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Reliability of Reported Occupational History Information for US Coal Miners, 1969–1977

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For estimating reliable exposure-response relations it is necessary that random variation in both the response and the exposure variables be sufficiently small. Variability in cumulative exposures can arise from uncertainties in self-reported work histories from interviews. In most epidemiologic surveys, the information gathered from questionnaires is used without knowing the validity or reproducibility of these data. This paper investigates the reliability of occupational histories reported by the same individuals on two occasions separated by 9 years in the US National Study of Coal Workers' Pneumoconiosis and its implications on the exposure-response relation for simple coal workers' pneumoconiosis. For 480 coal miners, from whom occupational histories were obtained twice (in 1969–1971 and 1977–1981), the reliability (intraclass correlation coefficient) of the cumulative exposures generated from each work history was 87%. Logistic model fitting of simple coal workers' pneumoconiosis prevalence to the cumulative coal dust exposure produced almost identical results. After accounting for intersurvey variability in the occupational histories, the authors found that the exposure-response coefficients estimated from information reported at the surveys were attenuated by 12%. In epidemiologic studies, knowledge of the reproducibility of self-reported occupational history information is important to ascertain whether the true exposure effect is underestimated. *Am J Epidemiol* 1998; 148:920–6.

occupational exposure; questionnaires; reliability

Duration of employment and qualitative indicators of exposure intensity are frequently used as surrogates of actual exposure (1–4). However, the combination of the two as cumulative exposure has often been the preferred measure in exposure-response studies (5–9). In occupational studies, individual cumulative exposure estimates are frequently determined by taking the sum of the products of workplace contaminant concentration and time for each job held. The precision of cumulative exposure estimates is therefore dependent on the variability of measured concentration levels and the reliability of recorded exposure histories. Workplace concentration information (i.e., industrial hygiene data) may be unreliable if large measurement and sampling errors exist or the number of samples is low. The reliability of exposure duration depends on factors such as the quality of personnel records or the ability to recall past employment precisely. The resulting imprecision in the estimated cumulative exposures can bias estimates of an exposure-response relation (10–12).

In epidemiologic research, various sources of obtaining occupational histories are used, for example, employer records, trade union records, government-run data banks, or questionnaires (administered or self-administered). In most retrospective studies, where employer records are not available, questionnaires about occupational histories are the only available source of information. Questionnaires have the advantage over employer records in that they often provide detailed job history information for more than one employer. However, the quality of this information depends on the ability of the person to remember specific events that may have occurred years ago. Many studies have been conducted to assess the validity of occupational histories reported on questionnaires by comparing the reported information with government-run data banks (13), public and union records (14), or employer records (15–19). Very few investigators have conducted longitudinal studies to compare occupational histories pertinent to the same period but collected on different occasions (i.e., the reliability of self-reported occupational histories) (20–

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Abbreviations: ICC, intraclass correlation coefficient; NSCWP, National Study of Coal Workers' Pneumoconiosis; OR, odds ratio.

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22). Only one of these studies has used this information to investigate the effect of the variability in work history information on the reliability of cumulative exposures (22), and none has looked at the resulting impact on exposure-response relations.

In retrospective studies, especially studies of diseases with long latent periods such as cancer, the quality of lifetime exposures of the study subjects is very important. The occupational history information gathered from questionnaires is used, in most epidemiologic surveys, without knowing the validity (accuracy) or the reproducibility (reliability) of these data. Since both validity and reproducibility can seriously affect the study results, the information gathered from the questionnaires should be checked. The accuracy of the reported occupational history information is very important in order to avoid misclassification of exposures that could result in an over- or underestimation of the true exposure effect in an exposure-response relation. The reliability of the reported occupational information is as important as the accuracy of the information; low reliability would result in an underestimation of the true exposure effect. The focus of this article is on 1) the reliability of occupational histories reported by the same individuals on two occasions separated by approximately 9 years in the US National Study of Coal Workers' Pneumoconiosis and 2) its implications on the exposure-response relation for simple coal workers' pneumoconiosis.

MATERIALS AND METHODS

Study population

In this article, the study group was drawn from the National Study of Coal Workers' Pneumoconiosis (NSCWP). The NSCWP is a large epidemiologic study of underground coal miners conducted under the auspices of the Federal Coal Mine Health and Safety Act of 1969. Four rounds of medical surveys were conducted from 1969 to 1988. During each survey, trained interviewers from the National Institute for Occupational Safety and Health visited the participating mines and collected information about occupational history, tobacco smoking history, and respiratory symptoms from each coal miner. The interviewer recorded this information on a standardized questionnaire. Each miner underwent a medical examination, including chest radiographs and a spirometric test, before or after the work shift. A population of 480 coal miners who were interviewed in both round 1 (1969–1971) and round 3 (1977–1981) were selected for study of the reliability of their work history information. The study group came from 10 of the 31 mines in the NSCWP (at the time of this analysis, the round 1 work histories for the remaining 21 mines were coded in a different scheme from that used at round 3 and therefore could not be easily compared). They were predominantly white males (96 percent), with an average age of 44 years at round 1 and 53 years at round 3.

Work histories

Each participant's work history for the period up to the medical examination was elicited at round 1 and at round 3. Hence, the round 3 history included the time covered in the round 1 history. To investigate the reliability of reported occupational histories, we compared the information collected at each of the two rounds for an identical work period prior to the round 1 medical survey for each individual.

Each work history comprised a detailed record of each job worked, including starting and ending dates, job title, industry, and other information. The job titles in both rounds were determined by reviewing the job description with the participant. Each job title was coded using the Mine Safety and Health Administration's occupational coding scheme. The duration of employment (years) was computed by taking the difference between the starting and ending dates (month and year) for each occupation reported for the period before the round 1 medical survey.

To enable comparison of tenure information from the two rounds, we divided a list of Mine Safety and Health Administration occupation codes into two main working areas: underground and surface. The underground coal mine occupations were further divided into two groups based on relative dustiness: face and nonface. Finally, nonface occupations were split into general underground and underground transportation.

A job diversity index (JDI) was computed by using the formula $JDI = -100\sum (n_i / N)\ln(n_i / N)$, where n_i is the tenure within job category i in years, N is the total tenure from the start date of the first job to the third medical survey (round 3), and the summation is over all jobs reported in the work history up to the third medical survey (17). This index will measure the complexity of a worker's personnel record; that is, a high index value implies that the worker changed jobs frequently throughout his entire employment tenure. An index value of zero would imply that a single job was held throughout the entire employment tenure.

Cumulative dust exposures

Each Mine Safety and Health Administration occupation code was assigned a mean respirable dust concentration level, which ranged from 0.2 mg/m^3 to 8.8 mg/m^3. These job-specific mean concentration levels were taken from the study of Attfield and Morring

(23), which was based on environmental data from a survey conducted by the US Bureau of Mines between 1968 and 1969 and on environmental data collected by the Mine Safety and Health Administration in 1970.

The cumulative dust exposure for each individual for the period before the round 1 medical survey was estimated by using the job-specific mean dust concentration and job tenure. The following formula was used to estimate cumulative dust exposure (mg-year/m^3) for each miner: $CE = \sum C_j D_j$, where CE is the sum of the product of the mean dust concentration level (C_j) and exposure duration (D_j) for the jth job held. Cumulative dust exposures estimated from the round 1 work history and the corresponding period from the round 3 work history were compared.

Radiographic readings

Chest radiographs taken between 1969 and 1971 were read by three certified "B" readers using the 1968 Union International Contre le Cancer/Cincinnati classification (24). This scheme was used to classify simple coal workers' pneumoconiosis according to the profusion and type of small opacities present in the chest film. The profusion was graded into four major categories: 0, 1, 2, and 3, while the type was graded as either small rounded or small irregular. This article focuses on small rounded opacities associated with simple coal workers' pneumoconiosis. The interpretations of only one reader, whose findings were consistent with prevalence rates of coal workers' pneumoconiosis found in coal miner surveillance data (25) and other studies, were used. (See Attfield and Castellan (26) for the rationale for this strategy.)

Coal rank

The study population was grouped into two regions based on the type of coal mined at the time of the first medical survey. This stratification was done because it has been shown that the relation between cumulative dust exposure and prevalence rates for simple coal workers' pneumoconiosis (category one or greater) differs depending on the percentage of carbon content in the coal dust (5). The first region included five mines from eastern Appalachia and consisted of 220 individuals who mined medium/low volatile bituminous coal, which has a high carbon content of 89–90 percent. The second region included five mines from western Appalachia and consisted of 260 individuals who mined high volatile "A" bituminous coal, which has a low carbon content of 80–87 percent.

Statistical methods

For the duration of employment and cumulative dust exposure for both Appalachian regions, the intraclass correlation coefficient (ICC), which is an estimate of reliability, was determined by using the following formula: $R = \sigma_\tau^2 / (\sigma_\tau^2 + \sigma_\epsilon^2)$ (27). For each of these variables, 480 pairs were created where members of each pair represent the occupational history information reported on two occasions. Analysis of variance techniques were used to estimate the variability within pairs or intersurvey variability (σ_ϵ^2) and the variability between pairs or true variability (σ_τ^2) (27).

Logistic regression analysis was applied to a binary response variable (0, 1) based on the presence of category one or greater simple coal workers' pneumoconiosis, with cumulative dust exposure as a predictor. Adjustments for rank of coal at the time of the first medical survey were considered in the analysis by introducing a dichotomous variable (e.g., eastern Appalachia = 1 and western Appalachia = 0) into the model. Two logistic models, each of which reflects the occupational history information reported from each round, were fitted and compared. The following model was used: $\pi(x)_i = \exp^{g(x)\,i} / (1 + \exp^{g(x)\,i})$, where $g(x)_i = \beta_0 + \beta_{i1}x_{i1} + \beta_{i2}x_{i2}$ is the logit for each ith round (28). The estimated coefficients for cumulative dust exposure and rank of coal at the time of the first medical survey are represented by β_{i1} and β_{i2}, respectively. The estimated adjusted odds ratio (OR) for each coefficient from each model (i.e., OR_{i1} and OR_{i2}) was computed.

The random variability associated with recalling and reporting occupational history information would be expected to lead to attenuation in the estimated cumulative dust exposure coefficient. To assess the magnitude of this downward bias, we adjusted the cumulative dust exposure coefficient (β_{i1}) estimated from the logistic model for each round by the inverse of the intraclass correlation coefficient ($1 / ICC = 1 / R$), that is, using the formula $\beta_{i1}^* = (1/R)\beta_{i1}$ (10), and compared it with the unadjusted estimated exposure. The estimated odds ratios for cumulative dust exposure were also adjusted and compared.

All statistical procedures were accomplished by using program modules provided by the SAS Institute, Inc. (29). Statistical significance was achieved if the p value, or the probability of obtaining a more extreme result than what was observed by chance alone, was less than the alpha (α) level of 0.05.

RESULTS

Table 1 shows the number of miners who reported working in various broad occupational groups and mean tenures within those groups for the period prior to the round 1 medical survey based on information gathered at round 1 and round 3. Overall, the average

TABLE 1. Average tenure (years) for reported underground and surface occupations for the work period prior to the round 1 medical survey for selected coal miners from the US National Study of Coal Workers' Pneumoconiosis, 1969–1977

Reported work areas	Round 1 (1969–1971)		Round 3 (1977–1981)		ICC*	95% CI*
	No.†,‡	Mean years	No.‡,§	Mean years		
Face	387	13.9 (9.3)¶	389	15.1 (9.4)	0.78	0.75–0.82
General underground	205	8.2 (6.9)	176	7.5 (7.3)	0.56	0.49–0.61
General transportation	109	8.9 (7.1)	117	8.4 (7.6)	0.61	0.55–0.66
Total underground	437	18.4 (10.4)	440	18.6 (10.2)	0.91	0.90–0.93
Surface	135	13.7 (10.1)	149	12.0 (9.9)	0.89	0.87–0.91
Total mining	480	20.6 (10.2)	480	20.8 (10.1)	0.95	0.94–0.96
Jobs held before 1953	239	7.1 (4.8)	239	7.3 (4.9)	0.69	0.62–0.75
Jobs held during 1953 and later	477	16.5 (7.8)	477	16.6 (7.9)	0.84	0.82–0.87
Low JDI*	240	20.8 (10.8)	240	21.0 (10.8)	0.96	0.95–0.97
High JDI	240	20.4 (9.5)	240	20.5 (9.4)	0.94	0.92–0.95

* ICC, intraclass correlation coefficient; CI, confidence interval; JDI, job diversity index.
† Total number of reported occupations prior to round 1.
‡ Numbers do not add to total because a miner could have worked in multiple locations at the mine.
§ Total number of reported occupations for work period prior to round 1 at round 3.
¶ Numbers in parentheses, standard deviation.

tenure in total mining was almost identical for the two different surveys, 20.6 and 20.8 years. For reported occupations held prior to 1953 and after 1953 but before the first medical survey, the average total mining tenures were also similar at round 1 and round 3. The reliability (intraclass correlation coefficient) in the total mining tenure was very good at 95 percent; however, the total mining tenure for occupations held prior to 1953 was less reliable (ICC = 0.69) than the tenure information for occupations held after 1953 (ICC = 0.84). As for the broad underground occupational groups, most of the miners (approximately 81 percent) reported working in the most dusty occupations, at the coal face, on both occasions. The average tenure for these miners was slightly higher for round 3 (15.1 years) compared with round 1 (13.9 years). For nonface occupations, which included general underground and general transportation occupations, the average tenure was slightly lower for round 3 compared with round 1. In addition, the number of miners reporting an occupation associated with a given work area was slightly different between rounds, especially for general underground occupations. The reliability of the tenure information for all underground occupations was very good; however, this was not true for the broad underground occupational groups, where the reliability ranged from 56 to 78 percent.

The total number of reported underground and surface occupations with reported tenures prior to round 1 was similar for both rounds. At round 1, 1,719 occupations were reported compared with 1,776 at round 3. Of the total number of reported occupations, 100 were unique occupations at both rounds. The average job diversity index for all jobs reported at round 3 was 150.6 with a range of 0–241.5. This corresponds to an average of six and a range of 1–12 job changes per individual. The job diversity index was divided into a low and high index based on the median value of 154.0, and the total mining tenure within each group was compared over surveys. The bottom half of table 1 shows that the average total mining tenures within each index group were not different between rounds. The reported total mining tenures for those with fewer job changes were slightly more reliable than were reported mining tenures for those with a higher index, which corresponds to an average of eight job changes per individual.

For each miner, cumulative dust exposures were generated on the basis of the type or rank of coal mined at the first medical survey. For both rounds, the average cumulative dust exposure for 220 eastern Appalachian miners was significantly lower than the average cumulative dust exposure for 260 western Appalachian miners. Although there was a significant difference in the average cumulative dust exposure between regions within each round, the average cumulative dust exposure within a region was very similar between rounds (see table 2). The reliability (ICC) of the cumulative dust exposure estimated for each region was identical at 87 percent (95 percent confidence interval 0.84–0.90).

Table 3 shows the results of fitting two logistic models, each one reflecting the occupational history information reported at each round. Both models suggested that the prevalence of simple coal workers' pneumoconiosis was associated with cumulative dust exposure after adjusting for coal rank at the time of the first medical survey. The estimated coefficients and

TABLE 2. Average cumulative dust exposure (mg-year/m³) and intraclass correlation coefficient by coal region at the time of the first medical survey for selected coal miners from the US National Study of Coal Workers' Pneumoconiosis by round, 1969–1977

Coal region	No.	Round 1 (1969–1971) (mean exposure, mg-year/m³)	Round 3 (1977–1981) (mean exposure, mg-year/m³)	ICC*	95% CI*
Eastern Appalachia	220	55.7 (35.3)†	56.5 (36.4)	0.87	0.84–0.90
Western Appalachia	260	67.1 (36.1)	68.5 (35.5)	0.87	0.84–0.90
Overall	480	61.9 (36.1)	63.0 (36.4)	0.87	0.85–0.89

* ICC, *intraclass correlation coefficient; CI, confidence interval.*
† Numbers in parentheses, standard deviation.

TABLE 3. Results from the logistic modeling of the presence or absence of category one or greater simple coal workers' pneumoconiosis for selected coal miners from the US National Study of Coal Workers' Pneumoconiosis by round, 1969–1977

Terms	Round 1 (1969–1971)				Round 3 (1977–1981)			
	Estimated coefficient (β)	SE* (β)	OR*	95% CI*	Estimated coefficient	SE (β)	OR	95% CI
Intercept	–4.880	0.488			–4.794	0.488		
Cumulative dust exposure†	0.032‡	0.005	1.03	1.02–1.04	0.030‡	0.005	1.03	1.02–1.04
Coal rank	1.509‡	0.306	4.52	2.52–8.40	1.479‡	0.303	4.39	2.46–8.10

* SE, standard error; OR, odds ratio; CI, confidence interval.
† Per mg-year/m³.
‡ $p = 0.0001$.

adjusted odd ratios for both cumulative dust exposure and coal rank were similar between rounds.

Although the estimated coefficients from the logistic models were very similar, random variability due to miners' reporting different information on their work history at different times naturally exists in these data. This variability would be expected to bias the estimated coefficient for cumulative dust exposure toward the null and bias the estimated adjusted odds ratio toward one. Accordingly, the estimated coefficient from each round needs to be adjusted to account for this intersurvey variability in the occupational histories. From the analysis of variance, the intersurvey variance (within-person variance) for cumulative dust exposure was 164.4 $(mg/m^3)^2$, and the true cumulative dust exposure variance (between-person variance) was 1,149.7 $(mg/m^3)^2$. The sum of these two variances estimates the total variance of cumulative dust exposure. The ratio of the estimated true cumulative dust exposure variance and the total variance of cumulative dust exposure (i.e., the reliability estimate, R) was 0.87. Multiplying the estimated cumulative dust exposure coefficient from both rounds by the inverse of the reliability (i.e., $1 / R$) resulted in a minor increase in both the estimated coefficients and odds ratios. The adjusted estimated cumulative dust exposure coefficient for round 1 was 0.036 (OR = 1.04) and for round 3, 0.035 (OR = 1.04). Hence, the unadjusted estimated coefficients and odds ratios were attenuated by 12 and 4 percent, respectively.

DISCUSSION

The focus of the present study was to determine the reproducibility or reliability of the occupational history information reported in two surveys that were 9 years apart for selected members of the NSCWP. The results showed good agreement between the two surveys for the reported tenure in total mining and the estimated cumulative dust exposure, with intraclass correlation coefficients of 0.95 and 0.87, respectively. These results are comparable with findings from an investigation of the reliability of self-reported occupational histories obtained twice (3-year span) from 164 capacitor manufacturing workers who had participated in an epidemiologic study relating health abnormalities to exposure to polychlorinated biphenyls (22). The results from that study showed that the reported information concerning duration of exposure and cumulative exposure to polychlorinated biphenyls was very reliable over a period of 3 years, the intraclass correlation coefficients ranging between 0.94 and 0.99. In both of these reproducibility studies, the self-reported information concerning work histories was shown to be reliable, and this finding is comparable with results found in some validation studies (13–16, 18), where they suggest that for periods up to 40 years there is minimal recall effect on the quality of the reported information.

A study by Rona and Mosbech (21) further investigated the reliability of self-reported occupational history information. They were able to show that the reported occupational history information that was farthest from the time of the interview or survey was less reliable than reported information that was closest to the time of the interview or survey. Their study investigated on two separate occasions the self-reported occupational and industrial history information from patients in countries that are part of the European Economic Community. They found that the percentage of agreement for the present or last job reported was greater than the agreement for the previous job reported (70 percent compared with 61 percent) and for jobs that were held more than 10 years from the interview (70 percent compared with 64 percent) (21). Similar findings were found in our study. For example, a comparison between the reported tenure information for occupations that were held more than 25 years from the third medical survey and the reported information for occupations that were held more than 15 years from the first medical survey showed the former information to be less reliable (ICC = 0.69) than the information reported closest to the surveys (ICC = 0.84). The reliability of the self-reported occupational information was dependent on the amount of random variability that existed in this reported information. The information provided from individuals that had to remember events farthest from the time of the interview was subjected to more random variability. Therefore, as the total variability in the reported information got further away from the true variability, the reported occupational history information became less reliable. When the reported occupational history information was considered overall (i.e., not grouped by time period), random variability in the reported information still existed. However, its effect over the entire employment history balanced out and, therefore, the reported data were more reliable. For example, in our study the reliability of the reported tenure in total mining for the entire employment history was 95 percent.

The number of job changes in a person's occupational history may impact the ability of that individual to recall specific events of those jobs. The studies by Rosenberg et al. (17, 22) of workers exposed to polychlorinated biphenyls showed that reported information from workers with several job changes was less reliable than reported information from workers with only a few job changes. Similar results were found in our study. For example, those coal miners with an average of four job changes over their entire work history, which was reported at the time of the third medical survey, were more likely to remember their occupational tenures reliably (ICC = 0.96) than were those with more complex work patterns (ICC = 0.94).

In epidemiologic research, random variability in the exposure variable should be sufficiently small to avoid underestimation of the true exposure-response relation. In this study, the average cumulative dust exposures determined from the work histories collected on two occasions were very similar; however, this similarity may conceal important differences when the association between cumulative dust exposure and the prevalence of simple coal workers' pneumoconiosis is considered. The results from the logistic regression analyses showed that, for every one-unit (mg/m^3) increase in cumulative dust exposure, there was a 3 percent increase in risk for developing simple coal workers' pneumoconiosis after adjusting for coal rank at the time of the first medical survey, and this risk was very similar between surveys. The estimated coefficients for cumulative dust exposure from these models were not adjusted for any large individual pairwise differences that might have existed and, therefore, might have underestimated the true relation between exposure and response. From this study, the intersurvey variability for cumulative dust exposure was 164.4 (mg-year/m^3)^2 and, after adjusting the estimated coefficient for cumulative dust exposure from each round by this intersurvey variability, we found that the exposure-response coefficients were attenuated by 12 percent. This amount of bias introduced into the exposure estimates from the exposure-response relation is tolerable (30). Although the degree of recall error is minimal, the long-term recall of reported occupational history information from selected members of the National Study of Coal Workers' Pneumoconiosis could still be improved. Methods developed by cognitive psychologists and survey researchers, who have studied stages of cognitive processes and devised and evaluated methods for improving recall and reducing reporting errors and bias, could be adopted (31).

The observed attenuation in the exposure-response coefficients is shown to be due to the uncertainties in the work histories and does not reflect the error that might exist in the sampling variation of the dust concentration measurements. Another factor that could be contributing to this unreliability of the exposure estimates is the elevation of status (i.e., promotion). A study by Heasman et al. (32) suggested that there was a tendency for the informant to inflate the status of the deceased coal miner. For example, the widow of a coal miner might report that her husband's occupation was at the coal face, whereas he had actually worked predominantly in the less prestigious jobs elsewhere underground or on the surface. In the present study, there was evidence of coal miners' promoting themselves to more prestigious occupations over time in round 3 compared with round 1. For example, when the types of reported occupations were carefully evaluated, there was a tendency to report more occupations at the face than elsewhere in the mine. In addition, the mean tenure at the face was reported to be greater at round 3 compared with round 1 and, thus, consistent with job promotion. The tenure data suggest that the promotion to face work was obtained at the expense of time in work in the other, lower status, jobs. Overall, the promotion effect, even if real, was small and of little consequence.

In summary, the data from this study suggest that the self-reported occupational history information on standardized questionnaires from the National Study of Coal Workers' Pneumoconiosis collected from US underground coal miners on two separate occasions is reliable and that the amount of bias introduced by recalling past employment history is minimal.

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