Agreement of Job-Exposure Matrix (JEM) Assessed Exposure and Self-Reported Exposure Among Adult Leukemia Patients and Controls in Shanghai

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Background *Estimating a person's history of occupational exposure in case-control studies is difficult.*
Methods *Percent agreement between selected self-reported occupational exposures and job-exposure matrix (JEM) exposure assessment for all participants and various subgroups of a population-based case-control interview study of 486 leukemia subjects and 502 healthy controls in Shanghai was evaluated.*
Results *With JEM as the "gold standard," the sensitivities for self-reported exposures ranged from 0.75 to 0.98. However, that for pesticide exposure was 0.44 in subjects >51 years old. Self-reported exposures specificities ranged from 0.87 to 0.99. Agreement between self-reported exposures and JEM assessment was good (kappa coefficients [κ]: 0.48–0.84). Variations in agreement for benzene exposure between males and females as well as between the direct interview and surrogate interview subgroups were observed.*
Conclusions *The levels of agreement between self-report and JEM in this study suggest that self-reported exposures are a suitable method for assessing occupational exposures in this population.* Am. J. Ind. Med. 45:281–288, 2004. *© 2004 Wiley-Liss, Inc.*

KEY WORDS: agreement; job-exposure matrix; self-report; occupational exposures; leukemia; Shanghai

INTRODUCTION

Estimating a person's history of occupational exposure is a difficult task in case-control studies [Stewart et al., 1991; Hsairi et al., 1992] because there are rarely historical records and it is usually necessary to reconstruct occupational exposures from interviews [Stewart and Stewart, 1994]. Questionnaires are often the main source of occupational exposure data in case-control studies. In such interviews, exposures may be directly reported by the subject or inferred from jobs held. Self-reported exposure, though fairly easy to obtain, may include considerable error regarding intensity, frequency, and duration, and may be prone to recall bias. Moreover, subjects often do not know to what chemicals they

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have been exposed [Van der Gulden et al., 1993]. As such, some industrial hygienists believe that exposure assessment based on job title may be more accurate. Under these circumstances, job-exposure matrices (JEM) have been developed to assign exposure status or a probability of exposure for specific agents using job titles and/or job descriptions [Siemiatycki et al., 1982]. A JEM may be defined as a cross-classification between a list of job titles and a list of agents to which persons carrying out the jobs may be exposed [Plato and Steineck, 1993]. Since the initial development of a JEM for case-control studies, hygienists have been improving this approach [Hoar, 1983; Goldberg et al., 1986; Stewart et al., 1990].

JEMs are widely used in occupational epidemiology, particularly when biological or environmental monitoring data are scanty or even in studies where they are not scanty, such as cohort studies. However, as with most exposure estimates, JEMs may be vulnerable to misclassification [Bouyer et al., 1993; London and Myers, 1998]. It has been noted that the accuracy of exposure assessment in a JEM is affected by: (1) lack of an objective lifetime measurement of the exposure; (2) the accuracy and thoroughness of the job description; (3) wide variability within a job title; and (4) the knowledge of experts making the assessment [Stengel et al., 1993; Benke et al., 2001]. Expert review of job histories whenever possible is expected to help minimize potential misclassification of exposure by JEMs [Rybicki et al., 1997]. The JEM has great potential value once developed, because it reduces the cost of exposure assessment in studies and provides an objective way of evaluating exposures [Bouyer et al., 1993].

Several studies have examined the consistency of self-reported occupational exposures and JEM-assessed exposures in different populations [Hsairi et al., 1992; Kromhout et al., 1992]. A study of 1,910 Canadian male cancer patients in 1996 concluded that self-reports of occupational exposure are not sufficiently accurate to warrant their sole use in most community-based studies [Fritschi et al., 1996]. Our study adds to the literature by comparing the self-reported exposure assessment by study subjects to a JEM exposure assessment to evaluate the agreement between the two methods using data from a population-based case-control study of adult leukemia in Shanghai, the People's Republic of China.

MATERIALS AND METHODS

Study Participants

Cases

Cases in this study were identified from the Shanghai Tumor Registry, which began operation in 1963 and has essentially complete ascertainment of all cancers diagnosed in the urban Shanghai area [Parkin et al., 1997]. All residents of urban Shanghai who were newly diagnosed with leukemia (ICD-9 codes 204–208 [WHO, 1997]) at age 15 years or older, from June 1, 1987 to August 31, 1989 were eligible for the study.

Five hundred and thirty-two eligible cases were identified and interviews were obtained for 486 (91.4%) of them. In-person interviews were obtained from 255 cases who were alive, while surrogates gave information on 231 cases who were deceased (N = 194) or too ill to be interviewed (N = 37). A total of 48% of the surrogates were spouses and 50% first-degree relatives. Forty-six (8.6%) eligible cases were not included in the study either because they could not be located (35 cases), or refused to participate (11 cases) [Zheng et al., 1993]. Informed consent was obtained from each subject after the nature of the study had been fully explained.

Controls

Controls were randomly selected from the general population of the city using the comprehensive, population-based resident registry in a two-step control selection process. The resident registry maintains a personal registry card for all adult residents (over age 15) in urban Shanghai. The information on each resident includes his or her name, address, date of birth, sex, and other demographic factors. In the first step, the expected age and sex distribution of cases for years 1987–1989 (the recruitment period of this study) was determined using leukemia incidence data from 1984 to 1985, which was then the most recently available information from the Shanghai Tumor Registry.

This distribution was then used to randomly select 502 potential controls from age- and sex-matched strata of residents as listed in the resident registry. If the first control selected was either not confirmed as eligible or refused to be interviewed, a second control was then chosen using the same method. Only 30 (6.0%) second controls were required, because the first controls could not be located (N = 12), died prior to being interviewed (N = 8), or for other reasons (N = 10) [Zheng et al., 1993]. This gave a 94% response rate among the controls.

Data collection

Trained personnel used structured standardized Chinese questionnaires to interview the cases and controls or their next-of-kin in person. All but ten of the controls were interviewed in person. Information was collected on demographic factors, occupational exposures, lifetime occupational history, family history of cancer, usual dietary habits, tobacco smoking, education, diagnostic X-ray procedures, and specific medications. This report used data from the demographic, personal habits, lifetime job/occupational exposures, and the medical history sections of the questionnaire. The employment data were classified using both industrial and occupational headings defined for the 1982 Chinese population census (Foreign Broadcast Information Services, 1985). The census code grouped industries and occupational headings according to three levels of increasing detail: the major headings reflected general industry or occupation groupings, whereas the two and three digit categories provided finer, more specific classifications of each industry or occupation [Levin et al., 1988].

Exposure assessment

The occupational exposures are benzene, other organic solvents (other than benzene, paints and toluene), pesticides, and electromagnetic fields (EMF). These were assessed using a JEM developed previously by one of the authors (MD). The JEM assigned an overall probability of exposure of none (0), low (1), medium (2), or high (3) to these substances using an algorithm based on a combination of 3-digit job title code and 3-digit industry code combination.

Participants were categorized into 'ever exposed' and 'never exposed' from self-report for each exposure. For the self-report, any 'yes' on the lifetime job history is 'ever exposed.' On the JEM, a low probability of exposure (level 1) or more over the subject's lifetime is 'ever exposed' for the JEM.

Data analysis

For each occupational exposure, the JEM exposure assessment method was compared to the self-reported exposure method by calculating both the percent that agree (proportion of Yes/Yes plus No/No) and the Cohen's kappa coefficient of agreement (κ) between the two methods [Cohen, 1960]. A 95% confidence interval (CI) for each kappa statistic was also calculated. To evaluate agreement for exposure to each occupational agent, sensitivity and specificity values were calculated under the assumption of the JEM used as being the "gold-standard." Sensitivity was defined as the proportion of subjects categorized as exposed to a particular occupational agent by JEM and to which the subject self-reported as exposed to that agent [Bauer et al., 1999]. Specificity was defined, as the proportion of subjects categorized as not exposed by JEM and by their self-report to a particular occupational agent [Bauer et al., 1999]. All analyses were performed using the Statistical Analysis Software (SAS).

RESULTS

The mean age of the study participants was 51.0 years with that of the 486 cases being 51.1 years and that of the 502 controls being 50.8 years. The mean years of education for cases was 8.4 years and for controls was 7.7 years. Neither the mean age nor the mean years of education differed significantly between the cases and controls. The mean household income is slightly higher for controls than for cases but not significantly. The mean age for the 521 men was 50.6 years and for the 467 women was 51.3 years. Men had more years of education than women (9.2 years vs. 6.7 years) and also had a higher mean household income than the female participants.

Table I shows some characteristics of cases and controls. The proportion of cases in the lowest income tertile is significantly higher than that of controls but the proportion of leukemia cases in the highest income tertile is significantly lower than that of controls.

Agreement

Comparisons of self-report and the JEM exposures are shown in Table II. As with many occupational exposures, for both self-report and JEM assessments, the majority of the individuals were classified as unexposed. The number of participants with 'No' on self-reports and 'Yes' for JEMs were consistently less than the number of participants with 'Yes' on self-reports and 'No' for JEMs for the occupational exposures with the exception of pesticide exposure. Among subjects with negative JEM, some over-reporting in cases for benzene exposure and in controls for other organic solvents and EMF exposures were noted, however, only the difference in reporting for the benzene exposure was significant ($P < 0.05$). Table II also shows the proportion of the

TABLE I. Comparison of Percentage Distribution of Controls and Adult Leukemia Participants According to Selected Demographic and Occupational Exposure Assessment; Shanghai

Characteristics	All participants (n = 988)	Controls (n = 502)	All Leukemia cases (n = 486)
Gender			
Male	52.7	52.8	52.7
Female	47.3	47.2	47.3
Age group (years)			
<35	24.7	25.1	24.3
35–54	24.3	24.7	23.9
55–64	24.0	23.1	24.9
65+	27.0	27.1	27.0
Education (years)			
<6	31.5	31.7	31.3
6–11	45.3	46.0	44.5
12+	23.2	22.3	24.2
Income tertile			
T_1 (low)	40.7	34.3	47.1
T_2	34.6	36.1	33.1
T_3	24.7	29.7	19.8

TABLE II. Comparison Between Self-Report and JEM Exposure Assessments; Leukemia Patients in China

	JEM							
Exposure	**Benzene**		**Other organic solvents**		**EMF**		**Pesticides**	
Self-report	**No (%)**	**Yes (%)**	**No (%)**	**Yes (%)**	**No (%)**	**Yes (%)**	**No (%)**	**Yes (%)**
All participants[a] (N = 988)								
No	878 (88.9)	8 (0.8)	803 (81.2)	6 (0.6)	712 (72.1)	7 (0.7)	935 (94.7)	8 (0.8)
Yes	49 (4.9)	53 (5.4)	54 (5.5)	125 (12.7)	76 (7.7)	193 (19.5)	7 (0.7)	38 (3.8)
% Agree[b]	94.3%		93.9%		91.6%		98.5%	
Control (N = 502)								
No	457 (91.0)	5 (1.0)	410 (81.6)	3 (0.6)	355 (70.7)	3 (0.6)	474 (94.4)	5 (1.0)
Yes	16 (3.2)	24 (4.8)	29 (5.8)	60 (12.0)	41 (8.2)	103 (20.5)	3 (0.6)	20 (4.0)
% Agree[b]	95.8%		93.6%		91.2%		98.4%	
Cases (N = 486)								
No	421 (86.6)	3 (0.6)	393 (80.9)	3 (0.6)	357 (73.4)	4 (0.8)	461 (94.9)	3 (0.6)
Yes	33 (6.8)	29 (6.0)	25 (5.1)	65 (13.4)	35 (7.2)	90 (18.5)	4 (0.8)	18 (3.7)
% Agree[b]	92.6%		94.3%		91.9%		98.6%	
Direct interviews[a] (N = 757)								
No	444 (81.6)	232 (0.8)	380 (73.3)	178 (0.4)	447 (65.9)	241 (0.8)	452 (92.1)	235 (0.8)
Yes	48 (8.6)	33 (9.0)	118 (7.9)	187 (18.4)	45 (10.2)	24 (23.1)	40 (1.2)	30 (5.9)
% Agree[b]	90.6%		91.7%		89.0%		98.0%	

[a]Group consists of both cases and controls.
[b]Percent agree is proportion of Yes/Yes plus proportion of No/No.

responses by self-report and JEM that agree for each occupational exposure. These proportions are all high with the least being 89% for EMF in the direct-interview subjects group.

Table III shows the kappa coefficients of agreement between the self-report assessment and JEM assessment of exposure to benzene, other organic solvents, EMF and pesticides among all participants (cases and controls), direct-interviewed subjects, and surrogate-interview subjects; leukemia cases only, controls only, all males and all females; young subjects (all participants = 51 years), as well as older subjects (all participants >51 years; the mean age) subgroups. The kappa coefficients of agreement between self-report and JEM exposure assessments for benzene exposure ranged from 0.48 among surrogate interview subjects to 0.74 among females and from 0.73 for females subgroup to 0.82 for surrogate interview subjects for 'other organic solvents' exposure. The kappa coefficients for benzene among surrogates is significantly lower than that for direct-interview subjects. Most of the kappas for the different subgroups for

TABLE III. Agreement Between Self-Reported and JEM Exposure Assessments; Leukemia Patients in China

		Benzene	**Other organic solvents**	**EMF**	**Pesticides**
Exposure	**N**	**κ (95% CI)**	**κ (95% CI)**	**κ (95% CI)**	**κ (95% CI)**
All participants[a]	988	0.62 (0.53–0.71)	0.77 (0.72–0.83)	0.77 (0.72–0.82)	0.83 (0.74–0.91)
Controls	502	0.67 (0.54–0.80)	0.75 (0.67–0.83)	0.77 (0.70–0.83)	0.83 (0.71–0.94)
Cases	486	0.58 (0.46–0.70)	0.79 (0.71–0.86)	0.77 (0.70–0.84)	0.83 (0.71–0.95)
Direct interviews[a]	757	0.65 (0.55–0.74)	0.76 (0.70–0.82)	0.76 (0.70–0.81)	0.83 (0.75–0.92)
Surrogate interviews[a]	231	0.48 (0.23–0.73)	0.82 (0.69–0.95)	0.82 (0.72–0.92)	0.75 (0.40–1.00)
Males[a]	521	0.53 (0.40–0.65)	0.80 (0.74–0.87)	0.76 (0.70–0.83)	0.81 (0.70–0.93)
Females[a]	467	0.74 (0.62–0.85)	0.73 (0.64–0.82)	0.78 (0.71–0.85)	0.84 (0.72–0.97)

κ, Cohen's kappa statistic of agreement; 95% confidence interval (CI).
[a]Group consists of both cases and controls

TABLE IV. Sensitivity and Specificity for Self-Reported and JEM Exposure Assessments

Exposure	Benzene		Other organic solvents		EMF		Pesticide	
Group	Sens.	Spec.	Sens.	Spec.	Sens.	Spec.	Sens.	Spec.
All participants[a]	0.87	0.95	0.95	0.94	0.97	0.90	0.83	0.99
Controls	0.83	0.97	0.95	0.93	0.97	0.90	0.80	0.99
Cases	0.91	0.93	0.96	0.94	0.96	0.91	0.86	0.99
Direct interviews[a]	0.92	0.90	0.98	0.90	0.97	0.87	0.88	0.99
Surrogate interviews[a]	0.86	0.95	0.90	0.98	0.94	0.95	0.75	0.99
Males[a]	0.89	0.93	0.95	0.94	0.97	0.89	0.88	0.99
Females[a]	0.85	0.97	0.96	0.93	0.96	0.92	0.77	0.99
Young ($\leq$51 years)[a]	0.89	0.95	0.97	0.91	0.98	0.89	0.92	0.99
Old ($>$51 years)[a]	0.84	0.95	0.92	0.96	0.95	0.92	0.44	0.99

[a]Group consists of both cases and controls.

each exposure were similar as the 95% CI overlapped for most of the subgroups. The only sizable difference in kappas we observed between males and females (0.53 and 0.74, respectively) occurred for benzene exposure only.

The sensitivity and specificity results for self-reported exposure when the JEM is assumed as the ''gold standard'' are presented in Table IV. With the exception of the sensitivity for reporting pesticide exposure among the old subgroup of 0.44, all other sensitivities ranged from 0.75 to 0.98. The specificity of reporting for all the occupational exposures ranged from 0.87 to 0.99.

DISCUSSION

In this comparison of a JEM with self-reported exposures, the level of agreement was quite good (kappas varying from 0.5 to 0.9). We did find that those classified as exposed by the JEM alone were generally fewer than the number assessed as exposed only by self-report across all exposures and subgroups with the exception of pesticide exposure among controls. This suggests that the disagreement between self-report and JEM was not random.

The kappa coefficients observed are not much different for the participants with leukemia, the controls, the direct-interviewed subjects, males, females, young, old, and all the participants. Agreements generally over 0.60 are considered good. It is suggested that a kappa over 0.75 represents excellent agreement beyond chance, that a kappa below 0.40 represents poor agreement, and that a kappa of 0.40 to 0.75 represents intermediate to good agreement [Landis and Koch, 1977]. Kappa is ''corrected'' for random chance by the subtraction of a probability that is based upon the observed Yes/Yes and No/No agreement. As such, the kappa coefficient can underestimate the observed agreement by a substantial margin when this probability is high as in this study. Nevertheless, based on the high levels of agreement we observed by the percent agreement and kappa coefficients, we can conclude that the self-report used in this study had from good to excellent agreement with the JEM for all the four occupational exposures evaluated here.

Because we assumed this JEM as a ''gold standard,'' we generally observed that self-report of exposure had both high sensitivity and high specificity for all the occupational exposures in all the subgroups. However, this JEM is not a gold standard. Since neither the self-report nor the JEM used in our study is a ''gold-standard,'' we have elected not to present the predictive value positives (PV + s) in our results as it might be misleading.

The reason for the low sensitivity for reporting pesticide exposure among subjects older than 51 years of age is unclear. Benzene and some organic solvents are listed as occupational hazardous materials in China. All workers are well-informed and would be compensated by the government if they were to be diagnosed with an occupational disease due to the exposure of these materials. Most pesticides and EMF, however, were not listed as occupational hazardous materials in China during the time period of this study. This could explain the lower kappas observed in this study for pesticides and EMF than benzene. While poor recall of pesticide exposure may also be responsible, it appears not to have affected recall of the other occupational exposures in this subgroup.

Several advantages have been noted in carrying out occupational epidemiologic investigations in the People's Republic of China in general to include large numbers of study subjects, fewer jobs held per subject, fewer exposures per subject, easier access to factory records, and administrative systems for tracing and follow-up [Dosemeci et al., 1994]. Because Chinese workers hold fewer jobs and generally have fewer types of exposures in industrial jobs than workers in western industrialized countries, the potential for confounding by other hazardous substances is reduced [Dosemeci et al., 1994]. The high participation rate among eligible cases (91.4%) represented a successful field effort. Direct in-person interview with over half of the participants who were cases ensured more complete and reliable information. A random sample of population-based controls as well as a high response rate minimized selection bias among the controls.

There are several disadvantages related to the use of self-reports in case-control studies. The first is recall bias because of better recall by the cases. This could arise for several reasons such as exposures and experiences could have been discussed with cases during their clinical management and their natural interest in the history of their disease. On the other hand, ill health and general condition of the patient before diagnosis might result in poorer recall by cases. We found little evidence however, of recall bias because there were few significant differences in the kappas and percent agreement between the cases and controls. Information bias and exposure misclassifications could arise because of the high proportion of interviews obtained from the next-of-kin of those who are cases (45.5% among cases vs. 2.0% among controls), yet we found kappas for direct and surrogate interviews quite similar.

It is generally accepted that individual-based retrospective exposure assessment in community-based studies of occupational cancer is a daunting task [Siemiatycki et al., 1997]. However, some studies have shown that self-reported occupational exposure may be sufficient for epidemiological studies especially when objective information on occupational exposure is not available [Holmes and Garshick, 1991; Van der Gulden et al., 1993]. The results of our study suggest that self-report of occupational exposure is sufficient for assessing occupational exposure in our study population and this may be due to the few number of jobs held by subjects in Shanghai and subsequently fewer exposures per subject.

JEMs are widely used in occupational epidemiology, particularly when biological or environmental monitoring data are scanty, to minimize the burden of retrospectively assessing occupational exposure. However, as with most exposure estimates, JEMs may be vulnerable to misclassification also [London and Myers, 1998]. In addition, the JEM used may not be directly relevant to Shanghai occupations. We were unable to compare the JEM with actual environmental or biological measurements, as we did not have this information. This will be a further useful validation of the JEM.

In summary, our results show that assessment of occupational exposure by self-report in our study population has a good- to excellent-agreement with the JEM developed and used in this study. This suggests that self-reported occupational exposure may remain a useful means of obtaining reliable assessment data for epidemiologic analyses of occupational exposure.

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APPENDIX

Translated Selected Sections of Questionnaire

Lifetime job history

4.1 Job or occupation? ....

4.2 Company name? ....

4.3 Specific department of occupation? ....

4.4 Type of job? ....

4.5 What is the general working condition? ....

4.6 Are you using protective equipment at work? ....

4.7 Which year did you start working? ....

4.8 Which year did you stop working? ....

4.9 Did you or do you have any exposure at work to the following materials? ....

4.10 Are you exposed to radiation or isotope at work? ....

4.11 Are you exposed to asbestos at work? ....

4.12 Are you exposed to other electrical equipment at work? ....

Occupational exposure/history

	Most recent	Before	Even before	Much more before
4.1 Job title code:	___	___	___	___
4.2 Name of job:	....	....	....	....
4.3 Industry code:	___	___	___	___
4.4 Kind of job (Public (1); Private in a group (2); Private (3); Others (6))				
4.5 Ventilation (Good (1); Average (2); Poor (3))				
4.6 Protection (Often (1); Sometimes (2); Never (3)):				
4.7 Starting year:	19__	19__	19__	19__
4.8 Ending year:	19__	19__	19__	19__
4.9 For the following exposures, indicates as follows for each job:				
Exposed? (Yes (1); No (2); Unknown (8))				
Frequency? (Daily (1); Weekly (2); Monthly (3); Occasionally (4))				
4.9.1 Gasoline:				
Exposed?	___	___	___	___
Frequency?	___	___	___	___
Years exposed?	___	___	___	___
4.9.2 Paints:				
Exposed?	___	___	___	___
Frequency?	___	___	___	___
Years exposed?	___	___	___	___
4.9.3 Benzene:				
Exposed?	___	___	___	___

(*Continued*)

Frequency?	___	___	___	___
Years exposed?	___	___	___	___
4.9.4 Toluene:				
Exposed?	___	___	___	___
Frequency?	___	___	___	___
Years exposed?	___	___	___	___
4.9.5 Solvents:				
Exposed?	___	___	___	___
Frequency?	___	___	___	___
Years exposed?	___	___	___	___
4.9.6 Pesticides:				
Exposed?	___	___	___	___
Frequency?	___	___	___	___
Years exposed?	___	___	___	___
4.9.7 Radioactive materials:				
Exposed?	___	___	___	___
Frequency?	___	___	___	___
Years exposed?	___	___	___	___
4.9.8 Electrical:				
Exposed?	___	___	___	___
Frequency?	___	___	___	___
Years exposed?	___	___	___	___
4.9.9 For the following, answer as indicated for each job (Yes (1) or No (2))				
a. Sulphuric acid:	___	___	___	___
b. Carbon dioxide:	___	___	___	___
c. Chlorine gases:	___	___	___	___
d. Chlorine liquids:	___	___	___	___
e. Lead:	___	___	___	___
f. Paint:	___	___	___	___
g. Asbestos:	___	___	___	___
h. Fiber:	___	___	___	___
i. Other:	___	___	___	___

Parent's job history:

When you were $>$15 years of age, what was your parent's job?

Father: . . . .

Mother: . . . .

Person providing answers: . . . .