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Cross sectional study on lung function of coke oven workers: a lung function surveillance system from 1978 to 1990

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Aims: To determine the association between lung function of coke oven workers and exposure to coke oven emissions.

Methods: Lung function data and detailed work histories for workers in recovery coke ovens of a steelworks were extracted from a lung function surveillance system. Multiple regressions were employed to determine significant predictors for lung function indices. The first sets of lung function tests for 613 new starters were pooled to assess the selection bias. The last sets of lung function tests for 834 subjects with one or more year of coke oven history were pooled to assess determinants of lung function.

Results: Selection bias associated with the recruitment process was not observed among the exposure groups. For subjects with a history of one or more years of coke oven work, each year of working in the most exposed "operation" position was associated with reductions in FEV_1 of around 9 ml (p = 0.006, 95% CI: 3 ml to 16 ml) and in FVC of around 12 ml (p = 0.002, 95% CI: 4 ml to 19 ml). Negative effects of smoking on lung function were also observed.

Conclusions: Exposure to coke oven emissions was found to be associated with lower FEV_1 and FVC. Effects of work exposure on lung function are similar to those found in other studies.

C oke is produced by continuously baking bituminous coal in ovens in the absence of oxygen for around 16–17 hours.[1 2] Hundreds of complex chemicals are generated during the coking process, with coal tar (phenols, cresols, naphthalene, benzene and its homologues, etc), light oil (benzene, toluene, the xylenes, etc) and gases (sulphur dioxide, nitrogen dioxide, ammonia, etc) being the main constituents of coke oven emissions.[1 3] Such emissions are reported to have harmful health effects on workers.[4] Evidence from various epidemiological investigations shows that emissions can increase risk of lung and other cancers.[5–9] Fewer studies have concentrated on lung function of coke oven workers.[10–13] Some investigations have reported lower lung function and higher prevalence of bronchitis.[10 12 13]

A lung function surveillance system has operated from 18 October 1978 at the recovery coke ovens of a steelworks. Since 2 July 1990, the surveillance system has continued with reselected surveillance parameters and modified assessment of smoking. Full utilisation of the information available necessitated separate analyses of the pre- and post-1990 data. One aim of this paper was to assess selection issues. Another was to conduct a cross sectional analysis on the pre-1990 data to assess determinants of the lung function of these coke oven workers.

MATERIALS AND METHODS

Study population

Of the 1727 subjects who ever worked in relatively highly exposed positions of coke ovens and hence were eligible to be registered in the surveillance system, 324 with no lung function measurements were excluded, along with 22 females (too few for useful analysis), and four subjects of unstated sex. There remained 1377 male subjects with at least one set of lung function measurements. The last sets (or the only sets) of lung function tests for all 1377 subjects were pooled to form the cross sectional database. This was a dynamic cohort, which allowed workers to freely join or withdraw.

More than half (738) of the subjects in the surveillance system began their coke oven work long before the surveillance system started. New starters were defined as those workers who had lung function tests within one year of commencing work at the coke ovens. A baseline analysis of the first (or only) sets of tests for 639 new starters was conducted to test for selection bias in the recruitment process. This study was approved by the ethics committee, the University of Wollongong.

Occupational exposure assessment

To assess occupational exposure level, it is desirable to obtain individual monitoring data. However, such data were not available. An alternative is to trace specific job positions at the coke ovens, and corresponding duration, for each subject. Records of the payment system in the steelworks were used to trace the detailed work history of 1163 individuals, around 84% of the population. The current job position was used to classify the 214 (around 16%) subjects with no detailed history.

Although seven job classifications are used in the coke ovens, it was deemed appropriate to group these into four, based on perceived exposure levels, as follows:

- *Operation*. Subjects are mainly responsible for charging, coking, and pushing operations at the coke oven battery section.
- *Maintenance*. Subjects are mainly responsible for repairing mechanical facilities at the coke oven battery section.
- *Electricity*. Subjects are mainly responsible for fixing and repairing electrical facilities at the coke oven battery section or elsewhere.

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Abbreviations: BSF, benzene soluble fraction; $FEF_{25–75\%}$, forced mid-expiratory flow; FEV_1, forced expiratory volume in one second; FVC, forced vital capacity; VC, vital capacity

- *Other*. This includes supervision, coal preparation, by-product operation, and any subject whose date of lung function test is earlier than the date of starting exposure.

While by-product operation exposes workers to extracted constituents, it is appropriately grouped with "other" as being the group least exposed to coke oven emissions. The "operation" group is regarded as the most exposed. Although top and side positions in battery operation are reported to involve substantially different exposure, information from the steelworks about time spent in top or side is limited to the general statement that workers rotate regularly between the two. The exposure levels for "maintenance" and "electricity" are between the least and the most.

While individual monitoring data are not available in this study, regular monitoring of coke oven emissions commenced during the late 1970s at the same time as the medical surveillance programme. The monitoring was based on the benzene soluble fraction (BSF) of total particulate material as described in the *US Federal Register* of 22 October 1976.[14] BSF has been an accepted universal measure of exposure to coke oven emissions throughout the world. In 1965 the American Conference of Governmental Industrial Hygienists proposed a threshold limit value (time weighted average) of 0.2 mg/m³ BSF.[1]

During the years 1983–85 the average exposure for people employed as extractor drivers, gas regulators, charger drivers, and hot car drivers (classified into "operation") was 0.19 mg/m³ BSF. These occupational groupings would have had some of the higher exposures in the exposure group.

The exposure groups as used in this analysis consist of many different occupations with different exposure levels over many years as a result of ongoing operational improvements to the coke ovens and to changes in personal protection equipment use; for example, the wearing of respirators while on top of the coke ovens became mandatory in the early 1980s. The respirators used had a protection factor of 10.

Whether analysing data on the first sets for new starters or on the last sets of tests for the whole study population, each subject was classified into the job category in which he spent the longest time up to the date of the relevant lung function test. The duration of employment in each work category was also recorded.

Lung function measurements

Initial tests were usually conducted at about the time of recruitment. For subjects having worked for five years in "operation" or having worked for 10 years in all other positions, lung function was retested at intervals of around one year.

Lung function indices measured at each test time were vital capacity (VC), forced vital capacity (FVC), and forced expiratory volume in one second (FEV_1). Forced mid-expiratory flow ($FEF_{25–75\%}$) was included after January 1983. All of these indices were measured in a uniform manner at one centre by trained technicians using a Vitalograph spirometer.

Smoking assessment

Along with age, height, and occupational factors, smoking is recognised as a major determinant of lung function.[13 15] Surveillance data only provided information, obtained at the dates of last sets of tests, on smoking status (non, ex, or current), the daily smoking level for current smokers only, and smoking years for both current and ex-smokers. For new starters, smoking status and duration for ex-smokers are compromised measures because they were only available at the dates of last sets of tests. The daily smoking level for current smokers was recorded as: 10 or fewer, 11–20, 21–50, or more than 50 cigarettes per day. The grouped values were respectively converted to: 0.25, 0.75, 1.75, and 3.0 packs/day. The pack-years measure for each current smoker is the product of the number of packs consumed per day and the number of smoking years.

Statistical methods

Mean and standard deviation for continuous data and frequency and relative frequency (expressed as a percentage) for categorical data were used to summarise the data from the surveillance system.

Multiple regressions using work and smoking history as predictors were used to assess the pooled first sets of lung function tests of the 639 new starters, after adjusting for age and height. Similar multiple regressions were employed to analyse the cross sectional database, being the last sets of lung functions for all 1377 subjects. All statistical analyses were performed using the SAS software.

Lung function measurements were adjusted for age and height effects prior to regression analysis. This was done for three reasons. Firstly, some of the intended predictors, such as smoking and occupation, were correlated with age. The correlation may bias results.[16 17] Secondly, age, height, and their interaction have been included in different regression models in different functional forms in the literature.[18–22] However, there is little objective evidence as to which functional forms for age, height, and their interaction should be selected as predictors.[23] Thirdly, excluding age and height from the predictors can simplify the predictor selection process and refine the regressions.

Reference regressions can be used to adjust for age and height effects on lung function.[10 23] In this study, measured lung function indices were adjusted to the values for an age of 35 years and a height of 175 cm using reference regressions reported by Gore *et al* for healthy male adult lifetime non-smokers in Australia[24]:

$$FVC\ (l) = 12.675 - 0.0002764\ A^2 - 10.736\ H^2 + 4.790\ H^3$$

$$FEV_1\ (l) = 2.081 + 0.5846H^3 - 0.01599\ AH$$

$$FEV_1/FVC\ (\%) = 92.963 + 0.002487\ A^2 - 0.2260\ AH$$

$$Log_{10}FEF_{25–75\%}\ (l/s) = 0.5707 - 0.00005695\ A^2 + 0.0258\ H^3$$

where A = age (years), H = height (m).

If a subject was 40 years old and 170 cm high, his measured FVC of, say, X (e.g. X = 5.25) litres would be adjusted for age and height effects to: adjusted FVC = X − 0.0002764 (35^2 − 40^2) − 10.736 (1.75^2 − 1.70^2) + 4.790 (1.75^3 − 1.70^3).[23] Other indices were adjusted similarly. Because Gore *et al* published no reference regression for VC, this index was excluded from the analysis. Regression analyses were limited to subjects older than 18 at the dates of first sets of tests for new starters or at the dates of last sets of tests for all the population, in order to match the age range of the study population of Gore *et al*. This eliminated 26 subjects from the new starters, leaving 613 subjects. Cross sectional analyses for the last sets of tests were carried out on data from the whole study population (1377 subjects) less those (24) who were under 18 years old. Since the bulk of the cross sectional information comes from the longer employed subjects, these are the focus of the main analyses reported here. Specifically, a further 519 subjects with an employment duration of less than one year were excluded, with 834 subjects remaining.

RESULTS

The baseline lung function at the starting time of exposure did not differ significantly among the exposure groups. Table 1 lists the characteristics of 613 new starters who were 18 years

Table 1 Characteristics of new starters who were 18 years or older at the first sets of tests

	Group				
	Operation	Maintenance	Electricity	Other	Total
Subjects (no.)	426	96	31	60	613
Age (years), mean (SD)	27.1 (8.8)	29.4 (11.5)	26.6 (8.8)	29.5 (9.9)	27.7 (9.4)
Min–max (years)	18.0–60.1	18.2–60.1	18.6–48.4	18.5–58.2	18.0–60.1
Height (cm), mean (SD)	173.7 (7.2)	173.3 (7.9)	175.7 (8.3)	173.6 (7.8)	173.7 (7.4)
Min–max (cm)	156–199	153–190	162–196	158–193	153–199
Non-smokers, no. (%)*	98 (23.0)	23 (24.0)	5 (16.1)	16 (26.6)	142 (23.2)
Ex-smokers, no. (%)*	30 (7.0)	12 (12.5)	6 (19.4)	1 (1.7)	49 (8.0)
Current smokers, no. (%)*	298 (70.0)	61 (63.5)	20 (64.5)	43 (71.7)	422 (68.8)
<10 pack-years, no. (%)†	262 (87.9)	49 (80.3)	17 (85.0)	36 (83.7)	364 (86.3)
10–20 pack-years, no. (%)†	26 (8.7)	7 (11.5)	2 (10.0)	4 (9.3)	39 (9.2)
≥20 pack-years, no. (%)†	10 (3.4)	5 (8.2)	1 (5.0)	3 (7.0)	19 (4.5)
Lung function, mean (SD)					
FEV_1 (l)‡	3.70 (0.70)	3.66 (0.66)	3.82 (0.73)	3.65 (0.76)	3.69 (0.70)
FVC (l)‡	4.47 (0.80)	4.40 (0.71)	4.54 (0.75)	4.37 (0.90)	4.45 (0.79)
FEV_1/FVC (%)‡	83.82 (8.14)	83.16 (8.02)	83.85 (5.53)	83.63 (6.97)	83.00 (7.89)
$FEF_{25-75\%}$ (l/s)‡	3.88 (1.30)	3.64 (1.29)	4.07 (1.57)	4.23 (1.14)	3.87 (1.29)

*Proportions of non-smokers, ex-smokers, and current smokers in each group.
†Distributions of current smokers by pack-years and their proportions.
‡The numbers of observations for FEV_1, FVC, and FEV_1/FVC are 613; for $FEF_{25-75\%}$ 202.

or older at the first sets of tests. The average starting age of the new starters was below 30, and similar in all groups. Most of the new starters (around 69%) were current smokers. Multiple regressions were fitted for FEV_1, FVC, FEV_1/FVC, and $FEF_{25-75\%}$ for these new starters to assess differences among exposure groups (table 2). Coefficients for the categorical variables "operation", "maintenance", and "electricity" are not significantly different from zero (p > 0.05). A smoking effect was observed for the new starters on FEV_1/FVC and $FEF_{25-75\%}$. The reduction for FEV_1/FVC was around 1.6% (p = 0.037, 95% CI: 0.1% to 3.0%) for being a current smoker, and the reduction for $FEF_{25-75\%}$ was around 37 ml/s (p = 0.005, 95% CI: 12 ml/s to 62 ml/s) associated with each pack-year of smoking, indicating lower lung function for current smokers.

Table 3 profiles the surveillance data on the 834 subjects. Each exposure group had similar average age, similar average height, and similar smoking status. Current smokers comprised a strikingly high percentage of subjects (around 60%). For subjects in the "operation" group, the average work time in "operation" was around 12 years, with a relatively short average period working in any of the other three categories and vice versa. This cross over, in term of work duration, between "operation" and the other groups was minimal.

For the multiple regressions fitted for age and height adjusted FEV_1, FVC, FEV_1/FVC, and $FEF_{25-75\%}$ for the 834 subjects, the coefficients for all predictors of interest are listed in table 4. These predictors explained between around 4% and 8% of the remaining variation (after age and height adjustment) in each lung function index.

Work duration in "operation" was associated with lower lung function. For each year in "operation", FEV_1 was lower by about 9 ml (p = 0.006, 95% CI: 3 ml to 16 ml) and FVC by around 12 ml (p = 0.002, 95% CI: 4 ml to 19 ml). Each year of working in positions other than "operation", grouped because of similar effects and small numbers, was also associated with a lower FVC, by around 7 ml (p = 0.034, 95% CI: 1 ml to 14 ml). The combined effects of being "operation" and work duration in "operation" on FEV_1 indicated that a typical worker had significant lower FEV_1 after working in "operation" for around one year.

Effects of smoking on lung function were also observed. For each pack-year of smoking for current smokers, FEV_1/FVC was

lower by around 0.04% (p = 0.040, 95% CI: 0.002% to 0.08%) and $FEF_{25-75\%}$ by around 20 ml/s (p = 0.0006, 95% CI: 9 ml/s to 31 ml/s). The average FEV_1 and FEV_1/FVC for current smokers were lower by around 116 ml (p = 0.034, 95% CI: 10 ml to 223 ml) and around 1.9% (p = 0.020, 95% CI: 0.3% to 3.4%) respectively, compared to those for non-smokers. For ex-smokers, FEV_1, FVC, FEV_1/FVC, and $FEF_{25-75\%}$ were lower for each year of past smoking by around 13 ml (p = 0.0006, 95% CI: 6 ml to 20 ml), 8 ml (p = 0.042, 95% CI: 0.3 ml to 16 ml), 0.3% (p = 0.0001, 95% CI: 0.1% to 0.4%), and 36 ml/s (p = 0.0003, 95% CI: 17 ml/s to 55 ml/s) respectively. While the average FEV_1/FVC for ex-smokers was around 2.6% (p = 0.033, 95% CI: 0.2% to 5.0%) higher than that for non-smokers, the combination of this effect with duration of ex-smoking indicates that this index was significantly lower only in ex-smokers who had smoked for more than around 10 years. This combination effect was consistent with effects found for FEV_1 and FVC, although in neither case was the effect of being an ex-smoker statistically significant.

When other reference regressions were used instead of those of Gore and colleagues,[24] the above results were not notably changed.[25-28] Furthermore, internal adjustment for age and height effects led to conclusions consistent with those obtained using reference regressions. Inclusion of the whole population of 1353 subjects, rather than only those with one or more years of work history, consistently showed weaker associations, but did not substantially change the results. The estimated decrease in FVC associated with each work year in "operation" was about 6 ml (p = 0.027, 95% CI: 0.1 ml to 12 ml). No such significant effect was observed for any of FEV_1, FEV_1/FVC, and $FEF_{25-75\%}$. The work location of "operation" had a significant effect on FEV_1 (lower by around 115 ml (p = 0.030, 95% CI: 12 ml to 218 ml)) and on FVC (lower by around 141 ml (p = 0.014, 95% CI: 29 ml to 254 ml)), compared with the work location of "other".

DISCUSSION

Although there were 324 male subjects without any lung function measurements in the surveillance system, non-response bias can be considered small because 81% of male subjects who ever worked in relatively highly exposed positions at the coke ovens are included in the study population.

Table 2 Regression coefficients for adjusted lung function indices for new starters who were 18 years or older at the first sets of tests

	FEV$_1$ (l)		FVC (l)		FEV$_1$/FVC (%)		FEF$_{25-75\%}$ (l/s)	
	Coefficient	p value	Coefficient	p value	Coefficient	p value	Coefficient	p value
Intercept	3.58 (3.43 to 3.73)*	0.0001	4.27 (4.10 to 4.43)	0.0001	83.5 (81.4 to 85.7)	0.0001	4.38 (3.76 to 5.00)	0.0001
Ex-smokers	−0.030 (−0.278 to 0.218)	0.813	0.129 (−0.149 to 0.407)	0.366	−3.26 (−6.79 to 0.28)	0.0731	−0.484 (−1.23 to 0.27)	0.217
Duration of smoking for ex-smokers (years)	0.00336 (−0.0196 to 0.0263)	0.776	−0.00728 (−0.0330 to 0.0184)	0.581	0.173 (−0.153 to 0.500)	0.302	0.0100 (−0.0762 to 0.0962)	0.824
Current smokers	−0.0631 (−0.165 to 0.039)	0.230	0.0190 (−0.095 to 0.133)	0.747	−1.56 (−3.02 to −0.11)	0.0366	−0.0392 (−0.431 to 0.353)	0.848
Pack-years for current smokers	0.00113 (−0.00412 to 0.00636)	0.676	0.00305 (−0.00282 to 0.00891)	0.313	−0.0694 (−0.144 to 0.005)	0.0705	−0.0370 (−0.0618 to −0.0122)	0.0046
Operation	−0.0125 (−0.153 to 0.128)	0.863	0.0731 (−0.084 to 0.230)	0.365	−1.46 (−3.45 to 0.541)	0.156	−0.479 (−1.06 to 0.101)	0.115
Maintenance	0.0154 (−0.152 to 0.183)	0.858	0.0523 (−0.135 to 0.240)	0.587	−0.669 (−3.05 to 1.71)	0.585	−0.523 (−1.17 to 0.125)	0.123
Electricity	−0.0145 (−0.240 to 0.211)	0.900	−0.0252 (−0.278 to 0.228)	0.846	−0.298 (−3.51 to 2.91)	0.857	0.0456 (−0.99 to 1.08)	0.933
R square	0.0035		0.0054		0.0231		0.0647	
No. of observations†	613		613		613		202	

*Limits of 95% CI for the parameter.
†FEF$_{25-75\%}$ was measured after January 1983, so the observation number is smaller than that for FEV$_1$, FVC, and FEV$_1$/FVC.

Table 3 Characteristics of subjects with age ⩾18 years and history in coke ovens ⩾1 year at the dates of last sets of lung function tests

	Group				
	Operation	Maintenance	Electricity	Other	Total
Total subjects (no.)	448	180	112	94	834
Subjects with 1 set tests	85	77	53	41	256
2 or more sets	363	103	59	53	578
Sets of tests, mean (SD)	5.9 (3.8)	3.9 (3.6)	4.0 (3.6)	2.9 (2.7)	4.9 (3.8)
Span between first and last tests*, mean (SD)	7.8 (3.2)	7.2 (3.3)	7.6 (3.1)	4.8 (3.4)	7.4 (3.3)
Age (years), mean (SD)	42.4 (12.0)	40.8 (14.6)	40.1 (14.1)	41.8 (13.3)	41.7 (13.0)
Min–max (years)	18.5–65.0	19.9–65.5	19.7–64.4	18.8–64.5	18.5–65.5
Height (cm), mean (SD)	170.8 (7.3)	172.3 (6.9)	174.0 (8.1)	174.2 (7.9)	171.9 (7.5)
Min–max (cm)	140–191	153–194	154–196	158–194	140–196
Non-smokers, no. (%)†	81 (18)	34 (19)	22 (20)	12 (13)	149 (18)
Ex-smokers, no. (%)†	105 (23)	36 (20)	25 (22)	17 (18)	183 (22)
Smoking duration (years), mean (SD)	15.6 (10.7)	18.9 (13.3)	17.2 (10.9)	13.9 (11.1)	16.3 (11.3)
Current smokers, no. (%)†	262 (59)	110 (61)	65 (58)	65 (69)	502 (60)
Pack-years, mean (SD)	13.7 (16.3)	13.1 (20.2)	14.0 (21.1)	13.0 (23.1)	13.5 (18.7)
Work duration in "operation" (years), mean (SD)	11.6 (7.9)	0.6 (1.8)	0.2 (1.0)	0.5 (1.3)	6.4 (8.1)
Work duration other than in "operation" (years), mean (SD)	0.5 (1.8)	11.1 (9.3)	11.1 (8.5)	10.7 (8.6)	5.4 (8.1)
Pure history‡, no. (%)	365 (81)	101 (56)	77 (69)	59 (63)	602 (72)
Mixed history§, no. (%)	83 (19)	79 (44)	35 (31)	35 (37)	232 (28)

*Only subjects with two or more sets of tests are included.
†Proportions of non-smokers, ex-smokers, and current smokers in each group.
‡Pure history means subjects had only one type of work position during the lung function surveillance period.
§Mixed history means subjects had more than one type of work position during the lung function surveillance period.

Exposure data from the payment system have their limitations in reflecting the real exposure levels for each subject, but such data are generally regarded as reliable in retrospective studies.[11][29]

According to our exposure classification method, around 28% of subjects had mixed work histories (table 3). This limits our capability to identify the exposure effect associated with work locations. However, we used work duration in a particular position as our primary indicator. Also, for workers classified in "operation", the average time spent working in "operation" was more than 20 times longer than that spent elsewhere, and vice verse. Thus, any misclassification of work location has minimal effect.

Selection bias associated with the recruitment process was not observed in the four exposure groups. Regression results show that lung function of new starters did not significantly differ among exposure categories. Clearly, this is only a partial analyses of selection bias, since it is based on only around 45% of all subjects (613 of 1377 subjects).

There are two reasons to pool the last sets of lung function tests for all subjects and treat them as cross sectional data. Firstly, subjects entered and left the system at different times during the 12 year surveillance period. Any narrow time interval, for example one year, would only include a small portion of all the subjects. Secondly, there were 797 subjects (around 58%) with only one set of lung function tests. They could not be included in a longitudinal analysis, but including them in the cross sectional study improves the power of analysis and avoids selection bias. Findings related to changes over time are extrapolations from the cross sectional analyses, and should not be expected to be equivalent to results from a true longitudinal analysis.

It is not surprising that the R^2 values for all fitted regressions (tables 2 and 4) are relatively small because the effects of age and height have been excluded. The effects of sex, age, and height on lung function are far more important than other factors. Sex, age, and height have been reported to account for approximately 30%, 8%, and 20%, respectively, of the variation of lung function in adults.[15] The most appropriate reference data were used (Gore et al).[24] However, it has to be

noted that the study population in question is reported to be of predominantly Southern European origin. Correction for ethnicity could not be made, as this was not recorded in the surveillance system.

Overall, the results showed that the duration of working in "operation" and/or working in "operation" were associated with lower lung function. These effects were observed for FEV_1 and FVC, but not for FEV_1/FVC and $FEF_{25-75\%}$. Similar findings have been reported in other studies on the lung function of coke oven workers.[10][12][13] In the study by Walker et al on 881 male coke oven workers,[10] FEV_1 was the only measured lung function index. Working at coke ovens was reported to be associated with a drop in mean FEV_1 of around 50 ml/ year (p < 0.01). Corhay et al compared the lung function of 137 male coke oven workers with those of 150 male blast furnace workers.[12] The average FEV_1 percentage of the predicted values (96.8 (SD 13.5)) was significantly lower than that of blast furnace workers (100 (SD 12.7)) (p < 0.05). Madison et al investigated 3799 male coke oven workers.[13] Among them were 2893 white workers and 906 black workers. After adjusting FEV_1 for age, height, and years at the coke ovens, they found that job location at the coke ovens had a significant effect on FEV_1 for white workers (p < 0.0001). The difference between the most exposed group and the least exposed group was around 470 ml for smokers and around 300 ml for non-smokers. However, for black workers, no job location effect on FEV_1 was found. In our study, FEV_1 was also significantly affected by each year of working in "operation", although the magnitude was less than effects found by Walker et al and Madison et al. Such differences in magnitude might be explained by different concentrations of coke oven emissions in different working environments.[22]

An effect of exposure to coke oven emissions on FVC was also observed in our study, but FVC was not reported in the studies by Corhay and colleagues and Madison and colleagues.[12][13] Chau et al investigated 354 retired male coke oven workers.[11] They found no effect of exposure to coke oven emissions on FVC, nor on other lung function indices (FEV_1, FEV_1/FVC, and $FEF_{25-75\%}$). They attributed the lack of association to bias of participants, healthy worker effect, and the exclusion of deceased subjects.

Table 4 Regression coefficients for adjusted lung function indices for subjects with age ≥18 years and history in coke ovens ≥1 year at the dates of last sets of lung function tests

	FEV$_1$ (l)		FVC (l)		FEV$_1$/FVC (%)		FEF$_{25–75\%}$ (l/s)	
	Coefficient	p value	Coefficient	p value	Coefficient	p value	Coefficient	p value
Intercept	3.70 (3.54 to 3.85)*	0.0001	4.54 (4.37 to 4.70)	0.0001	80.9 (78.6 to 83.1)	0.0001	3.99 (3.46 to 4.52)	0.0001
Ex-smokers	0.166 (0 to 0.331)	0.0517	0.139 (−0.0376 to 0.315)	0.126	2.62 (0.225 to 5.02)	0.0334	0.272 (−0.166 to 0.710)	0.230
Duration of smoking for ex-smokers (years)	−0.0128 (−0.0200 to −0.0055)	0.0006	−0.00805 (−0.0157 to −0.00035)	0.0420	−0.253 (−0.358 to −0.148)	0.0001	−0.0358 (−0.0548 to −0.0167)	0.0003
Current smokers	−0.116 (−0.223 to −0.010)	0.0341	−0.0390 (−0.152 to 0.074)	0.503	−1.85 (−3.40 to −0.31)	0.0195	−0.304 (−0.643 to 0.035)	0.0822
Pack-years for current smokers	−0.000181 (−0.00285 to 0.00249)	0.895	−0.000550 (−0.00339 to 0.00229)	0.706	−0.0407 (−0.0793 to −0.00208)	0.0404	−0.0198 (−0.0310 to −0.0087)	0.0006
Operation	0.0120 (−0.143 to 0.167)	0.880	−0.0707 (−0.235 to 0.094)	0.403	1.74 (−0.49 to 3.98)	0.129	0.0327 (−0.504 to 0.570)	0.906
Maintenance	−0.0164 (−0.154 to 0.121)	0.816	−0.0151 (−0.161 to 0.131)	0.841	0.207 (−1.78 to 2.19)	0.839	0.0869 (−0.399 to 0.573)	0.729
Electricity	−0.0359 (−0.187 to 0.115)	0.644	−0.0495 (−0.210 to 0.111)	0.548	−0.226 (−2.41 to 1.96)	0.840	−0.0429 (−0.575 to 0.489)	0.876
Work duration in "operation" (years)	−0.00945 (−0.0162 to −0.0027)	0.0062	−0.0116 (−0.0187 to −0.0044)	0.0016	−0.0856 (−0.183 to 0.012)	0.0866	−0.00239 (−0.0234 to 0.0186)	0.825
Work duration other than in "operation" (years)	−0.00206 (−0.00853 to 0.00441)	0.536	−0.00748 (−0.0144 to −0.0006)	0.0344	0.0695 (−0.0241 to 0.163)	0.149	0.00705 (−0.0133 to 0.0274)	0.502
R square	0.0372		0.0358		0.0508		0.0811	
No. of observations†	834		833		833		500	

*Limits of 95% CI for the parameter.
†FEF$_{25–75\%}$ was measured after January 1983, therefore the number of observations is smaller than that for FEV$_1$, FVC and FEV$_1$/FVC.

In this study, no evidence was found that FEV_1/FVC and $FEF_{25-75\%}$ were significantly affected by exposure to coke oven emissions. Corhay et al did not find that FEV_1/VC was significantly affected in coke oven workers, though they reported the average $FEF_{25-75\%}$ percentage of the predicted value in coke oven workers (82.4 (SD 27.0)) was significantly lower than that of blast furnace workers (96.7 (SD 30.4)).[12] Madison et al found no effect of work location on FEV_1/FVC for black subjects, and a small effect for white subjects.[13] Chau et al found that FEV_1/FVC and $FEF_{25-75\%}$ of subjects in the non-exposed group were lower than those of subjects in the exposed groups.[11] It has been reported that FEV_1/FVC may be unchanged or even become higher when FVC is reduced more than FEV_1 in restrictive lung defects.[15 30 31] It has also been claimed that $FEF_{25-75\%}$ might not be affected even if FEV_1 and FVC are affected.[15 32]

An effect of past smoking on lung function was also observed in this study. Our analyses suggested that ex-smokers had worse FEV_1/FVC than non-smokers if they smoked for more than 10 years (table 4). However, ex-smokers with shorter duration of smoking than 10 years had better FEV_1/FVC. Such an observation is not unique to this study. FVC for ex-smokers can become more like that of non-smokers after giving up smoking.[33] The lung function decrement for ex-smokers might be reversible before chronic bronchitis has developed.[34]

For current smoking, we found effects on FEV_1/FVC and FEV_1 but not on FVC. An effect of smoking on FEV_1/FVC is often found together with a FEV_1 effect in the absence of an effect on FVC.[31] Other authors have found that FEV_1 of smokers was more affected than FVC.[15 35] There have been similar findings in other occupational investigations.[36-38]

From our regressions (table 4) and those of Gore and colleagues,[24] we can estimate lung function loss for a non-smoking worker (height = 175 cm) working continuously in "operation" during a working life of 35 years, from age 25 to age 60. The FEV_1 loss caused by working in "operation" is around 320 ml (or 9 ml/year) and that caused by aging is around 970 ml (or 28 ml/year). The FVC loss caused by working in "operation" is around 480 ml (or 14 ml/year), and that caused by aging is around 820 ml (or 22 ml/year). Thus, the estimated FEV_1 loss caused by working in "operation" accounts for around 25% of total FEV_1 loss in the work life of a non-smoker. The percentage for FVC is around 37%. Smoking 35 pack-years will cause additional reduction in FEV_1 of around 120 ml (or 3.4 ml/year) and in FVC of around 58 ml (or 2 ml/year). Since aging effects for FEV_1 and for FVC reported by Gore et al are broadly similar to those in other reference regressions,[27 28] the above indication of percentage of loss attributable to the work place should be generally applicable.

The FEV_1 and FVC losses each year in the present study are similar to the findings from 13903 steel workers reported by Lowe and colleagues.[39] Workers from steelworks departments such as coke ovens, blast furnaces, steelmaking, hot mill, and cold mill were included. It was reported that the FEV_1 loss was about 40 ml/year and FVC loss was about 35 ml/year.

The pattern of lung function effects from exposure to coke oven emissions seems different from those caused by smoking but similar to those caused by coal dust. Smoking usually causes a lung function pattern typical of obstructive lung disease, which is associated with decreased FEV_1/FVC.[15] Both FEV_1 and FVC have been reported to be lowered by similar amounts by coal dust,[29] which might be interpreted as damage at the alveolar level.[31] For active non-smoking coal miners, the FEV_1 loss was reported by Bates et al to be around 46 ml/year and that for FVC was around 40 ml/year.[30] Love et al reported that the FEV_1 loss each year for non-smoking coal miners was about 39 ml/year.[40] Our results are consistent with these results.

In conclusion, work time in "operation" was observed to have a negative effect on FEV_1 and FVC. Such findings in a cross sectional study suggest the value of a longitudinal analysis of the relevant data from the database from which these cross sectional data were extracted. This will be reported separately.

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ECHO ....

Bar and restaurant staff are regularly overexposed

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Staff in bars and restaurants where the policy permits or limits smoking to certain areas absorb damagingly high amounts of nicotine, finds a study in New Zealand, the first of its kind there to determine objectively whether exposure to environmental tobacco smoke (ETS) varies with smoking policy.

A significantly greater proportion of staff had a higher cotinine concentration in their saliva after a work shift when customer smoking was unrestricted (83%) or limited (40%) than staff in non-smoking establishments (13%).

Cotinine concentration increased according to the policy of the workplace (median concentration for government staff 0.15 ng/g; for staff in workplaces with a policy of no smoking 0.1 ng/g, restricted smoking 1.6 ng/g, or unrestricted smoking 1.7 ng/g). When staff in each workplace were grouped by whether their cotinine rose or not the resulting trend was significant, showing a link between fewer restrictions and increased salivary cotinine.

The study recruited staff in 29 different bars and restaurants. All were non-smokers for six months or more and were not using nicotine replacement therapy. Their workplace permitted unrestricted customer smoking (12 subjects), restricted smoking (20), or no smoking (10). To compensate for the size of the non-smoking group 50 non-smoking government workers were included as a separate category. Saliva was collected from each worker immediately before and after a work shift.

In New Zealand smoking is restricted by law in the workplace but is permitted in enclosed areas where alcohol is served. Here workers inhale high levels of ETS over long periods.

▲ *Tobacco Control* 2002;**11**:125–129.