299–322.

Cook TD, Campbell DT (1979): "Quasi-experimentation: Design and Analysis Issues for Field Settings." Boston: Houghton Mifflin.

Corn M (1984): Public health approaches to chronic disease in the workplace and the environment: The role of environmental control technologies. Quasi-experimentation: Design and analysis issues for field settings. Arch Environ Health 39:235–240.

Deming WE (1986): "Out of the Crises." Cambridge: MIT-CAES.

Ewigman BG, Kivlahan CH, Hosokawa MC, Horman D (1990): Efficacy of an intervention to promote use of hearing protection devices by firefighters. Public Health Rep 5:53–59.

Fairfax RE (1989): Noise abatement techniques in Southern pine sawmills and planer mills. Am Ind Hyg Assoc J 50:634–638.

Feinstein AR (1977): "Clinical Biostatistics." St. Louis: CV Mosby.

Ferguson KJ, Gjerde CL, Mutel C, Donham KJ, Hradek C, Johansen K, Merchant J (1989): An educational intervention program for prevention of occupational illness in agricultural workers. J Rural Health 5:33–47.

Fisher RA (1935): "The Design of Experiments." Edinburgh: Oliver & Boyd.

Garg A, Owen B (1992): Reducing back stress to nursing personnel: An ergonomic intervention in a nursing home. Ergonomics 35:1353–1375.

Ghosh SK, Gokani VN, Doctor PB, Parikh JR, Kashyap SK (1991): Intervention studies against "green symptoms" among Indian tobacco harvesters. Arch Environ Health 46:5:316–317.

Goldenhar LM, Schulte PA (1994): Intervention research in occupational health and safety. J Occup Med 36:763–775.

Hamer AJ (1992): Hazards to surgeons in trauma and elective orthopaedic surgery: Use of an electronic device to warn of intraoperative glove perforations. J Hosp Infect 309–311.

Harrison RK (1989): Hearing conservation; implementing and evaluating a program. AAOHN J 37:107–111.

Hilyer JC, Brown KC, Sirles AT, Peoples L (1990): A flexibility intervention to reduce the incidence and severity of joint injuries among municipal firefighters. J Occup Med 32:631–637.

Hugentobler MK, Robins TG, Schurman SJ (1990): How unions can improve the outcomes of joint health and safety training programs. Labor Studies 14:16–38.

Hugentobler MK, Israel BA, Schurman SJ (1992): An action research approach to workplace health: Integrating methods. Health Ed Q 19:55–76.

Israel BA, Schurman SJ, Hugentobler MK (1992): Conducting action research: Relationships between organization members and researchers. J Appl Behav Sci 28:74–101.

Kamwendo K, Linton SJ (1991): A controlled study of the effect of neck school in medical secretaries. Scand J Rehabil Med 23:143–152.

Kercher SL, Mortimer VD (1987): Before and after: An evaluation of engineering controls for ethylene oxide sterilization in hospitals. Appl Ind Hyg 2:7–12.

Kerlinger F (1986): "Foundations of Behavioral Research." New York: Holt, Rinehart and Winston.

Kish L (1987): "Statistical Design for Research." New York: John Wiley & Sons.

Kolari PJ, Ojajari J, Lauharanta J, Makela P (1989): Cleansing of hands with emulsion—a solution to skin problems of hospital staff. J Hosp Infect 13:377–386.

LaMontagne AD, Kelsey KT, Ryan CM, Christiani DC (1992): A participatory workplace health and safety training program for ethylene oxide. Am J Ind Med 22:651–664.

Levy BS, Wegman DH (eds) (1988): Occupational health. "Recognizing and Preventing Work-related Disease." 2nd Ed. Boston: Little Brown.

Lillienfeld AM, Lilienfeld DE (1980): "Foundations of Epidemiology." 2nd Ed. Cambridge: Oxford University Press, pp 191–288.

Lipsey MW (1993): Theory as method: Small theories of treatment. N Directions Program Eval 57:5–39.

McGlothlin JD (1988): An ergonomics program to control work-related cumulative trauma disorders of the upper extremities. Doctoral dissertation. Ann Arbor: University of Michigan.

Menzies R, Tamblyn R, Farrant JP, Hanley J, Nunes F, Tamblyn R (1993): The effect of varying levels of outdoor-air supply on the symptoms of sick building syndrome. N Engl J Med 328:12:821–812, 877–878.

Michaels D, Zoloth S, Bernstein N, Kass D, Schrier K (1992): Workshops are not enough: Making right-to-know training lead to workplace change. Am J Ind Med 22:637–649.

National Institute for Occupational Safety and Health (1988): Comments on the Occupational Safety and Health Administration request for comments and information on general safety and health programs. 20 CFR Parts 1910, 1915, and 1918. Docket No. C-02.

Office of Technology Assessment (1985): "Preventing Illness and Injury in the Workplace (OTA-H-256)." Washington, DC: US Congress, pp 175–185.

Orgel DL, Milliron MJ, Frederick LJ (1992): Musculo-skeletal discomfort in grocery express checkstand workers: An ergonomic intervention study. J Occup Med 34:815–818.

Patrick DL, Erickson P (1993): "Health Status and Health Policy: Quality of Life in Health Care Evaluation and Resource Allocation." New York: Oxford University Press.

Porru S, Donato F, Apostoli P, Coniglio L, Duca P, Alessio L (1993): The utility of health education among lead workers: The experience of one program. Am J Ind Med 22:473–481.

Rom WN (ed) (1992): "Environmental and Occupational Medicine." 2nd Ed. Boston: Little, Brown.

Rossi PH, Freeman HE (eds) (1993): "Evaluation, A Systematic Approach." Newberry Park, CA: Sage, pp 215–260.

Saarela KL, Saari J, Aaltonen M (1989): The effects of an informational safety compaign in the shipbuilding industry. J Occup Accidents 10:255–266.

Sellick JA, Hazamy P, Mylotte JM (1991): Influence of an educational program and mechanical opening needle disposal boxes on occupational needlestick injuries. Infect Control Hosp Epidemiol 12:725–731.

Silverstein BA, Armstrong TJ, Longmate A, Woody D (1988): Can inplant exercise control musculoskeletal symptoms? J Occup Med 30:922–927.

Sloan RP (1987): Workplace health promotion: A commentary on the evolution of a paradigm. Health Ed Q 14:181–194.

Steckler A, McLeroy KR, Goodman RM, Bird ST, McCormick L (1992): Toward integrating qualitative and quantitative methods: An introduction. Health Ed Q 19:1–8.

Tamblyn RM, Menzies RI, Tamblyn RT, Farant P, Hanley J (1992): The feasibility of using a double blind experimental cross-over design to study interventions for sick building syndrome. J Clin Epidemiol 45:603–612.

Versloot JM, Rozeman A, van Son AM, van Akker veeken PF (1991): The cost-effectiveness of a back school program in industry: A longitudinal controlled field study. Spine 17:22–27.

Videman T, Rauhala S, Lindstrom K, Cedercreutz G, Kamppi M, Tola S, Troup JDG (1989): Patient-handling skill, back injuries, and back: An intervention study in nursing. Spine 14:148–156.

Vojtecky MA (1988): Education for job safety and health. Health Ed Q 15:289–298.

Weiss CH (1993): Where politics and evaluation research meet. Eval Pract 14:93–106.

White MK, Glenn PS, Hudnall J, Rice C, Clark S (1991): The effectiveness of ice- and freon-based personal cooling systems during work in fully encapsulating suits in the heat. Am Ind Hyg Assoc J 52:127–135.

Widtfeldt AK, Widtfeldt MA (1992): Total quality management in American industry. AAOHNJ 40:311–325.

Wos H, Lindberg HW, Jakus R, Norlander S (1992): Evaluation of impact loading in overhead work using a bolt pistol support. Ergonomics 35: 1069–1079.