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)

N Le Moual, P Bakke, E Orlowski, D Heederik, H Kromhout, S M Kennedy, B Rijcken, F Kauffmann

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 (FEV1) 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 FEV1 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.

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. 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. Self reported information and more recently job exposure matrices (JEMs) 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. 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. Self reported and population specific JEM assessment methods have never been compared formally although results with both methods have been published once.

Three general population surveys in France, The Netherlands, and Norway provided data on an individual basis on occupational airborne exposure and lung function. In the French surveys, associations between occupational exposures and lung diseases have already been studied, whereas in the Dutch surveys 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.
Material and methods

In the French Cooperative Pollution Atmosphérique et Affections Respiratoires Chroniques (PAARC) study, 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 the 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, 9,347 men and 3,256 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)), based on tobacco smoked as cigarettes, cigars, or in a pipe.

In the two phase Norwegian survey, a postal questionnaire was sent in 1985 to a sample of 4,992 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 1,275 subjects (653 men and 622 women), described previously, 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.
The probability of exposure in an occupation was considered high, moderate, or low, when \( \geq 50\% \), 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 in a job, was \( \geq \) 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.

### Statistical Analysis

Analyses were also performed for subjects whose occupation was carried out by at least 10 people, this involved 5046 men and 5000 women.

### Table 4 Description of subjects in the three general populations

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>Age (mean (SD))</td>
<td>41.7 (9.5)</td>
<td>42.4 (9.5)</td>
<td>42.2 (10.2)</td>
<td>41.9 (11.0)</td>
<td>42.5 (11.5)</td>
</tr>
<tr>
<td>Smoking (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-smokers</td>
<td>70.1</td>
<td>26.1</td>
<td>10.0</td>
<td>7.0</td>
<td>43.5</td>
</tr>
<tr>
<td>Ex-smokers</td>
<td>6.6</td>
<td>18.1</td>
<td>17.3</td>
<td>10.3</td>
<td>23.6</td>
</tr>
<tr>
<td>Smokers</td>
<td>23.4</td>
<td>55.8</td>
<td>72.7</td>
<td>82.7</td>
<td>32.9</td>
</tr>
<tr>
<td>Self reported exposure (%)</td>
<td>19.6</td>
<td>25.9</td>
<td>41.8</td>
<td>30.3</td>
<td>37.2*</td>
</tr>
<tr>
<td>Different jobs (n)</td>
<td>177</td>
<td>223</td>
<td>165</td>
<td>108</td>
<td>68</td>
</tr>
<tr>
<td>Subjects per job (n (%)</td>
<td>2.820</td>
<td>2.465</td>
<td>2.56</td>
<td>2.276</td>
<td>2.64</td>
</tr>
</tbody>
</table>

*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  FEV1 scores (mean (SD), n) after adjustment for age, height and smoking according to exposure to dusts, gases, fumes

<table>
<thead>
<tr>
<th></th>
<th>France</th>
<th>The Netherlands (men)</th>
<th>Norway (men)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Women (n=5571)</td>
<td>Men (n=6217)</td>
<td>Urban (n=854)</td>
</tr>
<tr>
<td>SELF REPORTED EXPOSURE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not exposed</td>
<td>0.01 (1.00), 4479</td>
<td>0.01 (1.01), 4605</td>
<td>−0.02 (1.02), 497</td>
</tr>
<tr>
<td>Exposed</td>
<td>−0.08 (0.90), 1092</td>
<td>−0.03 (0.90), 1612</td>
<td>0.03 (0.98), 357</td>
</tr>
<tr>
<td>p Value</td>
<td>0.06</td>
<td>0.13</td>
<td>0.41</td>
</tr>
<tr>
<td>Pp JEM</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not exposed</td>
<td>0.02 (1.00), 4379</td>
<td>0.03 (1.00), 4674</td>
<td>0.01 (1.00), 491</td>
</tr>
<tr>
<td>Exposed</td>
<td>−0.08 (1.01), 1192</td>
<td>−0.08 (1.01), 1543</td>
<td>−0.01 (0.94), 363</td>
</tr>
<tr>
<td>p Value</td>
<td>0.001</td>
<td>0.0001</td>
<td>0.82</td>
</tr>
<tr>
<td>P10–50 JEM (% of self reported exposure per job)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10</td>
<td>0.04 (1.03), 1519</td>
<td>0.09 (0.98), 861</td>
<td>0.00 (1.12), 216</td>
</tr>
<tr>
<td>10–49</td>
<td>−0.01 (0.90), 3733</td>
<td>0.00 (0.99), 4666</td>
<td>0.01 (0.97), 275</td>
</tr>
<tr>
<td>≥50</td>
<td>−0.08 (1.00), 319</td>
<td>−0.13 (1.08), 690</td>
<td>−0.01 (0.94), 363</td>
</tr>
<tr>
<td>p Value (test for trend)</td>
<td>0.02</td>
<td>0.0001</td>
<td>0.86</td>
</tr>
</tbody>
</table>

*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.

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, FEV1 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 FEV1 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 FEV1 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 FEV1 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 FEV1 was found among workers who reported themselves as being exposed versus those who did not.

In the Norwegian survey, lower FEV1 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.
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)

<table>
<thead>
<tr>
<th></th>
<th>First series</th>
<th>Second series</th>
</tr>
</thead>
<tbody>
<tr>
<td>Men (mean (SD))</td>
<td>849 (6.4)</td>
<td>3171 (4.1)</td>
</tr>
<tr>
<td>Different jobs (mean (SD))</td>
<td>110 (5.0)</td>
<td>184 (3.6)</td>
</tr>
<tr>
<td>Self reported exposure (mean (SD)) (%)</td>
<td>25.5 (1.5)</td>
<td>29.8 (0.5)</td>
</tr>
<tr>
<td>Men in each category of job (mean (SD)) (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;10</td>
<td>40.2 (2.6)</td>
<td>14.4 (0.8)</td>
</tr>
<tr>
<td>10–19</td>
<td>17.6 (3.2)</td>
<td>19.1 (1.4)</td>
</tr>
<tr>
<td>20–49</td>
<td>25.9 (5.2)</td>
<td>20.4 (1.8)</td>
</tr>
<tr>
<td>≥50</td>
<td>16.0 (4.4)</td>
<td>46.0 (1.5)</td>
</tr>
</tbody>
</table>

Significant positive associations (between exposure and FEV1) out of 100 draws (%):
- Self reported exposure: 6
- Pp JEM: 16
- P10–50 JEM: 15

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 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 FEV1 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 FEV1 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 FEV1 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 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 FEV1 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. 1 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: 2 (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 FEV1 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 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 and a theoretical calculation showed that population specific JEMs performed better than the external JEM when the prevalence of exposure was >10%. 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 with a British, an Italian and a JEM built by experts for the survey. In men, both the magnitude of the relation between exposure and FEV1 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. 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). 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. 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. Siemiatycki et al 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 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 FEV1 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 FEV1,” 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 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).

We were grateful to R Vermeulen for the coding of the jobs and to J Lellouch, H M Boezen and J P Schouten for their comments on this paper. This work was supported by ECOJEM (European collaborative analyses on occupational risk factors for COPD using JEMs), which is a subproject of the European concerted action “epidemiological surveys on chronic obstructive pulmonary diseases (COPD) in different European countries: prevalence rates and relationship to host and environmental risk factors” coordinated by C Giuntini (grant BMH-CT92-0849).


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