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Methods of Exposure Assessment for Community-Based Studies: Aspects Inherent to the Validation of Questionnaires

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Possible sources of inaccuracy in the data collecting stage and various methods to evaluate the quality of data are reviewed. Interviews of surrogates are often used in epidemiological studies, even if they are likely to introduce a higher level of inaccuracy than when subjects themselves are questioned. The preliminary results of a study on the accuracy of work history information obtained from the relatives of the subjects in a case–control study of lung cancer are presented. A mail questionnaire requested the same information from the surrogates as was asked of the original cases. Accuracy was measured for major occupational categories by evaluating sensitivity and specificity and calculating *k* statistic agreement. Some major occupational categories, which are well represented and traditional in the study area, showed a high specificity and sensitivity and a high *k* agreement.

Various methods of exposure identification are reviewed. Job exposure matrices generated *a priori* or *a posteriori* were obtained through the involvement of a panel of industrial hygienists. The contribution to development of job–exposure matrices using lists of workplace chemicals identified in the course of periodic or continual local surveys is discussed. **Miligi, L.; Masala, G.: Methods of Exposure Assessment for Community-Based Studies: Aspects Inherent to the Validation of Questionnaires. Appl. Occup. Environ. Hyg. 6:502–507; 1991.**

Introduction

In epidemiological research, one of the most frequently used instruments for collecting data is the questionnaire. It is usually the only source of information on exposures in community-based studies. The quality of information depends not only on the characteristics of the questionnaire, but also on the interview process itself and on subjects from whom the information is obtained. Each of these aspects could possibly be a source of inaccuracy, which leads to misclassification of exposure. Such misclassification, if random among the cases and controls, tends to reduce the observed degree of association between exposure and disease.[1,2]

Unfortunately, in epidemiological literature, understanding what impact the development, utilization, and validation of questionnaires has on epidemiologic research, in general, and exposure assessment, in particular, is insufficient. Gordis[3] stressed that too little attention has been given to this point, and compared this lack of knowledge with the field of biochemistry. In this field of research, the "materials" and "methods" sections of published papers generally describe all techniques used in detail, which is in contrast to papers describing epidemiological investigations. Therefore, this paper reviews various approaches to validating questionnaires.

Questionnaires and Interviewing Techniques

Epidemiologic studies and the interpretation of their results cannot be separated from a careful evaluation of the "quality of data." In fact, data of questionable quality can lead to possible biases that will affect the validity of the results.

Both the data-collecting stage and the instruments used can affect data quality. The accuracy of the information obtained is a direct result of the questionnaire structure, the language used, and the attitude of the interviewer. The questionnaire must offer a logical flow of ideas and must reflect certain psychological criteria.[4]

The questionnaire should begin with questions that create a relaxed atmosphere for the person being interviewed. Questions that may make the subject anxious or uneasy (e.g., questions about illnesses) should appear at the end of the questionnaire. The order in which the questions are asked and the language used can affect the information collected. Questions formulated in an unclear manner or with words difficult to understand can lead to misinterpretation or confusion, thereby affecting the quality of the answers. This is especially important for groups of subjects with particular demographic or socioeconomic character-

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istics (old age, low social class, use of dialects).

In the case of face-to-face interviews, an important aspect is the attitude of the interviewers. It must be stressed that the dynamics between the subject and the interviewer may significantly affect the quality of the answers. The interviewer should be able to obtain exhaustive and precise information but should make every effort not to introduce biases. It is essential for the interviewer to be an expert in interviewing techniques and to project professionalism. The interviewer must pose the questions in a clear and precise manner, showing interest in, without intimidating, the subject. In addition, the interviewer should also be able to create an atmosphere of emotional participation and to set the subject at ease to elicit exhaustive responses to specific questions.

Accuracy of Information from Subjects

In spite of careful work in developing better techniques for formulating and using questionnaires, the primary source of information (the subjects) may be, "per se," a source of inaccuracy. Events such as "memory failure" or "recall bias" can act on study subjects and produce inaccurate answers. By formulating questions properly or pointing out key events[5] in the subject's life (e.g., military service, marriage, etc.), the investigator may be able to enhance the subject's ability to remember the past, thereby partially reducing these sources of bias.

Methods of Internal Verification

To help understand the possible sources of bias, a method which could be described as "internal verification" of the instrument being used has been developed. The verification parameters include:

- Completeness (percentage of missing responses).
- Level of detail achieved (e.g., number of job titles reported).
- Incoherent or impossible information (e.g., incoherence in reporting dates of starting and ending jobs).

These parameters test if the type of question elicits a low level of completeness or a high frequency of erroneous answers. If such verification is used in an internal comparison (e.g., between cases and controls or among different interviewers), it is possible to identify the existence of selective differences in quality.[6] The advantage of using these methods, which are simple and inexpensive, is that they allow early verification of the questionnaire used. This verification could be carried out in the pilot phase of the study. The lack of such differences, however, is not sufficient to exclude a low level of quality of data.

Use of External Sources of Validation

Another method which can be used to validate information collected from subjects is the use of an external source for comparing information. The main problem in using this method, however, is finding an external source more valid than the subjects themselves. For certain nonoccupational variables, such as diet, smoking, and alcohol habits, it is quite difficult to find a suitable external source. Similarly, it is especially difficult to find a valid external source that covers the entire occupational history of a worker.

The problem of assessing the validity of an occupational history is often complicated by the inaccessibility or the unavailability of company records. Moreover, employees may be very mobile, particularly in certain industries or geographic areas, which further complicates the validation process.

The few studies available on validating work histories have compared the subjects' interview data with the corresponding information obtained by interviewing employers,[7,8] information recorded in company records,[9] or objective sources of information such as government retirement plan records.[10] In one study,[7] the level of agreement between workers and employers was quite high, especially for information regarding job duties, but it was lower for job titles and duration of employment. In another study,[9] when information furnished by workers was compared with that recorded in company records, there was relatively good agreement, especially with regard to job titles and starting dates; however, the validity of this information decreased with the number of jobs held and with their duration. In another study in which the information obtained from workers was compared with an external source, i.e., the Quebec Pension Plan, there was a mean agreement of 82 percent on employers' names over the 13-year study period.[10]

Surrogate Respondents

Determination of Accuracy of Information

Interviews of surrogates are often used in epidemiological studies; however, their participation is likely to result in a higher level of inaccuracy than when the subjects themselves are used. Nevertheless, in many studies, resorting to surrogates is compulsory, e.g., when study subjects are deceased or mentally impaired. The ability of a surrogate to answer questions depends upon the level of detail desired and the age and the relation of the surrogate to the subject originally involved.[11] Siblings are more competent to respond to questions about nonoccupational factors in the early life of a subject, while a spouse or offspring is more competent to describe events that occurred during adult life.[11] Obviously, the length of time the relatives have lived with the study subject influences the accuracy of the responses.

Some studies have examined the validity of the work history obtained from a surrogate compared to one collected from the subject. In one study,[12] wives, who were interviewed after the death of their husbands, reported significantly fewer jobs than had been reported by the subjects. The concordance of the coded occupational histories between the two sources was approximately 50 percent for occupation and industry; however, the agreement was higher for the last job and usual job held. Another study evaluated the validity of using surrogates to obtain

information on risk factors for neurologic diseases through a questionnaire in a case–control study.[13] In this study, subjects tended to report a greater number of jobs ever held than the corresponding next-of-kin; however, the agreement between subjects and next-of-kin for the last (or current) job held was excellent. When comparing employment histories elicited independently from a sample of middle-aged men and their wives, Coggon[14] found that of 122 occupations detailed by the husbands, only 62 were accurately reported by their partners. In contrast, Pershaghen and Axelson's study[15] shows very good validity (sensitivity, 98%; specificity, 99%) of information regarding employment in smelters obtained from relatives of deceased smelter workers compared with data from employer records. Information on exposures was less accurate in this study when an assessment of arsenic exposure was made through information obtained from the next-of-kins' questionnaires. When compared with company records, the sensitivity was only 40 percent; however, specificity was over 90 percent. Another study found poor concordance with the husbands' reports when wives were asked about specific substances (solvents) to which their husbands were exposed during work. In the same study, an occupation–exposure linkage system found higher agreement on the work history reported between husbands and wives.[16]

A Study of Surrogate Accuracy[17]

The following are the first results of a study on the accuracy of information about smoking habits and work histories obtained from relatives of subjects in a case–control study of lung cancer.[18] The subjects (281 men), incident cases of lung cancer (1981–1983) in the municipalities of Florence and Prato, Italy, were interviewed between 1981 and 1983. In 1987, the closest living relative of the deceased subjects (249) were identified. The following order was used in choosing the substitute subjects: wives, eldest son/daughter, other relatives. Of the 222 next-of-kin identified and located, 25 refused to respond to the questionnaire, resulting in a surrogate study population of 197. The surrogates who answered were primarily wives (73%) and children (19%). Other relatives represented a minor percentage (8%).

Unlike the original study, in which the subjects were interviewed in person, this study used a mail questionnaire. However, the same information asked of the original cases, i.e., smoking habits and work history, was requested. The questions were in the same sequence as in the original questionnaire but were worded in a way that took into consideration the different method of administering the questionnaire.

Preliminary Study Results

The accuracy of information obtained through surrogates about all the jobs ever worked was measured for major occupational categories by evaluating sensitivity and specificity and then calculating the *k* statistic agreement index.[19] The results are shown in Table I. In general, specificity was very high for all the categories, while sensitivity was quite low at times. Some major occupational categories, including textiles and shoes and leather manufacture, showed a high specificity and sensitivity and a high *k*. These categories with high validity are traditional and well-represented industries in the province of Florence. The high validity is very likely due to the general knowledge about these activities in the population of the area. Occupational categories that are not prevalent or traditional in the study area (food processing, electrical, and telecommunications) or that have become less common (agriculture) showed lower sensitivity. However, the *k* statistic shows a moderate agreement. For occupational categories not well defined and not homogeneous (wholesale and retail sales, social and personal services), the specificity was also not very high.

A similar analysis was conducted considering a limited time period in the subjects' lives, i.e., the period from 15 to 24 years before the incidence of the disease. The results are presented in Table II. The selection of this time window was made due to the latency between exposure and occurrence of lung cancer. This analysis found that the specificity remained very high if it did not actually improve. The sensitivity also increased except for agriculture which, in the period chosen, was already decreasing in prevalence as a job in the municipalities.

The percentage of agreement between subjects and surrogates for usual work, considered as the work carried out for the longest time, was also calculated. The percentage of agreement was computed only for 166 pairs: 31 pairs

TABLE I. Validity of Information Obtained from Surrogates, Expressed as Sensitivity, Specificity, and the *k* Statistic (as a measure of agreement) for "Ever Worked" in Major Occupational Categories (only occupations with more than 5 subjects are presented)

Major Occupational Categories	Number of Subjects	Sensitivity	Specificity	*k*
Administrative	23	69.56	94.25	0.60
Police	10	80.00	99.46	0.83
Wholesale and retail sales, social and personal services	52	71.15	88.99	0.60
Transportation	22	68.19	94.86	0.60
Agriculture	29	55.17	95.83	0.56
Food processing	7	57.14	96.84	0.45
Pottery, glass, stone	7	85.71	100.00	0.92
Chemical, drugs, and medicines manufacturing	10	60.00	99.46	0.69
Construction	30	73.33	96.41	0.71
Electricity and telecommunications	7	57.14	98.42	0.55
Gas, water, and heating plants	7	71.43	99.47	0.76
Wood and wood products including furniture	8	62.51	98.94	0.65
Metallurgy, metalworking, metal hot-working and cold-working	30	83.83	97.60	0.82
Textiles	49	95.92	94.59	0.87
Shoe and leather goods manufacturing	9	88.88	99.47	0.88

TABLE II. Validity of Information Obtained from Surrogates, Expressed as Sensitivity, Specificity, and the *k* Statistic (as a measure of agreement) for "Ever Worked" in Major Occupational Categories During the "Time Window" of 15–24 Years before Diagnosis (only occupations with more than 5 subjects are presented)

Major Occupational Categories	Number of Subjects	Sensitivity	Specificity	*k*
Administrative	18	72.22	97.73	0.71
Wholesale and retail sales, social and personal services	35	74.28	94.97	0.70
Transportation	17	64.70	98.28	0.68
Agriculture	7	28.57	98.39	0.31
Metallurgy, metalworking, metal hot-working and cold-working	20	85.00	97.14	0.79
Textiles	42	92.86	97.33	0.89

were excluded due to the difficulty of defining usual work (lack of starting or ending year for one of the jobs performed). The percentage of agreement for the major occupational categories of usual work was 77 percent and for job title, 57.2 percent.

The average duration of employment was not significantly different between subjects (37.6 ± 9.7) and surrogates (35.7 ± 9.9); the Pearson correlation coefficient demonstrated a good agreement (0.52). No significant difference was found for the average number of jobs reported: 1.8 ± 0.9 for subjects and 1.9 ± 0.9 for surrogates.

Recent Methods for Exposure Assessment

Information about work histories utilized in epidemiologic studies ranges from limited information about the occupation and the type of industry to a very detailed job description. The type of information is usually affected by the study design and consequent choice of different strategies in collecting information about work history. One method to identify exposures has been job–exposure matrices (JEMs) generated *a priori* or *a posteriori* obtained through the involvement of panels of industrial hygienists.

Both approaches usually involve a first step consisting of coding the occupation through a classification system. A major problem of coding according to the commonly used systems is that these systems are not based on exposures; rather, they were created for administrative purposes. Occupations cannot be defined in detail nor can occupations be considered together with different exposures. The second step in assessing exposures is to identify and attribute the likely exposures of each job. One such matrix was introduced in the early 1980s by Hoar,[20] which used current *a priori* information on chemicals and other exposures by industry and job title. *A priori* JEMs remain necessarily limited by the fact that exposures may vary widely from worker to worker and from place to place due to differences in processes and specific tasks, work conditions, use of protective equipment, changes over time, etc. *A priori* matrices cannot take into account this individual variability.

Another approach is the *a posteriori* procedure proposed by Semiatycki *et al.*[21] This method involves the examination of each study subject's work history and the detailed information collected from the questionnaire about specific jobs (i.e., department, tasks, materials manipulated, machines used, work organization, work environment, etc.) by one or more experts (chemists, engineers, hygienists) for the purpose of estimating the subject's occupational exposures. It is presumed that this method has better capability in discriminating between exposed and nonexposed than the *a priori* JEM.

A comparison of the efficiency of the two methods has been presented by Macaluso *et al.*[22] using data from a case–control study on lung cancer. In this study, a group of occupational physicians and industrial hygienists reviewed the detailed information about the jobs performed by each subject. With the help of "key questions," the questionnaire provided more detailed information to better identify the exposure. Each subject was assigned to five different categories of probability and intensity of exposure to a limited number of certain or suspected respiratory carcinogens. The same subjects were then assigned to the five categories applying an *a priori* matrix to the occupational histories coded according to ISCO/ILO and ISIC/UN classification systems. Comparing the two methods, the *a priori* JEMs and the *a posteriori* method, the estimates of relative risks for the asbestos-exposed subjects were higher and more precise using the *a posteriori* method. Thus, the use of the *a priori* JEMs may give lower sensitivity and specificity than the *a posteriori* approach; however, the latter method can be very expensive.

A contribution to JEMs can be made using lists of chemicals identified in the workplaces through the course of periodic or continual local surveys. This source of information may improve the classification of exposure if used in defining *a priori* and *a posteriori* matrices.

In some regions of Italy, computerized archives have been established with the primary objective of surveillance of chemical risks in industry; products/substances used in workplaces in these areas are listed.[23] The archives are derived from information received directly from the companies through the use of self-reported forms and inspections of the workplaces. The archives are maintained by industrial hygienists and epidemiologists from the Occupational Health Services or the Epidemiology Units of the National Health Service. Efforts are made to develop a broad knowledge of the chemical composition of each product. Producers of trade products are contacted directly by the retainers of the archives. If applied to epidemiologic studies, these efforts will allow a more accurate assignment of the subjects based on the exposures received. Due to the recent introduction of these archives, the available data have not yet been widely used for developing questionnaires and for improving exposure information on subjects involved in case–control studies.

Using a mathematical model in the context of a case–control study, Segnan et al.[24] evaluated the benefit of using such lists of chemicals in addition to JEMs for the

assessment of exposure versus using JEMs alone. According to the results of this simulation, the authors conclude that a benefit i.e., reduction of misclassification, can be expected from the use of such lists. This is true only if 1) these lists are available for a sufficient time period in the geographic area of interest and 2) the specificity of these lists is high in classifying the "truly exposed" job duties. The use of these lists could reduce misclassification in terms of the chemicals involved and the exposure levels associated with the chemicals.

In a multicentric, case–control study on hematolymphopoietic malignancies and occupational exposure, these lists were used to create questionnaires containing specific questions about exposure and forms explicitly designed for specific occupations. Exposures to solvents contained in products used in industrial and manufacturing activities and exposures to pesticides used in agriculture are being studied.

A complete history of the activities carried out in the occupation is collected (i.e., job duties, name and activities of the company, and the period the subjects worked for a given company). In addition, for each of the jobs, questionnaires were specifically created that provide more detail on technological aspects and working conditions rather than on specific chemicals used. For example, in-depth information for the various crops grown in the area is obtained for the agricultural classification.

The use of these questionnaires for specific occupations provides a noticeable increase in information and, subsequently, in the validity of exposure assessment. The increase of precision in information gathered can reduce the uncertainty area in exposure assessment. For example, the shoe making questionnaire asks about the activities of workers near the subjects. If the subject is a cutter but works very close to a worker who uses adhesives, the subject cannot be classified as a true "nonexposed." This information is not available with *a priori* JEM; however, it is useful to industrial hygienists in the exposure assessment phase.

At the end of the study, the questionnaires are reviewed by a panel of local experts (industrial hygienists, occupational health physicians, and agronomists) to estimate individual exposures, attributing specific chemicals to each job from the information available through the questionnaire, through the local archives listing job/products/substances, and through their own expertise.

Conclusions

The quality of the exposure assignments in epidemiologic studies is affected by the quality of the information obtained in the exposure assessment phase of the study. The validation process of questionnaires cannot be separated from the conception, formulation, and methods used for their administration.

The information obtained from the subjects with the use of questionnaires is also affected by the strategies adopted that, in turn, depend on both the objectives of the research and the resources available. If the aim of the study is, for example, to test hypotheses, it is obvious that, if appropriate resources are available, questionnaires should be developed that will elicit detailed information from the subjects, and strategies should be chosen that maximize the collection of this information (direct interviews, training for interviewers, etc.). If the objective is different (e.g., surveillance) and/or resources are limited, more limited questionnaires, possibly administered by mail, may be appropriate.

It would be useful to circulate questionnaires and have them validated by those involved in epidemiological research. Receiving expert feedback would enable study coordinators to save energy and resources and would increase understanding of the results obtained.

Questions remain, however. Having ensured that the best possible techniques were used, how valid is this information? How can the information be translated into exposures? If the disease under study is quickly fatal and surrogates must be interviewed, which strategy will obtain the best level of information?

If the objective of the study is to test hypotheses, it would be useful to have in-depth information from the subjects themselves, by using questionnaires explicitly designed for specific occupations. The use of cancer or mortality registries may not be appropriate in this case because it may lead to a larger number of surrogates interviewed. If these registries are used, it may be inappropriate to use expensive instruments, such as questionnaires specifically designed for different occupations, when it has been established already that the information obtained may be of poor quality.

The study of surrogates presented here gives encouraging results in terms of validity for those manufacturing activities which are prevalent in the area under study. The results suggest that it is possible to use quick instruments, such as mail questionnaires sent to surrogates, for epidemiologic research, specifically for epidemiological surveillance where the risk has been recognized in the past. From these data, it also appears that jobs in the predominant industries in the study area can be better characterized than jobs in less significant industries. The role of local occupational health services that carry out periodic surveys can be very important in defining exposure. An even better definition of the exposure will be available where biological and environmental monitoring data are maintained by a local service. Furthermore, the use of JEMs based not only on data from the literature but also on local knowledge of exposures in the study area (e.g., experiences or lists of products/substances) could allow a better assessment of exposure in terms of sensitivity and specificity.

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