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—The aim of the present analysis was to compare the performance of population-specific Job Exposure Matrices (JEM) and self-reported occupational exposure using data on exposure and lung function from three European general populations.

Methods—Self-reported occupational exposure (yes/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 FEV_1 (forced expiratory volume in one second) tracings and whose occupations were encountered at least two times, 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 JEM, based on the percentage of subjects who reported themselves exposed in each job, were constructed for each survey and each gender. The first matrix classified jobs in 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 in order to have the same statistical power as using the self-reported exposure, i.e. the exposure prevalence (p) was the same using both exposure assessment methods (Pp JEM). Relations of occupational exposure estimated by the two population-specific JEM and self-reported exposure with 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 relationship was found using 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 relationships in the Norwegian and the Dutch (urban area) surveys.

Conclusion—Population-specific JEM, easy to construct and at little cost, seem to perform better than crude self-reported exposures, in populations with a sufficient number of subjects per job.

Key words: 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 (JEM) [4] [5] have been used to estimate occupational risk factors in community-based studies on COPD. Population-specific job exposure matrices, 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 exposure per job. Using population specific JEM might lead to less misclassification in exposure than using self-reported exposure. 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 using 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 been performed yet. The aim of the present paper is to evaluate how occupational exposures estimated by population-specific job exposure matrices perform compared to self-reported exposures, in their relationships to lung function.

Material and methods

In the French Cooperative PAARC (Pollution Atmosphérique et Affections Respiratoires Chroniques) study [8], performed in 1975, 20310 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 one month), or smokers (light smokers (< 10 g/day), moderate smokers (10 to 19 g/day) and heavy smokers ($\geq$ 20 g/day)), based on grams of tobacco smoked as cigarettes, cigars or pipe per day.

In the Dutch survey [9], 3477 men and 3256 women, aged 15-64 years, were recruited over three 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 to 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 summarized 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/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 exposed to dusts, gases and fumes if they answered positively to one of two questions (exposed to dusts or exposed to gases/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 to at least one of eight questions about exposure in their more 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), one or more of the following products (petroleum products, solvents, detergents, pigments, plastics, paints/lacquers, insecticides /pesticides)). The occupational titles were coded using 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 JEM were constructed using computer calculations for each survey and in the French survey for each gender. The first step was to calculate in each job the proportion of subjects exposed to dusts, gases and fumes using 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 percent of the subjects who practise this job reported themselves exposed. The choice of the cutpoint x is arbitrary and may be chosen to obtain an overall fixed percentage of exposed and modified to increase the specificity or the sensitivity of the measure. By the same method, JEM with several classes of exposure may be defined. A matrix which classified exposure in three categories (P10-50 with the two cutpoints : $p < 10\%$, $p \geq 50\%$), as described by Post *et al* [5] was constructed. The probability of exposure in an occupation was considered high, moderate or low, when ≥ 50%, 10 to 49% or < 10% of the men (women) working in this occupation reported themselves occupationally exposed, respectively. Another JEM was built in order to have the same statistical power as using self-reported exposure. The construction of that two-class JEM was done in such a way that the prevalence of exposure using the Pp JEM would be the same as the prevalence in the self-reported data (p). For example, in the French survey 4605 men declared themselves as non-exposed. The closest figure of non exposed using the Pp JEM (4674) was obtained by considering as non exposed the jobs in which less than 33% (optimal cutpoint) of workers reported exposure (table 2). In that case, the prevalence of exposure using the Pp JEM (24.8%) was as close as possible to the prevalence based on the self-reported exposure (25.9% (table 4)). For the other populations, a job was classified exposed using the Pp JEM when the percentage of subjects, who declared themselves exposed in a job, was equal or greater to the following cutpoints : 30% in women from the French survey, 50% and 29% in 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 years old who performed good forced expiratory volume in one second (FEV_1) tracings and whose last occupation was encountered for 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 JEM in optimal conditions (prevalence of exposure about 10% or more) [6] [15]. In the

French survey, to compare present results with results previously described [4], analyses were also performed for subjects whose occupation was encountered at least 10 times, i.e. 5046 men and 5000 women.

STATISTICAL ANALYSIS

Standardised FEV_1 score (m ± SD = 0 ± 1) was obtained for each gender and city, after adjustment of FEV_1 on age, height and smoking habits (expressed by dummy variables, four in France (ex-smokers, light smokers, moderate smokers, heavy smokers), three in The Netherlands (ex-smokers, cigar/pipe smokers, cigarette smokers) and two in Norway (ex-smokers, smokers)), in multiple regression analyses. The relationship between exposure and FEV_1 was tested with a Student's t test for dichotomous variables and with a test for trend for P10-50 JEM [16]. Analyses were also done using FEV_1 score adjusted on age and height for each gender and city and regressing this score on occupational hazards, adjusting for smoking habits. As all analyses gave the same results, reported ones are thus for scores adjusted *a priori* on smoking. The comparison of the self-reported exposure and the Pp JEM (both exposure assessments classified in two categories) was performed using Cohen's Kappa statistic [17].

In order 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 encountered at least two times 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 to men in the French or the Dutch surveys. In contrast, in women (French survey) there were about 70% never smokers and only 23% smokers. In the French survey (manual workers households excluded by design), men reported themselves to be less exposed than men from the Dutch or the Norwegian surveys did. French women reported themselves to be less exposed than men did. The distribution of the number of subjects holding 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 to the French and the rural Dutch surveys.

OCCUPATIONAL EXPOSURE

Concordance of self-reported exposure and Pp JEM was low in the French survey and the rural Dutch residents and moderate in the other cases. Cohen's kappa values were 0.31, 0.30, 0.58, 0.34, 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 exposed subjects according to the self-reported exposure than among non exposed subjects, but the difference was not significant in men and of borderline significance in women. In contrast, using both the Pp JEM and the P10-50 JEM significantly lower FEV1 values were observed in subjects classified as exposed (table 5). Furthermore, the results show that the higher was 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 occupation encountered at least 10 times, showed consistent results (not shown).

In the rural Dutch residents, a significantly lower FEV_1 was observed in men exposed according to the Pp JEM whereas consistent, but non significant, associations were found using self-reported exposure and the P10-50 JEM (table 5). In the urban Dutch residents, no significant associations were found according to the three estimates, with a non significant trend to higher FEV_1 in exposed versus non exposed when using self-reported exposure.

In the Norwegian survey, lower FEV_1 values were observed in men who declared themselves exposed compared to non exposed, but the difference was not significant (table 5). The same trend was observed using the Pp JEM and the P10-50 JEM with however a weaker association than when using 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 POPULATION-SPECIFIC JEM

In the French survey, in both men and women, as in the rural Dutch residents, a large proportion of subjects practised a job encountered at least 50 times (table 4). In contrast, in the Norwegian survey and the urban Dutch residents there were possibly too few subjects per job to permit a good estimate of exposure.

A resampling procedure using the largest French data set was performed to test the hypothesis that the exposure estimate would be more precise when jobs were reported by a large number of individuals. 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 series of resamplings showed proportions of self-reported exposure similar to the prevalence observed in men from the whole data set (table 4, table 6). In the first series of draws (n around 900 in each sample like in the Dutch populations), about 40% of the men had a job seldom encountered (less than 10 times), whereas in the second series (with n four times larger), around 45% of the men had a job encountered at least 50 times in each sample (table 6). In both series, more significant relationships, between exposure and FEV_1, were found using the population-specific JEM than using self-reported exposure with more often significant associations in the second series than in the first one. No reverse associations were observed in the second series, and only one significant reverse association between FEV_1 and exposure out of 100 was found in the first series, using both self-reported exposure and the P10-50 JEM.

Discussion

Associations between occupational exposure estimated by the population-specific JEM and lower lung function were found, whereas no significant relationships were found using self-reported exposure in the French survey, in both men and women, and in the rural Dutch area. No significant relationship was found in the Norwegian survey and in the urban Dutch resident whatever the method used. Results suggest that population-specific JEM perform better than self-reported exposures, when there are enough jobs with a large number of 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 are in agreement 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 over 50 [10]. Although the association between self-reported occupational exposure and FEV_1 was not statistically significant, the magnitude was comparable to the magnitude found in men from the French survey using 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 using 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. One could hypothesize that in the Norwegian survey, if self-reported exposure was differentially biased and lead 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 questions on exposure in the Norwegian survey compared to the other surveys may also explain differences in the results. However, associations previously reported in the Norwegian survey [10] are not in favour of these hypotheses. The lack of relationship using the population-specific JEM could be explained by the imprecise assessment of exposure due to the low number of subjects per job in the Norwegian survey as in the urban Dutch residents.

Residual confounding for smoking when using JEM, related to job and therefore to social class, instead of individual exposure could be theoretically possible. However, associations of FEV_1 with exposure assessed by external JEM was unchanged by considering different adjustment for smoking (and considering pack years) in a previous analysis in the French survey [4]. In the present analysis, *a priori* and *a posteriori* adjustment for smoking led to similar results.

Performance of population-specific JEM compared to self-reported

The study of the performance of a JEM comprises three main elements as described by Bouyer *et al* [18]: (i) the ability of the JEM to evaluate accurately the exposure itself, (ii) its statistical performance in terms of bias and power, (iii) its ability to detect known associations between risk factors and disease. In our study, only the third point can be directly studied to estimate the performance of the population-specific JEM although the two other aspects may be addressed indirectly. The pattern of relationships 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 kappa values between self-reported exposure and the Pp JEM were observed 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 has been found using both an *ad hoc* 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 using a population-specific JEM than using an external JEM [19] and a theoretical calculation showed that population-specific JEM performed better than the external JEM when the prevalence of exposure was above 10 percent [6]. In the French survey, using both the Pp and P10-50 JEM, associations found with lung function are in agreement with findings previously reported [4] using a British [19], an Italian [20] and a JEM built by experts for the survey [4]. In men, both the magnitude of the exposure-FEV_1 relationship 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 parameters fluctuated according to the JEM [4]. A further advantage of using 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 by using population-specific JEM. As all threshold methods, population-specific JEM increase errors of classification and does 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 using the population-specific JEM when no association were observed using self-reported exposure. Group-based occupational exposure assessment strategies have been shown to be very effective and to yield essentially unbiased estimates of exposure response relationships whereas individual-based estimates of exposure might lead to precise but substantially attenuated relations [22]. Differential bias was diminished compared to self-reported method, as using population-specific JEM exposure was less dependent on health status. The discussion of the performance in term of power cannot be assessed here.

With the same power, associations were significant using Pp JEM whereas they were not significant using self-reported exposure, in the French survey and the rural Dutch area. Usually it is difficult to compare results using different exposure assessment methods because the statistical power is not the same[18][23]. Siematycki *et al* [23] described a method of exposure assessment based on expert evaluation, in which they choose a cutpoint for maximizing the power. Bouyer *et al* [18] emphasized that having comparable prevalence of exposure in two exposure assessment methods 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 cutpoint was chosen to optimize the comparison of the two methods, this is not necessarily the best for optimizing the specificity or the sensitivity of the estimate. In future studies using population-specific JEM, there is no *a priori* need to have the same prevalence as the self-reported one observed in the population.

Our results show that a good estimation of exposure using a population-specific JEM, required enough jobs with a large number of subjects. By doing resamplings, relationships between exposure and FEV_1 were more often significant using population-specific JEM than self-reported exposure and more frequently significant in large draws (better estimates of exposure) than in small ones. Therefore, resampling findings are consistent with results found in the three surveys. On the null hypothesis "no relationship between occupational exposure and FEV_1" the percent of significant relationships observed should be different from 5%, because the samples are not independent, but the exact proportion is difficult to estimate.

Population-specific JEM have been used previously [5] [6] [7] but no formal comparison with self-reported exposure was performed. Our results suggest that the assessment by both methods may be different and lead to different estimates of associations with health.

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

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Table 1 Methods in the three general populations

	France *1975* *7 cities*	The Netherlands *1965-1969* *Urban / Rural*	Norway *1985-1988*
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
Number of subjects excluded	8522 (42.0)	1843(53.0)	258(39.5)
Reasons of these exclusions :			
aged less 25 or more 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 smoke	81 (1.0)	12 (0.7)	3 (1.2)
occupation with less than 2 subjects	154 (1.8)	121 (6.6)	46 (17.8)
Analyses performed on	6217 men / 5571 women	854 men / 780 men	395 men

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

Percent of subjects who declared themselves exposed in a job	Number of subjects	Cumulative number of subjects	Cumulative Percent
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 non exposed, i.e. 74.1%; 1612 men exposed, i.e. 25.9%.

Pp JEM : 4674 men non exposed, i.e. 75.2%; 1543 men exposed, i.e. 24.8%.

* Cutpoints 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	Number of subjects	% of self-reported exposure in the job	P10-50 JEM	Pp JEM *
Physicians	147	9%	low	non exposed
Office workers	465	19%	moderate	non exposed
Stock clerks	144	35%	moderate	exposed
Bakers - Pastrycooks	51	67%	high	exposed

* The cutpoint for exposure assessment was 33% in men from the French survey.

Table 4 Description of subjects in the three general populations

	France		The Netherlands (men)		Norway (men)
	Women (5571)	Men (6217)	Urban (854)	Rural (780)	(395)
Age (m ± SD)	41.7 ± 9.5	42.4 ± 9.5	42.2 ± 10.2	41.9 ± 11.0	42.5 ± 11.5
Smoking habits					
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*
Number of different jobs	177	223	165	108	68
Number of subjects per job (min. - max.)	2 - 820	2 - 465	2 - 56	2 - 276	2 - 64
Distribution of the number of subjects per job					
Jobs with < 10 subjects, number of subjects (%)	449 (8.1)	438 (7.0)	416 (48.7)	183 (23.5)	188 (47.6)
Jobs with 10 -19 subjects, number of subjects (%)	320 (5.7)	634 (10.2)	208 (24.4)	86 (11.0)	121 (30.6)
Jobs with 20 -49 subjects, number of subjects (%)	1003 (18.0)	1464 (23.6)	161 (18.8)	104 (13.3)	22 (5.6)
Jobs with ≥ 50 subjects, number of subjects (%)	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), or petroleum products, solvents, detergents, pigments, plastics, paints/lacquers, insecticides /pesticides.

Table 5 Smoking adjusted FEV_1 (m±SD) scores according to exposure to dusts, gases, fumes

	France		The Netherlands (men)		Norway (men)
	Women (5571)	Men (6217)	Urban (854)	Rural (780)	(395)
Self-reported exposure					
non 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*					
non 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 percent of self-reported exposure / 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

( ) : number of men

* The 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.

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
Number of men (m ± SD)	849 ± 6.4	3171 ± 4.1
Number of different jobs (m ± SD)	110 ± 5.0	184 ± 3.6
% self-reported exposure (m ± SD)	25.5 ± 1.5	25.8 ± 0.5
% of men in each category of job		
Job with < 10 men, % men sampled (m ± SD)	40.2 ± 2.6	14.4 ± 0.8
Job with 10 -19 men, % men sampled (m ± SD)	17.9 ± 3.2	19.1 ± 1.4
Job with 20 - 49 men, % men sampled (m ± SD)	25.9 ± 5.2	20.4 ± 1.8
Job with ≥ 50 men, % men sampled (m ± SD)	16.0 ± 4.4	46.0 ± 1.5
Number of significant positive associations (between exposure and FEV_1) out of 100 draws		
Self-reported exposure	6	8
Pp JEM	16	61
P1050 JEM	15	63