SECTION II

APPLICATION OF EPIDEMIOLOGY IN OCCUPATIONAL HEALTH

by
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In public health, epidemiology is recognized as the basic diagnostic discipline for populations. This recognition is also true in the field of occupational health where working people are more accessible for epidemiological observation. Occupational health has always suffered from the limited use of the epidemiological approach by occupational physicians and hygienists. This lack reflects on workers' health in several ways: incomplete information on etiological and causative factors of occupational health problems, including effects of chemicals and other single or multifactorial environmental hazards of working people; failure to recognize health trends and to decide on priorities in planning occupational health services; and failure to evaluate the effectiveness of preventive health programmes.

A definite need exists to disseminate epidemiological knowledge among occupational health personnel, occupational and environmental hygienists and toxicologists. A need also exists to improve epidemiological understanding among the workers, management and the general public because scientific findings are useful only to the extent that they can be intelligently applied by those responsible for decision making.

In 1970, the WHO Regional Office for Europe initiated a study on the epidemiology of industrial intoxication in some European countries (1). The study showed the great need for standardization of methods to be able to compare the results of studies in different countries. A great need also exists for more knowledge on the design of epidemiological studies of various occupational health problems. For these reasons, WHO has decided to develop a special programme area on "occupational health epidemiology" in its recent programme of action on workers' health. This programme area includes training courses and seminars, the preparation of manuals and conducting epidemiological health service research in places of employment (2).

Epidemiology may be defined as the study of the relationship of the various factors that influence the occurrence and distribution of a disease or a physiological state in the human community. Epidemiological methods are used for the assessment of health risks arising, for example, from exposure to occupational hazards. If exposure to intensive noise is a hazard, and the occurrence, which means prevalence and/or incidence, of hearing loss among workers exposed is the risk resulting from such exposure, then epidemiology would be the study and analysis of the cause-effect relationship of the various determinants, such as noise level, duration of exposure, etc., in producing this particular effect and the evaluation of the effect's magnitude.

In the history of epidemiology, the epidemiological patterns of infectious diseases depend upon factors that influence the probability of contact between the infectious agent and a susceptible person known as the host. The presence of causative material varies with environmental factors, including temperature and reservoirs. This aspect also applies to noninfectious diseases. For example, whether or not a person develops a specific form of cancer may depend upon the extent of his/her exposure to the carcinogenic agent, the dose and the susceptibility which may be influenced by genetic or immunological factors. For example, carbon monoxide, carbon tetrachloride and hook worm are carcinogenic agents. Host factors include age, sex, physiological state (nutritional status and fatigue), background of health (e.g. anaemia) and individual susceptibility. Examples of environmental factors are the mode of entry (inhalation, ingestion or skin contact) and physical factors such as heat.

The epidemiologist is interested in the occurrence of disease by time, place and persons. He/she tries to determine whether or not an increase or decrease of the disease has occurred over time or by geographic location (or work site) and whether or not the individual characteristics of persons influence the occurrence and magnitude of a particular state of health. Another way of defining epidemiology identifies three main elements: a science (which, when applied, becomes a discipline) rather than simply a method dealing with the occurrence of a particular state of health, in the negative or positive sense, and concerned with humans, not other animals or plants (3).

some general consideration should be given to epidemiology before going into its application in occupational health, particularly occupational toxicology.

General Purposes of Epidemiology

Epidemiology has three main purposes. First, it provides data that can, together with some other basic information on, for example, experimental toxicology or microbiology, identify the causes and etiology of disease. Such data, for example, are provided by etiological studies of bladder tumours among workers exposed to betanaphthylamine and analine. Death rates from bladder tumours within chemical plants were compared with similar rates from the entire country to determine which chemicals and, to some extent, what degree of exposure resulted in more bladder tumours among the workers than would have been expected if no special risk were involved (4).

Second, epidemiology proves or disproves a hypothesis developed on the basis of impressions from clinical practice or from experimental studies that a certain phenomenon is associated with a causative factor or independent from it. For example, potentiation of harmful effects in smokers exposed to particulate matter was at one time a reasonable hypothesis based on the fact that cigarette smoke has a harmful effect on cilia of the bronchi and also causes thickening of the mucous membranes from the prolonged contact of irritant tobacco smoke with the bronchial wall. Several studies by Schilling et al. (5) demonstrated that smokers suffer more from obstructive lung disease in occupational exposure to cotton dust which causes byssinosis in the textile industry. Smoking became further recognized as a factor potentiating the carcinogenic activity of asbestos. Studies by Selikoff et al. (6) indicated that nonsmoking asbestos workers had a slightly increased risk of lung cancer whereas cigarette smokers had a much higher risk of developing lung cancer, as compared to nonsmokers and smokers not exposed to asbestos.

Third, epidemiology provides the basis for the development and evaluation of preventive methods, including those introduced in the environment, in personal protection or early diagnosis of deviation from normal health. The evaluation role of epidemiology in health services can be demonstrated, for example, by the evaluation of a particular intervention in the environment to bring down the concentration levels of certain chemicals to which the workers are exposed by further environmental and health monitoring. In addition, the possibility exists to compare various means of control (e.g. ventilation against the use of masks), with various cost implications, to minimize the occurrence of a disease.

In the national planning of health services, epidemiological surveys have often been used to determine specific needs in personnel training, laboratory facilities and other functions including research and legislative interventions (7).

Uses of Epidemiology in Occupational Health

Establishing and revising occupational exposure limits

A more detailed examination of the relationship between prevalence and severity of disease and levels of exposure to a causal agent makes possible the determination of "exposure-effect" and "exposure-response" relationships[a] in the form of a curve from which "exposure limits" are derived. Many existing "exposure limits" have been based on inadequate data from animal experiments and routine human observations. Reliable epidemiological studies of workers and their exposure to contaminants provide the most valid data on which to base permissible levels. Good examples are those for cotton dust (9), lead, cadmium and mercury (8).

In order to draw reliable conclusions on exposure-effect and exposure-response relationships, the prevalence and severity of disease, or its early manifestations, must be related to exposure levels. Measurements of exposure to a harmful agent should include its concentration,

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[a] "Exposure" may be used in preference to dose. It is the amount of the agent taken up by the body per unit time over a period of time (8). A dose or uptake/response relationship indicates the relationship between the uptake or level of exposure to a contaminant and the proportion of individuals affected.

characteristics (such as particle size in the case of dusts), duration and other concomitant exposures. Current exposures can be measured at the time of the investigation, but data on past exposures may not be available. From existing information and the subjective opinions of management and workers, a crude classification into light, moderate and severe exposures may be possible and thus enable the extent of the risk to be assessed. Tentative hygiene standards can be established until more accurate data are available (10).

Studying "normal values" and their recognition

In studies in which the aim is to discover early adverse effects of work exposure, the normal range of function of the organ system being investigated (e.g. lung in the case of respiratory disease, liver for exposures to hepatotoxins and the inner ear for noise exposures) must be known. Normal ranges can only be derived from epidemiological studies of representative but healthy populations. Assessment of risk of occupational respiratory disease depends increasingly on lung function measurements and comparison with predicted normal values. A world study of normal values of lead and mercury among nonexposed populations was conducted by the World Health Organization (WHO) in 1965 (11).

Identifying work factors that promote health

As early as 1950, a joint committee of WHO and the International Labour Office recognized the promotion of health and wellbeing as one of the aims of occupational health (12). This aim has been neglected in favour of the prevention of sickness and injury - largely because positive health and wellbeing are difficult to define and measure and health personnel are not trained in this area. Attempts to quantify physical wellbeing have been made by measuring physiological function and the absence of the precursors of disease. Mental wellbeing, or its absence, which is one of the most important human problems in modern industry, is generally evaluated negatively in terms of mental and psychosomatic disorders, absenteeism, alcohol abuse, labour turnover, dissatisfaction and social unrest. Psychosocial and physical factors related to these disorders may be identified by epidemiological methods. In this way, the effects of work on wellbeing can be investigated. The next step forward is likely to be a change in emphasis from negative to positive aspects in attempts to identify sources of people's good health (13).

Providing information on community health problems not work related

The analysis of the daily experience of an occupational health service permits the early recognition of epidemic outbreaks of diseases, such as influenza, and can give an indication of the occurrence of the disease in the general population. If workers are considered a representative sample of the adult population, their general health patterns may serve as indicators of the health status of the community.

Where occupational health is an integral part of total medical care, even better opportunities exist for investigating community health problems. Occupational health services may also participate in randomized controlled trials for various vaccines and, if possible, in intervention trials for heart disease and hypertension.

Types of Epidemiological Study

Descriptive epidemiology

Descriptive epidemiology describes situations relating to mortality, morbidity, sickness absence, etc., at different places and times for different groups of people. Descriptive epidemiology is the basic activity of epidemiology within occupational health. It is usually the first stage which can then be developed into a cross-sectional, case control or cohort study or an experimental epidemiological study (intervention epidemiology). Examples can be cited from analyses of official statistics of mortality, trade union records, records of occupational health services and other health records. Some of the best-known examples are cardiovascular diseases in carbon disulfide workers, increased mortality from lung cancer in chromate workers, mortality from bladder cancer among azodye-exposed workers and the observations of mortality from lung cancer among smokers.

At times the use of national mortality data or general medical records has serious limitations, especially some degree of inaccuracy about the cause of death and the precise occupation. Other disadvantages stem from the fact that national mortality rates may be given for a whole industry and not for its separate trades - let alone specific work exposures and their magnitude and duration.

Cross-sectional studies

Cross-sectional studies constitute a more dynamic form of descriptive epidemiology which describes the state of health and ill-health in various sectors of the population by type of exposure and other human (age, sex, habits, etc.) and general environmental factors at a certain point in time. Examples of studies include the types and magnitude of health problems or prevalence of various occupational or other diseases in occupational sectors. As in all epidemiological research, such studies should first identify the aims and tasks, make the design (e.g. a stratified sample to represent various parameters), standardize methods of environmental and health examination, implement the methods, collect the data and evaluate the results.

Case control studies (etiological epidemiology)

The aims of case control studies are to carry out tests and form hypotheses on the etiology of specific occupational or work-related diseases. Normally, a number of cases forms the basis for hypothesis. The cases collected should be matched with controls with respect to sex, age, genotype, smoking habits, etc. Blind examination of exposed and control workers is advisable to avoid observer bias. An analysis of exposure(s) in retrospect and possible causation is then made. Examples include lung function studies in byssinosis, studies of mesothelioma and asbestos, and studies of angiosarcoma of the liver and vinyl chloride. The study of two factors at the same time, such as asbestos and smoking or malnutrition and exposure to certain pesticides, may be useful.

Cohort studies (prospective or longitudinal studies)

The principle is to study an occupational group exposed to a risk factor and compare it with the general population not exposed to this risk factor. The study will usually take several years and is useful for studying long-term effects. The advantages of this method are that a well-defined risk factor, or several risk factors at the same time, can be studied and that the same individuals can be observed over a long period. This method is especially useful for occupational health as the cohort, the working population under observation by the occupational health services, is already available. This method is useful for studying occupational diseases as well as work-related diseases. The disadvantages of this method are that rare symptoms or rare diseases cannot be studied and that the study will take a long time and is usually costly.

Experimental epidemiology (intervention epidemiology)

The role of experiments in biological research should be considered, together with their advantages and limitations, especially with regard to experiments with humans. The aims of these studies are to prevent diseases, to study etiology for preventive purposes and to assess the efficiency of preventive measures. For example, intervention leading to the reduction of cases of heart disease would support a hypothesis claiming that the particular factor removed in the invervention study is causative.

A need for pilot studies usually exists. Intervention may be directed towards the human being (the worker), the work involved or to the interaction between work and humans. One should use "natural" experiments, such as major changes in production, for studies in experimental epidemiology.

This type of study is a cohort study. The population under observation may change during the observation time, as, for example, when older workers leave the group. The use of dynamic cohorts may be necessary. The exposure should be evaluated. Ways in which the work environment has been improved through intervention should be studied, and the results considered in relation to a series or endpoints. The effect of an intervention should be determined by means of measurements before and after it takes place. Baselines should, therefore, be established for exposure and workload on the one hand and health and physiological functions on the other. The effects on health after intervention should be studied, e.g. the effects on morbidity or sickness absence. The approach to this type of study should be interdisciplinary, e.g. the study on the effect of respirable or total cotton dust, the use of occupational health services to study public health problems, such as the effect of influenza vaccinations on an industrial population, or the application of preventive measures against cardiovascular diseases in an industrial population.

It is important to use epidemiological methods to study specific long-term effects such as carcinogenic, teratogenic and mutagenic effects.

Both environmental evaluation and health evaluation have their place in epidemiology; they are not mutually exclusive but, indeed, complementary. Environmental evaluation can be used only to anticipate the risk and determine the nature and behaviour of causative factor(s). Environmental measurements and assays are reliable indicators of health hazards. Ways to evaluate a health hazard or a hazardous exposure include air analysis in various ways with dynamic or static methods and biological monitoring of total body burden or absorption. For an adequate evaluation, attention should be given to describe:

- the source of exposure;
- the material or behaviour of the substance in the environment;
- the purity of exposure or the multitude of substances, e.g. as in mixtures;
- the changes in concentration levels over time; and
- the duration of exposure in various work sites.

In health evaluations, this concern has to be carried out in a standardized manner with questionnaires, batteries of tests and examination procedures.

Tests of early health effects must be distinguished from biological tests indicative of exposure, e.g. blood trichloroacetic acid levels are indicative of exposure and absorption of organochlorine compounds, whereas electroencephalographic abnormalities may be significant in the case of early adverse health effects.

Tests must comply with certain criteria, including validity which constitutes both sensitivity and specificity. Validity is the extent to which subjects in case control studies are correctly classified, i.e. the extent to which a situation as observed reflects the true situation. It consists of sensitivity and specificity.

Sensitivity is the extent to which persons who truly manifest a particular characteristic are so classified. The probability of false negative data is low. For example, the examination of workers exposed to inorganic lead by means of a questionnaire will only result in many subjects being declared healthy (a false negative data) whereas laboratory examinations (e.g. haemaglobin determination, ALA in urine) may reveal many more affected workers.

Specificity is the extent of which persons who do not manifest a particular characteristic are correctly classified. The probability of false positive data, is low. For example, workers who do not have manifest lead poisoning will be expected to have ALA in the urine at concentrations of less than 10 mg/l, and workers without noise-induced deafness will not be expected to show dips in their audiograms.

Sensitivity and specificity may be expressed in quantitative terms. In one method, each term is expressed on a scale ranging from zero to one (maximum), the "validity" being the sum of the two values, thus ranging from zero to two. Many examples on the use of this approach in epidemiological toxicology are available; a validity of 1.80 was regarded as an indication of a valid prediction.

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