Personal factors influencing agreement between expert and self-reported assessments of an occupational exposure

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Abstract

This study aimed to identify personal factors associated with expert and respondent agreement on past occupational exposure. Epidemiologic data was collected from 1995 to 1998 in a community-based, case-control study of prostate cancer. Using longest jobs and excluding agreement on "never" exposure, self-reported and expert estimates of ever/never exposure, by skin or ingestion, to polycyclic aromatic hydrocarbons were compared. Agreement between respondents and the expert was 53.9% (N = 1,038), with overreporting being more common than underreporting relative to the expert (31.8% versus 14.4%). In multiple logistic regression models, white-collar occupational status was significantly associated with overreporting (odds ratio [OR] = 0.142; 95% confidence interval [CI]: 0.095-0.211; blue-collar versus white-collar), while age was associated with underreporting (OR = 1.077; 95% CI: 1.043-1.112; one-year increase). Neither job satisfaction nor risk perception appeared to confound other associations. In future studies, overreporting by white-collar workers might be avoided by providing clearer definitions of exposure, whereas elderly respondents may require aids to enhance exposure recall.

Key words: *epidemiologic measurement, expert opinion, logistic models, occupational exposure, questionnaires, retrospective studies*

Introduction

Choosing the best method of occupational exposure assessment when designing community-based, case-control studies of chronic disease etiology is a significant challenge faced by epidemiologists. Although "expert" assessment of exposure has been regarded as a more valid[1-3] and reliable[4] approach than others, it has not always been used in the past and may not be feasible, given financial constraints.[5] Additionally, the quality of this practice can vary in community-based settings[6] in which "experts" is often subjectively defined.

Self-reporting of exposure is a logical alternative to expert assessment. While this method continues to be used on its own,[7-10] it has also been used by experts[11] and with job exposure matrices[12] to help estimate exposure. In retrospective research, self-report data can be obtained in a consistent manner across industries, unlike occupational hygiene measurements, which may not exist or may vary in quality, the latter depending on when and why the measurements were taken.[13,14] In contrast to the use of job titles or job exposure matrices, self-reporting provides individual estimates of exposure. Despite these advantages, however, reports have described only fair-to-substantial repeatability of self-reported exposures[15,16] and wide-ranging values for inter-method reliability,[17-20] with workers in one study recalling only 2.6% of the exposures reported by an expert.[20]

If the factors that influence valid and reliable self-reporting of exposure can be better understood, so can the research that was based on self-reports. Also, in future studies, the validity of risk estimates derived from self-reports might be improved through adjustments in questionnaire design and better-informed decision making in data analysis.

Attempts to identify influential factors have been made.[15,17,18,20-23] However, some studies may not have controlled adequately for confounding[15,17,24] or may have failed to discriminate between under- and overreporting of exposure[15,21,22] when there may be different factors involved in each case. While logic suggests that attitudes, such as risk perceptions and job satisfaction, may lead to underestimation or exaggeration of exposure, we have not found any study examining attitudes in this context.

This study aimed to identify personal characteristics that increase the risk of exposure misclassification in a community- based, case-control study of cancer—exposures that are the most difficult to assess. Logistic regression modeling was used to study the effects of demographic factors and attitudes on inter-method reliability[25] (criterion validity[26]), with control for confounding. Reliability was measured by comparing self-reports to corresponding expert assessments of exposure, which was considered to be the gold standard for the purposes of this study. Use of data from the Northeastern Ontario

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Men's Health Study conducted in Ontario, Canada[27] allowed for these analyses.

Materials and methods

Epidemiologic study of prostate cancer

The Northeastern Ontario Men's Health Study is a community-based, case-control study of occupational and other risk factors for prostate cancer.[27] Ethics approval was obtained from the Laurentian Hospital Research Ethics Board in Sudbury, Ontario, Canada. Cancer cases were identified through the Ontario Cancer Registry. Cases were defined as men having primary, histologically confirmed prostate cancer (ICD9-185[28]) diagnosed between January 1995 and December 1998. Consent to contact cases was first acquired from physicians named on pathology reports, and agreement to participate was obtained by telephone. Eligible cases were living in one of nine Statistics Canada census divisions in northeastern Ontario and were aged 45 to 84 years at the time of diagnosis. Controls were randomly selected from the same census divisions using residential telephone listings and were 2:1 frequency matched based on five-year age group. Eligible controls reported never having had prostate cancer prior to January, 1995. If prostate cancer was diagnosed after that time, these men were deemed cases.

Questionnaires were offered in English and French and subsequently administered by mail or telephone. Prior to the study, translation of the entire English questionnaire into French was reviewed for full compatibility with Franco-Ontarian dialects. Each respondent was required to provide a work history, including job titles and start and end dates for every job held longer than one year. Respondents were asked a number of questions about each job (years worked, industry, name and description of employer, hours of work, job duties, location, level of activity, job satisfaction, odours and use of respiratory protective equipment). An exposure checklist was completed, in which the respondents indicated whether they ever had been exposed to (and if so, with what frequency and intensity) 14 chemical and physical agents (e.g., lubricating oils and greases, asphalt fumes, pesticides, metals and metal compounds). On a separate checklist developed for the purposes of this study, each respondent indicated his risk perception of ten agents (not including polycyclic aromatic hydrocarbons [PAH]). They were specifically asked, "On a scale of 1 to 5, where 1 means 'not harmful' and 5 means 'extremely harmful', please circle the appropriate number that indicates to what extent you believe that exposure to each of following is harmful to human health."

Data collection began in March, 1996 and was completed by December, 1999. The response rate for cases was 72.8% and for controls was 46.4% (if hang-ups were considered as refusals, or 53.1% if considered ineligible).

Expert exposure assessment

Photocopies of completed work histories were given to an expert assessor who was a chemical engineer and occupational hygienist with 12 years experience. For each job, the expert assigned exposure ratings while blinded to cancer status. Exposures were rated as ever/never having occurred and also according to frequency, magnitude and duration. The expert used a simpler definition of exposure frequency than did the respondents, as well as a more objective definition for magnitude, based on occupational exposure limits (Table 1). Also, whereas the expert assessed many exposures in chemically specific terms (e.g., PAH exposure by skin or ingestion), the respondents were presented with more familiar terminology (e.g., lubricating oils and greases).

In assessing exposures, the expert first considered the entire work histories provided by the case or control and then applied his own knowledge, experience and, if necessary, consulted other experts, the scientific literature and/or occupational hygiene documentation from key industries in northeastern Ontario. To maintain consistency across similar jobs, handwritten notes were kept of all non-zero exposure ratings, along with any other pertinent information. Industrial and occupational codes based on Statistics Canada's systems of Standard Industrial Classification (SIC)[29] and Standard Occupational Classification (SOC)[30] were also assigned.

Measurement of reliability and its determinants

The aim of this study was to analyze jobs of greatest relevance to estimating risk of cancer; in particular, each respondent's longest held job was used as the unit of observation. Of 2,388 respondents (8,279 jobs), 2,351 respondents/jobs were eligible for this analysis after excluding 1) eight jobs starting less than one year before date of diagnosis (or date of initial contact for controls); 2) 37 respondents with more than one job and at least one job of unknown duration (138 jobs); and 3) 5,782 jobs that were not of the longest duration, or were jobs tied for the longest (in such cases, the earliest held job was used). Forty-one respondents (and 41 longest held jobs) with missing assessments were excluded from PAH-specific analyses, resulting in a sample size of 2,310 respondents/jobs. For these analyses, 1,272 cases of agreement on no exposure were removed (55.1%) since it was believed that reliability in these cases would depend more on the low likelihood of exposure than on personal factors of interest.

Exposure to PAH served as a focus for two reasons. First, this exposure is occupationally prominent and is a postulated risk factor for prostate cancer.[31-33] Second, PAH exposure was assessed similarly by the expert and respondents. Whereas respondents assessed exposures to lubricating oils and greases, the expert assessed PAH exposure via skin/ingestion. However, this comparison was thought to be valid given that exposure to lubricating oils and greases mainly occurs via the skin, with the exception of oil mists.

A dichotomous index of exposure was used for analyses. Ever/never exposure assessments were compared since this index of exposure was used similarly by the expert and respondents (i.e., the index "ever exposed" in Table 1). Expert and respondent assessments of frequency and magnitude of exposure were not compared on account of differing interpretations, in which case other factors related to

TABLE 1
Indices of exposure to polycyclic aromatic hydrocarbons used by respondents* and expert

Index of exposure	Respondents	Expert
Ever exposed	Yes, No	Yes, No
Frequency	None Monthly Weekly Daily	None Less than daily Daily
Magnitude	None Low Medium High	None < 50% OEL** 50% - 100% OEL > 100% OEL
Duration	Not assessed	None < 2 hours per day or shift > 2 hours per day or shift

* Participants in the Northern Ontario Men's Health Study

**OEL – Occupational Exposure Limit

agreement would have been difficult to distinguish.

While the selection of independent variables for analysis was driven largely by *a priori* hypotheses, the sample size needed to reliably estimate risk was also considered.[34] Eleven independent variables were ultimately chosen. One variable designated "occupational group" categorized workers as blue-collar or white-collar. To create these categories, unit group-level Standard Occupational Classifications (SOCs) assigned by the expert were first collapsed into Broad Occupational Categories defined by Statistics Canada,[30] and then into blue- and white-collar status whereby blue-collar occupations were defined by Broad Occupational Categories H, I, J (see Figure 1). Average risk perceptions were derived from a risk perception summation scale (Cronbach's α = 0.92, indicating internal consistency and a reliable scale).[35,36] An average of all the risk perception scores in the scale was used for analysis. For each respondent, if more than four of the ten items on the risk perception checklist were missing, the respondent's average risk perception score was also recorded as missing.

Eleven characteristics of respondents who under- and overreported ever/never exposure to PAH, respectively, were compared to those who agreed with the expert, using univariable and then multivariable logistic regression models. Underreporters were excluded from overreporting models and vice versa. "Overreporting" occurred if the respondent reported workplace exposure, but the expert reported no exposure for him, whereas "underreporting" was the opposite pattern.

It was postulated that confounding effects of attitude variables could have important implications in the interpretation of studies such as this one. To investigate the role of risk perceptions in self-reporting, associations were measured between 1) average risk perceptions and reliability; and 2) average risk perceptions and four factors associated with risk perceptions in the literature: age,[37,38] education level,[37,38] cultural group,[39] and occupational group.[37,40] The same analyses were performed for job satisfaction in relation to cultural group, occupational group and age, respectively.[41] It was believed that if associations 1) and 2) were both statistically significant, this would be suggestive of a confounding or an intermediate role.[26,42]

Statistical methods

All statistical analyses were conducted using SAS© version 8.2 for Windows[43] and a significance level of 0.05. Reliability was measured as percent agreement and percent under- and overreporting, respectively.

Multiple logistic regression models were built using stepwise variable selection. To assess selection bias, respondents with missing values for "average risk perceptions" were compared to those without missing values using chi-square and Wilcoxon rank sum tests. Descriptive statistics for model subgroups were compared to those of the study population as a whole.

Results

Respondent characteristics are shown in Table 2. The mean age for the respondents in this analysis was 68.7 years, with over 72% of respondents being 65 years or older at the time of interview. The majority of respondents (80.3%) reported no formal education beyond high school, most were English-speaking (56.0%), and blue-collar occupations were slightly more prevalent than white-collar (57.2% versus 42.8%). More than half of the subjects had jobs of

FIGURE 1
Standard Occupational Classification (SOC) definitions – Broad occupational categories

A	Management occupations
B	Business, finance and administrative occupations
C	Natural and applied sciences and related occupations
D	Health occupations
E	Occupations in social science, education, government service and religion
F	Occupations in art, culture, recreation and sport
G	Sales and service occupations
H	Trades, transport and equipment operators and related occupations
I	Occupations unique to primary industry
J	Occupations unique to processing, manufacturing and utilities

Source: Statistics Canada: Standard industrial classification, 1980.[29]

TABLE 2
Characteristics of respondents*, frequencies and percentages (N=2,310)**

		N	%
Age	45 - 59	277	12.2
	60 - 64	355	15.6
	65 - 69	618	27.1
	70 - 74	562	24.7
	75 - 86	468	20.5
Highest education level attained	Elementary	755	32.9
	Secondary	1,087	47.4
	Post-secondary	453	19.7
Cultural group	English-Canadian	1,288	56.0
	French-Canadian	491	21.3
	Other	523	22.7
Occupational group	Blue-collar	1,319	57.2
	White-collar	986	42.8
Time elapsed since job ended (years)	0 - 9	495	21.5
	10 - 19	823	35.8
	20 - 52	984	42.8
Job duration (years)	4 - 19	538	23.4
	20 - 39	1,498	65.0
	40 - 71	268	11.6
Number of jobs	≥ 5	594	25.7
	2 - 4	1,318	57.1
	1	398	17.2
Job satisfaction***	High	2,098	91.5
	Indifferent	122	5.3
	Low	74	3.2
Average risk perception†	Low	202	10.9
	Medium	197	10.6
	High	1,453	78.5
Questionnaire administration mode	Mail	1,745	75.6
	Telephone	564	24.4
Cancer status	Case	729	31.6
	Control	1,581	68.4

* Participants in the Northern Ontario Men's Health Study

** Totals may not equal 2,310 due to missing values

***High - highly satisfied or satisfied; Indifferent - neither (indifferent); Low - highly unsatisfied or unsatisfied

† High - average score ≥ 3.5 on a scale from 1 to 5, indicating extremely harmful; Medium - average score > 2.5 and < 3.5, indicating medium harm; Low - average score ≤ 2.5, indicating little harm

longest duration ending more than a decade before they completed the questionnaire (median = 11.0 years), and these jobs were still ongoing for 212 respondents (9.2%). The mean job duration was 27.3 years and the median number of jobs held was 3.0. As might have been expected when jobs were held the longest, the vast majority of respondents reported being satisfied or highly satisfied with these jobs (91.5%). Average risk perception scores were generally high, with a median of 4.1 on a scale from 1 to 5 (5 indicating the most harm).

A substantial number of scores for average risk perception were missing (458/2,310; 19.8%). Respondents with missing values were significantly more likely to have only elementary school education ($p < 0.0001$), less likely to be English-Canadian ($p = 0.039$), were significantly older ($p < 0.0001$) and were more likely to be blue-collar workers ($p < 0.0001$). There was no significant difference between the groups in terms of cancer status ($p = 0.53$).

The majority of respondents agreed with the expert on having had no PAH exposure (55.1%; 1,272/2,310). Before excluding these respondents, percent agreement was 79.3, with overreporting being more common that underreporting (14.3% [330/2,310] versus 6.5% [149/2,310]). Kappa was equal to 0.54 and sensitivity and specificity were both 0.79. By excluding those who agreed with the expert on no exposure, agreement fell to 53.9% (N = 1,038), resulting in 31.8% overreporting and 14.4% underreporting; sensitivity remained at 0.79.

Subgroups used to study under- and overreporting contained 543 and 700 respondents, respectively, and were similarly distributed across 11 variables. Compared to the study population as a whole, PAH subgroups had fewer respondents with post-secondary education (8.7% in the underreporting subgroup and 13.1% for overreporting, versus 19.7% for study population); were more frequently blue-collar workers (89.9% for underreporting and 77.4% for overreporting, versus 57.2%); and were less likely to complete questionnaires by mail (69.4% for underreporting and 68.7% for overreporting, versus 75.6%). Subgroups were otherwise distributed similarly to the study population.

The results of univariable analyses are presented in Table 3. Three statistically significant associations were found with PAH underreporting, including a positive association with age (odds ratio [OR] = 1.077 for every one-year increase in age; 95% CI: 1.043-1.112). Time since job completion was also significant, with the odds of underreporting being higher for jobs ending a decade or more before interviews than for jobs held more recently (OR = 2.342; 95% CI: 1.324-4.143 for 20 years or more; OR = 2.065; 95% CI: 1.225-3.484 for 10 to 20 years). Third, a graded effect was observed with job duration whereby underreporting was not as likely

TABLE 3
Odds ratios (OR) and 95% confidence intervals (CI) from univariable logistic regression models for risk of under- and overreporting exposure to PAH* (ever/never) in jobs held the longest by respondents**

Independent variable		Underreporting			Overreporting		
		N	OR	95% CI	N	OR	95% CI
Age	Each one-year increase	543	1.077***	1.043, 1.112	700	0.991	0.971, 1.012
Highest education level attained	Elementary	233	2.111	0.851, 5.238	260	0.370***	0.228, 0.603
	Secondary	263	1.449	0.581, 3.613	348	0.485†	0.305, 0.773
	Post-secondary	47	1.000		92	1.000	
Cultural group	French-Canadian	138	1.250	0.756, 2.066	157	0.681	0.459, 1.010
	Other	134	0.989	0.582, 1.682	172	0.842	0.580, 1.223
	English-Canadian	271	1.000		371	1.000	
Occupational group	Blue-collar	488	0.866	0.449, 1.706	542	0.142***	0.095, 0.211
	White-collar	55	1.000		158	1.000	
Time elapsed since job ended (years)	≥ 20	130	2.342†	1.324, 4.143	140	0.645‡	0.421, 0.988
	10 - 19	208	2.065†	1.225, 3.484	258	0.891	0.634, 1.253
	< 10	205	1.000		302	1.000	
Job duration (years)	< 20	128	0.436‡	0.193, 0.982	180	0.958	0.529, 1.738
	20 - 39	365	0.761	0.385, 1.502	459	0.915	0.529, 1.582
	≥ 40	50	1.000		61	1.000	
Number of jobs	≥ 5	122	0.959	0.485, 1.896	179	1.416	0.868, 1.738
	2 - 4	336	0.876	0.487, 1.576	414	0.874	0.563, 1.359
	1	85	1.000		107	1.000	
Job satisfaction	High	477	0.526	0.209, 1.326	621	1.000	0.342, 1.180
	Indifferent	44	0.338	0.098, 1.173	53	0.635	0.533, 2.612
	Low	22	1.000		26	1.180	
Average risk perception	Low	55	1.140	0.576, 2.256	69	1.000	0.455, 1.755
	Medium	61	0.898	0.448, 1.800	77	0.893	0.607, 1.705
	High	427	1.000		554	1.017	
Questionnaire administration mode	Mail	377	0.838	0.534, 1.315	481		0.602, 1.159
	Telephone	166	1.000		219		
Cancer status	Case	180	0.925	0.588, 1.455	235	1.010	0.731, 1.396
	Control	363	1.000		465	1.000	

* PAH = Polycyclic aromatic hydrocarbons
** Participants in the Northern Ontario Men's Health Study
***$p < 0.0001$
† $p < 0.01$
‡ $p < 0.05$

for jobs of shorter duration as for jobs 40 years or more in duration (OR = 0.436; 95% CI: 0.193-0.982 for jobs less than 20 years; OR = 0.761; 95% CI: 0.385-1.502 for 20 to 39 years).

In terms of PAH overreporting, men with less education were significantly less likely to overreport PAH exposures than respondents with post-secondary education (OR = 0.370; 95% CI: 0.228-0.603 for elementary school; OR = 0.485; 95% CI: 0.305-0.773 for secondary school), and blue-collar workers had lower odds of overreporting than white-collar workers (OR = 0.142; 95% CI: 0.095-0.211). Overreporting was also less common for jobs completed at least 20 years earlier than for jobs held in the decade prior to interviews (OR = 0.645; 95 % CI: 0.421-0.988). Graded effects were also observed for this variable.

Using stepwise variable selection, the only variable that entered the multivariable model for PAH underreporting was age (Table 4). With respect to overreporting, occupational group was the only variable in the final model, again showing overreporting to be less common in blue-collar than white-collar workers.

Final models were checked statistically in several ways. When predictor variables were selected using backward or forward selection techniques (*p*-entry/removal = 0.15), both final models contained the same variables as selected when using stepwise variable selection, demonstrating model

TABLE 4
Odds ratios (OR) and 95% confidence intervals (CI) from multiple logistic regression models for risk of under- and overreporting exposure to PAH* (ever/never) in jobs held the longest by respondents**

Model outcome	Parameter	OR	95% CI
Underreporting***	Intercept		
	One-year increase in age	1.077	1.043, 1.112
Overreporting†	Intercept		
	Occupational group‡	0.142	0.095, 0.211

* PAH = Polycyclic aromatic hydrocarbons

**Participants in the Northern Ontario Men's Health Study

***$N_{agreement}$ = 436, $N_{underreporting}$ = 107

† $N_{agreement}$ = 436, $N_{overreporting}$ = 264

‡ Blue-collar vs. white-collar occupations

robustness. The assumption of linearity between the continuous variable "age" and log odds ratios in the underreporting model was confirmed graphically, using the Mantel-Haenzsel chi-square test for trend ($p < 0.05$). Adding non-significant variables to each model did not change the influences of the significant factors, age and occupational group (i.e., beta coefficients changed by less than ten percent), with one exception: addition of the variable "time since job completion" to the model for PAH underreporting slightly decreased the effect of age by 12.8%, but the effect remained statistically significant.

Since the number of exclusions relied heavily on the risk perception variable, there was concern that inclusion of this variable may have biased the results. Therefore, both models were fit again excluding average risk perceptions, thereby including respondents with missing values. The same variables remained statistically significant. However, in the PAH underreporting model, respondents who were highly satisfied with their jobs were less likely to underreport PAH exposure than those who were unsatisfied (OR = 0.401; 95% CI: 0.175-0.916). Also, French Canadians had higher odds of underreporting than did English Canadians (OR = 1.629; 95 % CI: 1.046-2.535).

It was hypothesized that attitudes might behave as confounders or intermediate variables in associations between various personal characteristics and reliability. However, no significant associations were found. Though, due to the scarcity of respondents with low job satisfaction (N = 22), this result may not have been valid. By combining the "low" and "indifferent" job satisfaction categories to increase category sample size, there was still no evidence of an intermediate or confounding role for job satisfaction.

Discussion

These results suggest the reliability of PAH exposure self-reporting in community-based studies may depend on 1) the likelihood of exposure (i.e., reports of negative exposure were typically reliable), and 2) certain respondent characteristics, such as age and occupational group.

It was not surprising to observe a significant positive association between age and PAH underreporting, since exposures could naturally be forgotten over time or may not have been realized in jobs held decades earlier. Similar results have been reported in the past for asbestos[17] and heavy metal exposure.[18] The fact that age has consistently been found to *not* influence work history reporting (e.g., reporting of job titles and dates of employment)[24,44-47] suggests this effect may be specific to exposure reporting. Time since job completion also appeared to be weakly associated with PAH underreporting after controlling for age. It is possible that a more precise variable (i.e., using category widths < 10 years) or some account for job start date might have revealed a stronger trend.

The finding that white-collar workers were significantly more likely to overreport than blue-collar workers was convincing given the strengths of these associations: over seven-fold higher odds for PAH overreporting in white-collar workers were found compared to blue-collar ($OR^{-1}_{\text{blue vs. white-collar}}$ = 7.0). As well, the direction of the association was plausible. While white-collar workers, overall, would have had fewer direct exposures to PAH than blue-collar workers, they may have had a greater awareness of these agents in the workplace. For some, this may have been accompanied by misinterpretation and exaggeration of "exposure". Ahrens *et al.* did not observe this influence,[17] but they provided a definition of exposure and respondents specified whether "direct" or "bystander" exposure occurred. Even more detailed definitions have been provided in other questionnaires.[48] In contrast, respondents in this study were simply asked to "describe your exposure to the following", with a subsequent exposure checklist. However, van der Gulden *et al.* similarly asked, "Have you ever worked with…or been exposed to…in your job?",[15] and like Ahrens *et al.*, did not observe differences between occupational groups. An alternative reason for the present finding may have been the focus on workers who were more likely to have been exposed, unlike the latter studies that analyzed cases of agreement on no exposure (presumably groups with more white-collar workers).

In this study, neither underreporting nor overreporting was associated with cancer status, in agreement with past studies.[15,17,23] Therefore, the observed inconsistencies between expert and respondents would translate into non-differential misclassification error in estimating prostate cancer risk, which would likely bias risk estimates towards the null value and therefore underestimate risk.[49]

In regards to risk perceptions, it is noteworthy that the items in this study concerned harm to "human health" in general, rather than personal health risk. Although a correlation between perceptions of personal risk and societal risk has been observed,[50] people may perceive risks to themselves to be lower than risks to the general population.[50,51] Therefore, questions of personal risk might have resulted in different associations with personal exposure reporting. Nevertheless, the present findings should be regarded as informative and novel, given this may have been the first attempt to examine risk perceptions in this context.

The study of the role of job satisfaction in self-reporting was an additional strength of this study, as no other group has explored this possibility to our knowledge. However, the associations observed should be interpreted cautiously given the few respondents reporting low job satisfaction. The validity of this finding might have been improved if more than one questionnaire item were used to measure this attitude. Similarly, different techniques for assessing risk perceptions have been used in the past[52-54] and if applied to this study, may have elicited different responses.

Although the different ways in which PAH exposures were assessed by the expert and respondents could have lowered internal validity, the effect was probably minimal. Whereas respondents reported exposures to lubricating oils and greases, corresponding expert assessments focused on skin contact and/or ingestion of all possible sources of PAH. In a discussion with the expert, however, it was learned that lubricating oils and greases were typically the only skin/ingestion PAH exposure with the exception of some unusual exposures to tar.

The validity of the expert assessments may be viewed as a possible limitation of this study. More specifically, the associations observed could reflect the expert's strengths (i.e., the expert may have been more knowledgeable about more recent exposures or blue-collar occupations, thereby leading to better agreement on these jobs and poorer agreement on others). Exposures that are highly dependent on human technique would also be more difficult for an expert to assess. Using more than one expert in future studies might help to alleviate this problem since assessments would draw from a broader range of personal knowledge and experience, and more extensive consultation with the literature. However, others have rationalized,[55,56] as do the present authors, that expert ratings are more objective and consistent than self-reports. Some industry-based validity studies support this idea.[3,57] In the community-based setting, Fritschi *et al*. found that three experienced expert raters working independently were able to identify 64%, 70% and 80% of past occupational exposures, respectively, across a variety of workplaces.[58] As well, in the present study, we observed no statistically significant trends in over- or underreporting across three time periods of expert assessment (PAH exposures were sorted in order of expert assessment and then split into tertiles; trends in percent under- and overreporting were $p > 0.05$, respectively, in Mantel-Haenzsel chi-square tests for trend), thus providing some evidence of expert consistency over time (data not shown). Furthermore, the associations we observed with age and occupational group were both plausible and consistent with *a priori* hypotheses and past research, thereby also supporting the use of the present expert.

In terms of generalizability, it should be recognized that the factors involved in "all jobs" reporting may differ from job of longest duration reporting[20] and factors may differ for current versus past exposures. Questions also remain about the validity of these findings for other exposures that are less easily sensed than lubricating oils and greases, or queried using less familiar terminology.[59] Our findings may not extend to respondents less than 45 years of age or to females since it is possible these groups may have different attitudes and occupational characteristics than the men in this study. Moreover, the present analyses were based on subgroups that excluded respondents for whom exposures were improbable (i.e., white-collar workers and post-secondary educated men). Modeling results may therefore only extend to similar populations in which exposure is conceivable; namely, industry-specific groups or subgroups of community-based populations similar to this.

Many aspects of these analyses are relevant to studies of long-latency disease. First, this study focused on exposure reporting for job held the longest, which is useful for studying diseases resulting from cumulative exposures. Second, recall in this study was primarily retrospective (90.8%), with jobs ending 11 to 12 years prior to questionnaire completion on average. Third, PAH exposure is currently of interest to occupational epidemiologists and continues to be assessed by way of retrospective self-report in community-based studies of cancer.[9]

In Canadian males, who were mainly blue-collar and 69 years of age on average, different personal characteristics were found to be associated with PAH under- and overreporting. There was a strong association between white-collar status and overreporting, which could have arisen from misinterpretation of exposure terminology on the questionnaire.[8,56] In addition, older respondents under-reported more often than younger respondents, suggesting memory probes may be needed to enhance recall in older populations if poor memory is to blame. If awareness of exposure underlies the effect of age, improved recall by older respondents should be anticipated, given the increase in workplace safety education programs implemented in Canada since the 1980s.[60] In all further work of this kind, it is recommended that under- and overreporting be distinguished from each other and potential confounding be controlled adequately. There may also be a need to distinguish between factors influencing exposure and work history reporting since our findings suggest they could differ (e.g., the variable "age"). Further analyses similar to this are encouraged, perhaps using an improved gold standard, such as an expert panel.

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References

1. Teschke K, Olshan AF, Daniels JL, De Roos AJ, Parks CG, Schulz M, et al. Occupational exposure assessment in case-control studies: opportunities for improvement. Occup Environ Med 2002;59(9):575-93.

2. McGuire V, Nelson LM, Koepsell TD, Checkoway H, Longstreth WT, Jr. Assessment of occupational exposures in community-based case-control studies. Annu Rev Public Health 1998;19:35-53.

3. Kromhout H, Oostendorp Y, Heederik D, Boleij JS. Agreement between qualitative exposure estimates and quantitative exposure measurements. Am J Ind Med 1987;12(5):551-62.

4. Benke G, Sim M, Fritschi L, Aldred G, Forbes A, Kauppinen T. Comparison of occupational exposure using three different methods: hygiene panel, job exposure matrix (JEM), and self reports. Appl Occup Environ Hyg 2001;16(1):84-91.

5. Siemiatycki J, Dewar R, Richardson L. Costs and statistical power associated with five methods of collecting occupation exposure information for population-based case-control studies. Am J Epidemiol 1989;130(6):1236-46.

6. Mannetje AA, Fevotte J, Fletcher T, Brennan P, Legoza J, Szeremi M, et al. Assessing Exposure Misclassification by Expert Assessment in Multicenter Occupational Studies. Epidemiology 2003;14(5):585-92.

7. Neale AV, Demers RY, Severson RK. Consistency of occupational exposure history from pattern and model makers. J Occup Environ Med 2000;42(1):76-82.

8. Schuz J, Spector LG, Ross JA. Bias in studies of parental self-reported occupational exposure and childhood cancer. Am J Epidemiol 2003;158(7):710-6.

9. Ugnat AM, Luo W, Semenciw R, Mao Y. Occupational exposure to chemical and petrochemical industries and bladder cancer risk in four western Canadian provinces. Chronic Dis Can 2004;25(2):7-15.

10. De SE, Boffetta P, Brennan P, eo-Pellegrini H, Ronco A, Gutierrez LP. Occupational exposures and risk of adenocarcinoma of the lung in Uruguay. Cancer Causes Control 2005;16(7):851-6.

11. Gerin M, Siemiatycki J. The occupational questionnaire in retrospective epidemiologic studies: recent approaches in community-based studies. Applied Occupational and Environmental Hygiene 1991;6(6):495-501.

12. Tielemans E, Heederik D, Burdorf A, Vermeulen R, Veulemans H, Kromhout H, et al. Assessment of occupational exposures in a general population: comparison of different methods. Occup Environ Med 1999;56(3):145-51.

13. Stewart PA, Herrick RF, Blair A, Checkoway H, Droz P, Fine L, et al. Highlights of the 1990 Leesburg, Virginia, International Workshop on Retrospective Exposure Assessment for Occupational Epidemiology Studies. Scand J Work Environ Health 1991;17(4):281-5.

14. Tielemans E, Marquart H, De CJ, Groenewold M, Van HJ. A proposal for evaluation of exposure data. Ann Occup Hyg 2002;46(3):287-97.

15. van der Gulden JW, Jansen IW, Verbeek AL, Kolk JJ. Repeatability of self-reported data on occupational exposure to particular compounds. Int J Epidemiol 1993;22(2):284-7.

16. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics 1977;33(1):159-74.

17. Ahrens W, Jockel KH. Assessment of exposure to asbestos in a case-control study of lung cancer: comparison of supplementary questionnaires and an exposure check-list. Occupational Hygiene 1996;3(1-3):125-36.

18. Rybicki BA, Johnson CC, Peterson EL, Kortsha GX, Gorell JM. Comparability of different methods of retrospective exposure assessment of metals in manufacturing industries. Am J Ind Med 1997;31(1):36-43.

19. Fritschi L, Siemiatycki J, Richardson L. Self-assessed versus expert-assessed occupational exposures. Am J Epidemiol 1996;144(5):521-7.

20. Bond GG, Bodner KM, Sobel W, Shellenberger RJ, Flores GH. Validation of work histories obtained from interviews. Am J Epidemiol 1988;128(2):343-51.

21. Holmes E, Garshick E. The reproducibility of the self-report of occupational exposure to asbestos and dust. J Occup Med 1991;33(2):134-8.

22. Hsairi M, Kauffmann F, Chavance M, Brochard P. Personal factors related to the perception of occupational exposure: an application of a job exposure matrix. Int J Epidemiol 1992;21(5):972-80.

23. Joffe M. Validity of exposure data derived from a structured questionnaire. Am J Epidemiol 1992;135(5):564-70.

24. Brisson C, Vezina M, Bernard PM, Gingras S. Validity of occupational histories obtained by interview with female workers. Am J Ind Med 1991;19(4):523-30.

25. Armstrong BK, White E, Saracci R. Principles of Exposure Measurement in Epidemiology. Oxford: Oxford University Press; 1994.

26. International Epidemiological Association. A Dictionary of Epidemiology. 4th ed. Last JM, editor. Oxford: Oxford University Press; 2001.

27. Lightfoot N, Kreiger N, Sass-Kortsak A, Purdham J, Buchan G. Prostate cancer risk. Medical history, sexual, and hormonal factors. Ann Epidemiol 2000;10(7):470.

28. World Health Organization. International Classification of Diseases, 9th Revision. Geneva: WHO; 1977.

29. Statistics Canada. Standard Industrial Classification, 1980. Ottawa: Minister of Supply and Services Canada; 1989.

30. Statistics Canada. Standard Occupational Classification, 1991. Ottawa: Minister of Industry, Science and Technology; 1993.

31. Aronson KJ, Siemiatycki J, Dewar R, Gerin M. Occupational risk factors for prostate cancer: results from a case-control study in Montreal, Quebec, Canada. Am J Epidemiol 1996;143(4):363-73.

32. Krstev S, Baris D, Stewart P, Hayes R, Blair A, Dosemeci M. Risk for prostate cancer by occupation and industry: a 24-state death certificate study. Am J Ind Med 1998;34(5):413-20.

33. Seidler A, Heiskel H, Bickeboller R, Elsner G. Association between diesel exposure at work and prostate cancer. Scand J Work Environ Health 1998;24(6):486-94.

34. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. J Clin Epidemiol 1996;49(12):1373-9.

35. Abramson JH. Survey methods in community medicine. 4th ed. New York: Churchill Livingstone; 1990.

36. Katz MH. Multivariable analysis. A practical guide for clinicians. Cambridge: Cambridge University Press; 1999.

37. Kraus N, Malmfors T, Slovic P. Intuitive toxicology: expert and lay judgments of chemical risks. Risk Analysis 1992;12(2):215-32.

38. Krewski D, Slovic P, Bartlett S, Flynn J, Mertz CK. Health risk perception in Canada I: rating hazards, sources of information and responsibility for health protection. Human and Ecological Risk Assessment 1995;1(2):117-32.

39. Finucane ML, Slovic P, Mertz CK, Flynn J, Satterfield TA. Gender, race, and perceived risk: the 'white male' effect. Health, Risk & Society 2000;2(2):159-72.

40. Mertz CK, Slovic P, Purchase IF. Judgments of chemical risks: comparisons among senior managers, toxicologists, and the public. Risk Anal 1998;18(4):391-404.

41. Spector PE. Job satisfaction, application, assessment, cause, and consequences. Barling J., Kelloway K., editors. Thousand Oaks: Sage Publications Inc.; 1997.

42. Rothman KJ, Greenland S. Modern Epidemiology. Second ed. Philadelphia: Lippincott-Raven Publishers; 1998.

43. The SAS system. Version 8.2 for Windows. Cary, North Carolina: SAS Institute Inc.; 2001.

44. Baumgarten M, Siemiatycki J, Gibbs GW. Validity of work histories obtained by interview for epidemiologic purposes. Am J Epidemiol 1983;118(4):583-91.

45. Bourbonnais R, Meyer F, Theriault G. Validity of self reported work history. Br J Ind Med 1988;45(1):29-32.

46. Rosenberg CR, Mulvihill MN, Fischbein A, Blum S. An analysis of the validity of self reported occupational histories using a cohort of workers exposed to PCBs. Br J Ind Med 1987;44(10):702-10.

47. Stewart WF, Tonascia JA, Matanoski GM. The validity of questionnaire-reported work history in live respondents. J Occup Med 1987;29(10):795-800.

48. Haight RR, Vuskovich MA, Brooks SM, Berish TS. Evaluation of the reliability and validity of the University of South Florida Environmental Assessment Questionnaire. Am J Ind Med 2004;46(2):142-50.

49. Stewart PA, Dosemeci M. Recommendations for reducing the effects of exposure misclassification on relative risk estimates. Occupational Hygiene 1996;3(1-3):169-76.

50. Sjoberg L. Factors in risk perception. Risk Anal 2000;20(1):1-11.

51. Wahlberg A.A.F., Sjoberg L. Risk perception and the media. Journal of Risk Research 2000;3(1):31-50.

52. Arcury TA, Quandt SA, Russell GB. Pesticide safety among farmworkers: perceived risk and perceived control as factors reflecting environmental justice. Environ Health Perspect 2002;110 Suppl 2:233-40.

53. Sjoberg L, Drottz-Sjoberg BM. Knowledge and risk perception among nuclear power plant employees. Risk Anal 1991;11(4):607-18.

54. Ostry AS, Hertzman C, Teschke K. Risk perception differences in a community with a municipal solid waste incinerator. Can J Public Health 1993;84(5):321-4.

55. Stewart WF, Stewart PA. Occupational case-control studies: I. Collecting information on work histories and work-related exposures. Am J Ind Med 1994;26(3):297-312.

56. Daniels JL, Olshan AF, Teschke K, Hertz-Picciotto I, Savitz DA, Blatt J. Comparison of assessment methods for pesticide exposure in a case-control interview study. Am J Epidemiol 2001;153(12):1227-32.

57. de Cock J, Kromhout H, Heederik D, Burema J. Experts' subjective assessment of pesticide exposure in fruit growing. Scand J Work Environ Health 1996;22(6):425-32.

58. Fritschi L, Nadon L, Benke G, Lakhani R, Latreille B, Parent ME, et al. Validation of expert assessment of occupational exposures. Am J Ind Med 2003;43(5):519-22.

59. Teschke K. Exposure surrogates: job-exposure matrices, self-reports, and expert evaluations. In: Nieuwenhuijsen MJ, editor. Exposure assessment in occupational and environmental epidemiology.Oxford: Oxford University Press; 2003. p. 119-32.

60. Ontario Ministry of Labour; Government of Ontario. A guide to the Occupational Health and Safety Act. 2005 [cited 2005 Nov 29]. Available at: http://www.labour.gov.on.ca/english/hs/ohsaguide/index.html