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Performance of population specific job exposure matrices (JEMs): European collaborative analyses on occupational risk factors for chronic obstructive pulmonary disease with job exposure matrices (ECOJEM)

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Abstract

***Objectives*—To compare the performance of population specific job exposure matrices (JEMs) and self reported occupational exposure with data on exposure and lung function from three European general populations.**

***Methods*—Self reported occupational exposure (yes or no) and present occupation were recorded in the three general population surveys conducted in France, The Netherlands, and Norway. Analysis was performed on subjects, aged 25–64, who provided good forced expiratory volume in 1 second (FEV_1) tracings and whose occupations were performed by at least two people, in the French (6217 men and 5571 women), the Dutch (men from urban (854) and rural (780) areas), and the Norwegian (395 men) surveys. Two population specific JEMs, based on the percentage of subjects who reported themselves exposed in each job, were constructed for each survey and each sex. The first matrix classified jobs into three categories of exposure according to the proportion of subjects who reported themselves exposed in each job (P10–50 JEM, low < 10%, moderate 10–49%, high ⩾ 50%). For the second matrix, a dichotomous variable was constructed to have the same statistical power as the self reported exposure—that is, the exposure prevalence (p) was the same with both exposure assessment methods (Pp JEM). Relations between occupational exposure, as estimated by the two JEMs and self reported exposure, and age, height, city, and smoking adjusted FEV_1 score were compared.**

***Results*—Significant associations between occupational exposure estimated by the population specific JEM and lung function were found in the French and the rural Dutch surveys, whereas no significant relation was found with self reported exposure. In populations with few subjects in most jobs, exposure cannot be estimated with sufficient precision by a population specific JEM, which may explain the lack of relation in the Norwegian and the Dutch (urban area) surveys.**

***Conclusion*—The population specific JEM, which was easy to construct and cost little, seemed to perform better than crude self reported exposures, in populations with sufficient numbers of subjects per job.**

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Keywords: job exposure matrix; occupational exposure; lung function

Associations between occupational exposures and chronic obstructive lung disease (COPD) have been investigated mostly in occupational populations.[1 2] In community based studies, selection bias due to the healthy worker effect is a less important issue than in occupational cohorts, but the validity of exposure assessment methods in such studies is a matter of debate.[3] Self reported information and more recently job exposure matrices (JEMs)[4 5] have been used to estimate occupational risk factors in community based studies on COPD. Population specific JEMs, which use the subjects with the same job as experts for that job, have also been proposed.[6] Building a population specific JEM is easy as it results from simple computer calculations on self reported exposures. A population specific JEM estimates exposure taking into account the percentage of self reported exposures per job. Population specific JEMs might lead to less misclassification in exposure than self reported exposures. However, the heterogeneity of exposure in a given job is not taken into account by the JEM.[3] Self reported and population specific JEM assessment methods have never been compared formally although results with both methods have been published once.[7]

Three general population surveys in France,[8] The Netherlands,[9] and Norway[10] provided data on an individual basis on occupational airborne exposure and lung function. In the French[11] and the Norwegian[10] surveys, associations between occupational exposures and lung diseases have already been studied, whereas in the Dutch survey[9] no analyses on occupational exposure have yet been performed. The aim of the present paper was to assess the performance of population specific JEMs compared with that of self reported exposure in the relations between exposure and lung function.

Table 1 Methods in the three general populations

	France	*The Netherlands*	*Norway*
	1975 7 Cities	1965–9 Urban or rural	1985–8
Pulmonary spirometer	Dry spirograph Vitalograph	Lode spirograph 53	Gould 2100 spirometer
Job classification	INSEE (French), 4 digits	Dutch, 4 digits	Nordic, 3 digits
Population in each survey	20310 Men and women	3477 Men	653 Men
Subjects excluded (n (%))	8522 (42.0)	1843 (53.0)	258 (39.5)
Reasons of these exclusions (n (%)):			
Aged <25 or >64 (Norway)	—	816 (44.3)	185 (71.7)
Lack of answer or no occupation	3896 (45.7)	165 (9.0)	5 (1.9)
Lack of answer to exposure	113 (1.3)	31 (1.7)	4 (1.6)
FEV_1 not performed	1298 (15.2)	525 (28.5)	1 (0.4)
Without good tracings	2981 (35.0)	173 (9.4)	14 (5.4)
Lack of answer to height or smoking	81 (1.0)	12 (0.7)	3 (1.2)
Occupation with <2 subjects	154 (1.8)	121 (6.6)	46 (17.8)
Analyses performed on	6217 Men/5571 women	854 Men/780 men	395 Men

Material and methods

In the French Cooperative Pollution Atmosphérique et Affections Respiratoires Chroniques (PAARC) study,[8] performed in 1975, 20 310 men and women, aged 25–59 years, residing in seven French cities (Bordeaux, Lille, Lyons, Mantes-la-Jolie, Marseilles, Rouen, Toulouse), were surveyed at home. The primary aim of the survey was to investigate a possible effect of air pollution on respiratory symptoms and lung function. Households headed by manual workers were excluded to reduce the effect of occupational hazards. Therefore, subjects in the French survey were less occupationally exposed than the general population. In the French questionnaire, derived from the British Medical Research Council/European Coal and Steel Community questionnaire, subjects were classified as non-smokers, ex-smokers (stopped for at least 1 month), or smokers (light smokers (<10 g/day), moderate smokers (10–19 g/day) and heavy smokers (⩾20 g/day)), based on tobacco smoked as cigarettes, cigars, or in a pipe.

In the Dutch survey,[9] 3477 men and 3256 women, aged 15–64 years, were recruited over 3 years (1965, 1967, 1969) from both urban (Vlaardingen) and rural (Vlagtwedde) areas. The aim of the Dutch survey was to assess the prevalence and risk factors of COPD. In the Dutch questionnaire, a shortened version of the British Medical Research Council/ European Coal and Steel Community questionnaire was applied. Subjects were classified as non-smokers, ex-smokers, cigarette smokers (light smokers (<10 cig/day), moderate smokers (10–19 cig/day) and heavy smokers (⩾20 cig/day)), or cigars or pipe smokers.

In the two phase Norwegian survey,[10] a postal questionnaire was sent in 1985 to a sample of 4992 subjects of which 90% responded. The primary aims were to estimate the prevalence of obstructive lung disease and of asbestos or quartz exposure. In a second phase, conducted between 1987 and 1988, a stratified sample of 1275 subjects (653 men and 622 women), described previously,[10] aged 18–73 years were examined. Using the Norwegian questionnaire, subjects were then classified as non-smokers (never smoked daily), ex-smokers, or smokers (smoking daily at the time of the survey).

Details of the population available in each survey are summarised in table 1.

SELF REPORTED EXPOSURE AND JOB EXPOSURE MATRIX (JEM)

In the French survey, self reported exposure to dusts, gases, and fumes (were you exposed to dusts, gases and/or chemical fumes? yes or no), in their last occupation was reported and occupation coded with the French four digit classification.[12] In the Dutch survey, occupational exposure to dusts, gases, and chemical fumes were obtained by questionnaire in 1965 (present and previous jobs) and in 1967 and 1969 (present, previous, and longest jobs). Occupations were coded with the Dutch four digit classification.[13] Subjects were considered to be exposed to dusts, gases, and fumes if they answered positively to one of two questions (exposed to dusts or exposed to gases or vapour) in 1965, and to one question (exposure to dusts, gases, and fumes) in 1967 and 1969, in the present occupation. In the Norwegian survey, subjects were interviewed about their complete occupational history since leaving school and self reported exposure to eight occupational hazards. Subjects were considered occupationally exposed if they answered positively at least one of eight questions about exposure in their most recent occupation, six on specific hazards (asbestos, quartz, wood dust, aluminium dust, welding, soldering), and two on hazard groups (metal compounds in dust or gas form (chromium, nickel, platinum), and one or more of the following products (petroleum products, solvents, detergents, pigments, plastics, paints or lacquers, insecticides or pesticides)). The occupational titles were coded with the Nordic 3 digit classification.[14]

A job exposure matrix is a table in which each cell contains for each job an estimation of exposure for a given hazard. Two population specific JEMs were constructed with computer calculations for each survey and in the French survey for each sex. The first step was to calculate in each job the proportion of subjects exposed to dusts, gases, and fumes with the self reported dichotomous variable. A JEM with two classes of exposures is then built by considering as exposed any job for which more than x% of the subjects who practise this job reported themselves exposed. The choice of the cut off point x is arbitrary and may be chosen to obtain an overall fixed percentage of exposed people and modified to increase the specificity or the sensitivity of the measure. By the same method, a JEM with several classes of

Table 2 Construction of the dichotomous JEM based on the self reported exposure (Pp JEM)

Subjects who declared themselves exposed in a job (%)	Subjects (n)	Cumulative subjects (n)	Cumulative subjects (%)
0	188	188	3.0
3	30	218	3.5
4	49	267	4.3
5	229	496	8.0
31	13	4312	69.4
32	362	4674	75.2
33*	42	4716	75.9
34	119	4835	80.5
80	10	6164	99.1
82	17	6181	99.4
83	18	6199	99.7
100	18	6217	100.0

Example in men from the French survey.
Self reported exposure: 4605 men not exposed (74.1%); 1612 men exposed (25.9%).
Pp JEM: 4674 men not exposed (75.2%); 1543 men exposed (24.8%).
*Cut off points for other groups analysed: 30% in women from the French survey; 50% and 29% in urban and rural Dutch residents, respectively; and 50% in the Norwegian survey.

Table 3 Exposure assessments in four jobs in men from the French survey

Jobs	Subjects (n)	Self reported exposure at work (%)	P10–50 JEM	Pp JEM*
Physicians	147	9	Low	Not exposed
Office workers	465	19	Moderate	Not exposed
Stock clerks	144	35	Moderate	Exposed
Bakers or pastrycooks	51	67	High	Exposed

*The cut off point for exposure assessment was 33% in men from the French survey.

exposure may be defined. A matrix was constructed which classified exposure in three categories (P10–50 with the two cut off points p<10%, p⩾50%), as described by Post *et al*[5]. The probability of exposure in an occupation was considered high, moderate, or low, when ⩾50%, 10–49%, or <10% of the men (or women) working in this occupation reported themselves occupationally exposed. Another JEM was built to have the same statistical power as the self reported exposure. The construction of that two class JEM was done in such a way that the prevalence of exposure with the Pp JEM would be the same as the prevalence with the self reported data (p). For example, in the French survey 4605 men declared themselves to be non-exposed. The closest figure of non-exposed men with the Pp JEM (4674) was obtained by considering as non-exposed the jobs in which <33% (optimal cut off point) of workers reported exposure (table 2). In that case, the prevalence of exposure with the Pp JEM (24.8%) was as close as possible to the prevalence based on the self reported exposure (25.9%). For the other populations, a job was classified as exposed with the Pp JEM when the percentage of subjects, who declared themselves to be exposed in a job, was ⩾ the following cut off points: 30% in women from the French survey, 50% and 29% among urban and rural Dutch residents, respectively, and 50% in the Norwegian survey. The different classifications of exposure for a few typical jobs is illustrated in table 3.

ANALYSED POPULATION

For the current study, analyses were restricted to subjects aged 25–64 who performed good forced expiratory volume in 1 second (FEV_1) tracings and whose last occupation was carried out by at least two men (women) in each of the three surveys. Analyses in women were done only in the French survey. In the Dutch and the Norwegian surveys too few women reported exposures to use a JEM in optimal conditions (prevalence of exposure about ⩾10%).[6 15] In the French survey, to compare present results with results previously described,[4] analyses were also performed for subjects whose occupation was carried out by at least 10 people, this involved 5046 men and 5000 women.

STATISTICAL ANALYSIS

Standardised FEV_1 score (mean (SD) 0 (1)) was obtained for each sex and city, after adjustment of FEV_1 on age, height, and smoking (expressed by dummy variables, four in France (ex-smokers, light smokers, moderate smokers, heavy smokers), three in The Netherlands (ex-smokers, cigar or pipe smokers, cigarette smokers) and two in Norway (ex-smokers, smokers)), in multiple regression analyses. The relation between exposure and FEV_1 was tested with a Student's t test for dichotomous variables and with a test for trend for the P10–50 JEM.[16] Analyses were also done with FEV_1 score adjusted for age and height for each sex and city and this score was regressed on occupational hazards, with adjustment for

Table 4 Description of subjects in the three general populations

	France		The Netherlands (men)		Norway
	Women (5571)	Men (6217)	Urban (854)	Rural (780)	(Men) (395)
Age (mean (SD))	41.7 (9.5)	42.4 (9.5)	42.2 (10.2)	41.9 (11.0)	42.5 (11.5)
Smoking (%):					
Non-smokers	70.1	26.1	10.0	7.0	43.5
Ex-smokers	6.6	18.1	17.3	10.3	23.6
Smokers	23.4	55.8	72.7	82.7	32.9
Self reported exposure (%)	19.6	25.9	41.8	30.3	37.2*
Different jobs (n)	177	223	165	108	68
Subjects per job (n (%))					
Range	2–820	2–465	2–56	2–276	2–64
<10	449 (8.1)	438 (7.0)	416 (48.7)	183 (23.5)	188 (47.6)
10–19	320 (5.7)	634 (10.2)	208 (24.4)	86 (11.0)	121 (30.6)
20–49	1003 (18.0)	1464 (23.6)	161 (18.8)	104 (13.3)	22 (5.6)
⩾50	3799 (68.2)	3681 (59.2)	69 (8.1)	407 (52.2)	64 (16.2)

*In the French and the Dutch surveys, subjects were considered exposed if they answered positively to one or two questions on exposure to dusts, gases, or chemical fumes. In the Norwegian survey, subjects were considered exposed if they answered positively to at least one of the following hazards : asbestos, quartz, wood dust, aluminium dust, welding, soldering, metal compounds in dust or gas form (chromium, nickel, platinum), petroleum products, solvents, detergents, pigments, plastics, paints or lacquers, or insecticides or pesticides.

Table 5 FEV_1 scores (mean (SD), n) after adjustment for age, height and smoking according to exposure to dusts, gases, fumes

	France		*The Netherlands (men)*		*Norway (men) (n=395)*
	Women (n=5571)	*Men (n=6217)*	*Urban (n=854)*	*Rural (n=780)*	
Self reported exposure:					
Not exposed	0.01 (1.00), 4479	0.01 (1.01), 4605	−0.02 (1.02), 497	0.04 (1.00), 544	0.04 (1.04), 248
Exposed	−0.05 (0.99), 1092	−0.03 (0.96), 1612	0.03 (0.98), 357	−0.08 (1.00), 236	−0.06 (0.94), 147
p Value	0.06	0.13	0.41	0.13	0.34
Pp JEM*:					
Not exposed	0.02 (1.00), 4379	0.03 (1.00), 4674	0.01 (1.04), 491	0.04 (0.95), 566	0.01 (0.98), 235
Exposed	−0.08 (1.01), 1192	−0.08 (1.01), 1543	−0.01 (0.94), 363	−0.12 (1.11), 214	−0.02 (1.04), 160
p Value	0.001	0.0001	0.82	0.04	0.75
P10–50 JEM (% of self reported exposure per job):					
<10	0.04 (1.03), 1519	0.09 (0.98), 861	0.00 (1.12), 216	0.11 (0.84), 105	0.02 (1.00), 174
10–49	−0.01 (0.99), 3733	0.00 (0.99), 4666	0.01 (0.97), 275	−0.01 (1.03), 543	−0.02 (0.91), 61
⩾50	−0.09 (1.00), 319	−0.11 (1.06), 690	−0.01 (0.94), 363	−0.04 (1.01), 132	−0.02 (1.04), 160
p Value (test for trend)	0.02	0.0001	0.86	0.29	0.69

*Pp Population specific JEM, based on the percentage of subjects who reported themselves exposed in each job, was constructed such as the exposure prevalence (p) was close to the self reported one.

smoking. As all analyses gave the same results, reported ones are thus for scores adjusted initially on smoking. The comparison between the self reported exposure and the Pp JEM (both exposure assessments classified in two categories) was performed with Cohen's κ statistic.[17]

To assess the influence of the number of subjects per job on the precision of the exposure estimates by the population specific JEM, a resampling procedure was used. Two series of draws were obtained by sampling 100 times, without replacement, in men from the largest survey (French PAARC survey). Each sample included 900 men in the first series and 3200 men in the second series. Restricting analyses to men whose occupations were carried out by at least two men resulted in respectively about 850 (a similar number of subjects as in the urban and rural Dutch residents) and 3170 men in each sample.

Results

In the men from the three populations as well as the women from the French survey, the mean age was about 42 years old (table 4). Fewer men were smokers in the Norwegian survey (non-smokers included by design), compared with men in the French or the Dutch surveys. By contrast, in women (French survey) there were about 70% never smokers and only 23% smokers. In the French survey (households of manual workers excluded by design), men reported themselves to be less exposed than did men from the Dutch or the Norwegian surveys. French women reported themselves to be less exposed than did men. The distribution of the number of subjects with the same job differed across the surveys. In the Norwegian survey and the urban Dutch surveys the maximum number of men per job was low compared with the French and the rural Dutch surveys.

OCCUPATIONAL EXPOSURE

Agreement between self reported exposure and the Pp JEM was low in the French survey and among the rural Dutch residents, and moderate in the other cases. Cohen's κ values were 0.31, 0.30, 0.58, 0.34, and 0.71, in women, men from the French survey, men from urban and rural Dutch residences, and men from the Norwegian survey, respectively.

In the French survey, FEV_1 was lower among subjects who reported themselves to be exposed than among non-exposed subjects, but the difference was not significant in men and was of borderline significance in women. By contrast, with both the Pp JEM and the P10–50 JEM significantly lower FEV_1 values were found in subjects classified as exposed (table 5). Furthermore, the results show that the higher the proportion of people exposed in the group the lower was the mean FEV_1 score. Results from the analyses in the French survey restricted to occupations carried out by at least 10 people, showed consistent results (not shown).

Among the rural Dutch residents, a significantly lower FEV_1 was found in men exposed according to the Pp JEM, whereas consistent but non-significant associations were found with self reported exposure and the P10–50 JEM (table 5). Among the urban Dutch residents, no significant associations were found with exposures estimated by any of the three methods, but a non-significant trend towards higher FEV_1 was found among workers who reported themselves as being exposed versus those who did not.

In the Norwegian survey, lower FEV_1 values were found in men who declared themselves exposed than in those not exposed, but the difference was not significant (table 5). The same trend was found with the Pp JEM and the P10–50 JEM but the association was weaker than with self reported exposure.

No interaction between occupational exposures estimated by the three methods and smoking habits was found in any of these analyses.

PRECISION OF OCCUPATIONAL EXPOSURES ESTIMATED BY A POPULATION SPECIFIC JEM

In the French survey, in both men and women, as among the rural Dutch residents, many subjects did a job that was done by at least 50 people (table 4). By contrast, in the Norwegian survey and among the urban Dutch residents there were possibly too few subjects per job to permit a good estimate of exposure.

A resampling procedure with the largest French data set was performed to test the hypothesis that the exposure estimate would be more precise when jobs were done by many

Table 6 Effects of the distribution of subjects per job on the performance of population specific JEM (resampling (two series of 100 draws) performed in men from the French survey)

	First series	*Second series*
Men (mean (SD))	849 (6.4)	3171 (4.1)
Different jobs (mean (SD))	110 (5.0)	184 (3.6)
Self reported exposure (mean (SD)) (%)	25.5 (1.5)	25.8 (0.5)
Men in each category of job (mean (SD)) (%):		
<10	40.2 (2.6)	14.4 (0.8)
10–19	17.9 (3.2)	19.1 (1.4)
20–49	25.9 (5.2)	20.4 (1.8)
⩾50	16.0 (4.4)	46.0 (1.5)
Significant positive associations (between exposure and FEV_1) out of 100 draws (n):		
Self reported exposure	6	8
Pp JEM	16	61
P10–50 JEM	15	63

people. The resampling was performed with varying sample size to obtain a varying proportion of jobs with few subjects, which in a given population depends on the sample size. Results from the two resampling series showed proportions of self reported exposure similar to the prevalence found in men from the whole data set (table 4, table 6). In the first series of draws (n around 900 in each sample as in the Dutch populations), about 40% of the men had an unusual job (<10 men), whereas in the second series (with n four times larger), around 45% of the men had a job done by at least 50 men in each sample (table 6). In both series more significant relations between exposure and FEV_1 were found with the population specific JEM than with self reported exposure. Significant associations occurred more often in the second series than in the first. No reverse associations were found in the second series, and only one significant reverse association between FEV_1 and exposure out of 100 was found in the first series, with both self reported exposure and the P10–50 JEM.

Discussion

Associations were found between estimated occupational exposure by the population specific JEM and lowered lung function, whereas no significant relations were found with self reported exposure among either men or women in the French survey, or in the rural Dutch area. No significant relation was found in the Norwegian survey, or in the urban Dutch area whatever the method used. Results suggest that population specific JEMs perform better than self reported exposures, when there are enough jobs done by enough subjects, a hypothesis supported by results obtained by resampling procedures.

ASSOCIATIONS OF OCCUPATIONAL EXPOSURE WITH LUNG FUNCTION

Significant associations between exposure estimated by the population specific JEM and lung function found in three out of the five populations studied agree with findings previously reported in other community and workforce based surveys.[1 2] In the Norwegian survey, our results are not inconsistent with associations previously reported on a larger sample between self reported occupational exposure to specific hazards and spirometric airflow limitation for subjects >50.[10] Although the association between self reported occupational exposure and FEV_1 was not significant, the magnitude was comparable with the magnitude found in men from the French survey with the Pp JEM. In the urban Dutch area no trend was found whatever the method used. In the three surveys, the analyses were done on the last occupation. In the Norwegian survey, the OR between occupational exposure and obstructive lung disease was higher with exposure in the present job than in the job held longest.[10]

Another possibility is that there is no effect of occupational exposure on FEV_1 in urban Dutch and Norwegian populations. It could be hypothesised that in the Norwegian survey, if self reported exposure was differentially biased and led to a false positive effect the Pp JEM corrected this and correctly indicated no effect of occupational exposure on FEV_1 in this population. Furthermore the differences in assessment of exposure in the Norwegian survey compared with the other surveys may also explain differences in the results. However, associations previously reported in the Norwegian survey[10] do not agree with these hypotheses. The lack of relations with the population specific JEM could be explained by the imprecise assessment of exposure due to the low numbers of subjects per job in the Norwegian survey and among the urban Dutch residents.

Residual confounding for smoking could be theoretically possible as JEMs relate to job and therefore to social class. However, associations between FEV_1 and exposure assessed by an external JEM was unchanged by different adjustments for smoking (including pack-years) in a previous analysis in the French survey.[4] In the present analysis, initial and subsequent adjustment for smoking led to similar results.

PERFORMANCE OF POPULATION SPECIFIC JEM COMPARED WITH SELF REPORTED EXPOSURE

The study of the performance of a JEM comprises three main elements as described by Bouyer *et al*[18]: (*a*) the ability of the JEM to evaluate accurately the exposure itself, (*b*) its statistical performance in terms of bias and power, (*c*) its ability to detect known associations between risk factors and disease. In our study, only point (*c*) can be directly studied to estimate the performance of the population specific JEM although the two other aspects may be considered indirectly. The pattern of relations between the probability of exposure and a decrease in FEV_1 found in the French survey and evidence of known associations in two different populations (French survey and rural Dutch residents) are arguments in favour of the validity of the population specific JEM. The lowest κ values between self reported exposure and the Pp JEM were found in the groups in which the population specific JEM performed better than self reported exposure.

An argument in favour of the accurate exposure assessment of the population specific JEM is that similar results have been found with both a JEM built by experts and a population specific JEM, in a population based study on COPD.[7] More significant associations between specific exposures and incidence of lung cancer were found with a population specific JEM than with an external JEM[19] and a theoretical calculation showed that population specific JEMs performed better than the external JEM when the prevalence of exposure was >10%.[6] In the French survey, with both the Pp and P10–50 JEM, associations were found between exposure and lung function and agree with findings previously reported[4] with a British,[19] an Italian[20] and a JEM built by experts for the survey.[4] In men, both the magnitude of the relation between exposure and FEV_1 and the number of subjects in the highest category of exposure were similar whatever the JEM used (British, Italian, internal, or P10–50 JEM), whereas in women these two variables fluctuated according to the JEM.[4] A further advantage of the population specific JEM is the absence of additional error due to job recoding, whereas the use of an external JEM required translation of occupation codes into the coding system used by that JEM. A population specific JEM, by its mode of construction, can be applied whatever the classification used to code occupation.

Decrease of classification bias (both non-differential and differential) may be obtained with a population specific JEM. As with all threshold methods, population specific JEMs increase errors of classification and do not take into account all the available information (in our case, the proportion of subjects exposed in a job).[21] However, our results suggest that the error due to misclassification of exposure by subjects may be larger than the error due to the heterogeneity of exposures among subjects with the same job. Significant associations were found with the population specific JEM when no associations were found with self reported exposure. Group based strategies to assess occupational exposure have been shown to be very effective and to yield essentially unbiased estimates of exposure-response relations whereas self reported estimates of exposure might lead to precise but substantially attenuated relations.[22] Differential bias was less than with the self reported method, as assessment of exposure with a population specific JEM was less dependent on health. The discussion of the performance in terms of power cannot be assessed here.

With the same power, in the French survey and the rural Dutch area, associations were significant with a Pp JEM whereas they were not significant with self reported exposure. Usually it is difficult to compare results with different exposure assessment methods because the statistical power is not the same.[18 23] Siematycki *et al*[23] described a method of assessing exposure based on expert evaluation, in which they choose a cut off point for maximising the power. Bouyer *et al*[18] emphasised that having comparable prevalence of exposure with two methods of assessing exposure should help to compare the methods. By the mode of construction of the Pp JEM, the prevalence of exposure and therefore the statistical power were the same for the self reported exposure and the Pp JEM. Although in our study the cut off point was chosen to optimise the comparison of the two methods, this is not necessarily the best for optimising the specificity or the sensitivity of the estimate. In future studies with population specific JEMs, there will be no need to have the same initial prevalence as the self reported prevalence found in the population.

Our results show that a good estimation of exposure with a population specific JEM required enough jobs with many workers. By resampling, relations between exposure and FEV_1 were more often significant with population specific JEM than with self reported exposure and more often significant in large groups of workers (better estimates of exposure) than in small ones. Therefore, resampling findings are consistent with results found in the three surveys. Considering the null hypothesis "no relation between occupational exposure and FEV_1" the percentage of significant relations found should be different from 5%, because the samples are not independent, but the exact proportion is difficult to estimate.

Population specific JEMs have been used previously[5–7] but no formal comparison with self reported exposure was performed. Our results suggest that the assessment by the two methods may be different and lead to different estimates of associations with health.

In conclusion, our results show that many subjects with the same job are required to make a population specific JEM sufficiently precise. However, the choice of optimal cut off points depends on the population studied. Population specific JEMs are easy to construct and their applications are not limited by the classification of jobs used in the studies. Furthermore, population specific JEMs perform better than the self reported method, when optimum conditions for their use are fulfilled (large populations or populations with similar jobs).

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