

Total population study of factors affecting chronic bronchitis prevalence in the coal mining industry of New South Wales, Australia

J LEIGH, A N WILES, AND M GLICK

From the Joint Coal Board, Medical Division, Box 3842 GPO, Sydney, NSW 2001, Australia

ABSTRACT The period prevalence of simple chronic bronchitis (SCB) (mucus hypersecretion), defined as chronic cough and sputum production by the MRC respiratory symptom questionnaire administered by occupational physicians and of obstructive chronic bronchitis (OCB) (airflow obstruction) (defined as SCB plus $FEV_1 < 80\%$ predicted) have been measured over the period 30 June 1977-30 June 1980 in the entire work force aged between 21 and 60 of the coal industry of New South Wales, Australia (12 357 men). Four dimensional contingency table analysis by a logistic transform method showed highly significant ($p < 0.001$) additive affects of age (exposure duration), site of work, smoking, and alcohol consumption on development of overall chronic bronchitis (SCB + OCB). Odds ratios were face work: surface work = 1.78:1, smoker: non-smoker = 4.23:1, alcohol > 300 g/wk: alcohol < 300 g/wk = 2.13:1. There was no evidence for synergistic effects of these factors on the development of mucus hypersecretion. When OCB was analysed separately, the effect of site of work, although in the same direction, was not statistically significant and this was assumed to be due to a "healthy worker" effect or a "swamping" effect of smoking. Age, smoking, and alcohol effects were highly significant ($p < 0.0001$) and there was a sharp increase in prevalence of OCB in the age groups 41-50 and 51-60. Odds ratios were face work: surface work = 1.11:1, smoker: non-smoker = 2.66:1, alcohol > 300 g/wk: alcohol < 300 g/wk = 2.91:1. There was no evidence of synergistic effects. These results are consistent with a hypothesis of additive effects of smoking, alcohol, and coal mine dust and fumes on the development of chronic mucus hypersecretion leading to airflow obstruction or a hypothesis of similar additive effects on the development of two separate conditions—mucus hypersecretion with airflow obstruction and mucus hypersecretion without airflow obstruction.

The relative importance of occupational factors in the coal industry in the aetiology of simple chronic bronchitis (SCB) and obstructive chronic bronchitis (OCB) is still undecided.¹ Studies in the United Kingdom show a progressive decrement of FEV_1 with increasing exposure to dust,²⁻⁴ but only respirable dust ($1-5 \mu$) was quantified, and it is thought that particles $> 5 \mu$ are more likely to be important in causing bronchitis.⁵ In the United States a decreasing gradient of bronchitis prevalence between face, underground non-face, and surface workers has been shown, most obviously in non-smokers.⁵ Similar findings have been reported from West Germany.⁶ Further studies

in the United States have shown a relation between indices of large airways obstruction and indices of dust exposure in non-smokers.⁷ Other studies, however, have shown less consistent effects.⁸⁻¹⁰

The coal mining industry in New South Wales has represented, except in the past 15 years, almost the whole bituminous coal industry in Australia. The New South Wales work force at present is about 20 000. Most mines are underground but in recent years open cut mining has increased and about 7% of the work force is currently employed in open cut mining. About 72% of the 8000 workers employed in Queensland mines are in open cut mines. Before 1970 the Queensland coal industry was negligible by comparison with that of New South Wales. Bituminous coal is mined to a very small extent in other parts of Australia. Most underground mining in New South

Wales is bord and pillar but long wall systems are being increasingly used.

Thus the results in this paper, although based solely on New South Wales data, may be taken to reflect the evidence for coal mining effects on bronchitis in Australia as a whole over the period in which men have been exposed.

In 1948 the Joint Coal Board began a continuous occupational medical service. The examination includes a full clinical examination, doctor administered respiratory symptom questionnaire, detailed industrial history, smoking history, alcohol consumption history, spirometry, standard posterior-anterior chest *x* ray examination, and in some cases electrocardiography and exercise electrocardiography. The medical staff has been the same since 1977.

Medical bureaux in the mining districts keep lists of all employees. The men are scheduled for an examination every two to three years, by appointment in their working time. They get a shift off work for attending for a medical examination and non-attenders are vigorously followed up. The entire population at work in any given three year period will thus be examined with only a few isolated incidences of non-examination (<0.1%).

Early sample surveys showed a gradient of decreasing prevalence of SCB and OCB between face, other underground, and surface workers. This gradient persisted when standardised for age and smoking and suggested a part coal dust aetiology for these conditions.^{11 12} It has now been possible to extend these studies to the entire work force.

The further opportunity was taken to examine the effects of alcohol on chronic bronchitis as recent experimental data has shown decreased mucociliary clearance with acute alcohol administration in man¹³ and alcohol consumption has also been shown to have relations with respiratory disease symptoms.¹⁴

Methods

The prevalence period was 30 June 1977 to 30 June 1980. All workers who worked throughout the period were examined. Workers who had joined the work force in the period and men under 21 or over 60 (retiring age) were excluded from the study. Workers who had retired or died in the period were included if they had been examined in the period. Men under 21 were excluded to be consistent with the study of Rogan *et al* 1973.² These workers excluded men under 25 on the grounds that ventilatory capacity increases with age until a peak is reached between the ages of 21 and 25. They were considering FEV₁ as the dependent variable in a multiple regression equation and presumably wished to avoid non-linear effects. We did

not use this approach but compared actual FEV₁ with a predicted value dependent on age. The prediction equations were based on data from subjects aged 25–74¹⁵ and we did not want to extrapolate excessively, while maintaining equal sized age groups. The number of workers under 21 excluded was 891.

Examinations were conducted by occupational physicians and technicians whose techniques had been previously standardised. Data were recorded on standardised data entry forms, coded centrally, and entered into computer files via intelligent data entry terminals. Details of the computer system have been previously published.¹⁶

Data set

(1) AGE (YEARS)

(2) SITE OF WORK

Underground (face).

Underground (non-face).

Surface (includes open cut workers).

Except in a few cases, present site of work was the same as site of work since entering the industry. This is so because of the nature of labour employment in the coal mining industry.

After a training period workers specialise in either face work, other underground support work, or surface work and remain in this job for most of their working lives. A few older miners (aged 55–60) through disability or choice may move from face to other underground or surface work.

Thus, in general, age may be taken as an index of years worked and hence exposure to industrial dust, diesel, and shot firing fumes. Face work is known to have the highest concentration of dust and shot firing fumes. Other underground work also entails exposure to dust and fumes in lower concentration than at the face.

Surface workers are exposed to environmental concentrations similar to the general community in which mines are located. In New South Wales mines are located largely around two industrial cities, Newcastle (410 250 population) and Wollongong (233 650 population).

(3) CATEGORY OF BRONCHITIS

(1) Chronic cough and sputum production as evidenced by responses to questions on MRC respiratory symptom questionnaire (1966) administered by occupational physician.

The questions in the MRC questionnaire used were:

Cough 1—Do you usually cough first thing in the morning, or on getting up, in the winter?

Cough 3—Do you usually cough during the day (or at night) in the winter?

Cough 5—Do you cough like this on most days (or nights) for as much as three months each year?

Phlegm 6—Do you usually bring up any phlegm from your chest first thing in the morning (or on getting up) in the winter?

Phlegm 8—Do you usually bring up any phlegm from your chest during the day (or at night) in the winter?

Phlegm 10—Do you bring up phlegm like this on most days (or nights) for as much as three months each year?

Bronchitis grade 1 required positive responses to: cough 1 (and/or) cough 3 and cough 5 plus phlegm 6 (and/or) phlegm 8 and phlegm 10. (Estimated sputum of > 2 cc/day (total) required for positive response).

(2) (1) plus history of recurrent bronchial infection.

(3) (1) plus 60% < FEV₁ < 80% predicted from equations of Ferris *et al.*¹⁵

(4) (1) plus 40% < FEV₁ < 60% predicted.

(5) (1) plus FEV₁ < 40% predicted.

Categories 1 and 2 are SCB.

Category 3, 4, and 5 are OCB.

Categories 1–5 are mutually exclusive.

FEV₁ was measured by Vitalograph spirometer as the better of two satisfactory efforts.

SMOKING (FROM HISTORY)

(1) Current smoker—g/wk tobacco (manufactured cigarette, handrolled, pipe and cigars included).

(2) Ex-smoker.

(3) Lifelong non-smoker.

Table 1 Prevalence of chronic bronchitis. (Percentages denote prevalence)

Site	Non-B	SCB	OCB	Total
Face	4244	786 (15.1%)	165 (3.2%)	5195
Underground non-face	3152	497 (13.1%)	159 (4.2%)	3808
Surface	2905	344 (10.3%)	105 (3.1%)	3354

ALCOHOL CONSUMPTION (CALCULATED FROM HISTORY) G/WK ETHANOL

Complete data for all these variables were obtained from all examinees. Four dimensional contingency tables were produced with ICL package X on an ICL 2904 computer. Cox's method of logistic transform analysis was used to analyse statistical significance of results.¹⁷

Results

The total population studied comprised 12 357 men aged between 21 and 60. Of these, 338 had some degree of radiological pneumoconiosis (ILO 1980 categories 1/0: 196; 1/1: 125; 1/2: 8; 2/1: 6; 2/2: 3) and these men were included in the study. Rogan *et al* have shown that pneumoconiosis has no effect on relations between chronic bronchitis and other variables under consideration,² and this is confirmed by extensive postmortem studies from this institution^{18 19} and by other workers.²⁰

The overall prevalence of SCB was 1627/12 357 = 13.2% and of OCB 429/12 357 = 3.5%.

Table 2 Age distribution of chronic bronchitis. (Percentages denote prevalence)

Bronchitis grade	Age (years)			
	21–30	31–40	41–50	51–60
0	2319	3120	2842	2020
1 } SCB	155 } (6.4%)	338 } (9.7%)	544 } (15.6%)	573 } (20.3%)
2 }	4 }	2 }	3 }	8 }
3 } OCB	3 } (0.1%)	32 } (0.9%)	125 } (3.7%)	256 } (9.0%)
4 }	0 }	0 }	3 }	6 }
5 }	0 }	0 }	2 }	2 }

Table 3 Age distribution of work force. (Percentages denote prevalence)

Site	Age (years)				Total
	21–30	31–40	41–50	51–60	
Face	1136 (21.9%)	1577 (30.4%)	1514 (29.1%)	968 (18.6%)	5195
Underground non-face	831 (21.8%)	979 (25.7%)	1033 (27.1%)	965 (25.4%)	3808
Surface	514 (15.3%)	936 (27.9%)	972 (29.0%)	932 (27.8%)	3354

Table 4 Overall effect of smoking. (Percentages denote prevalence)

	Smoker	Ex-smoker	Lifelong non-smoker
Non-CB	4627	2031	3610
SCB + OCB	1540 (25.0%)	288 (12.4%)	261 (6.7%)

For comparison:

UK² SCB 29.7% (n = 3581 face workers)

OCB 6.9%

US⁷ SCB + OCB 38.4% (n = 6014)

West Germany⁶ SCB + OCB = 13% (n = 9935)

Table 1 shows overall prevalence of SCB and OCB by site of work. Prevalence of SCB is highest in face workers, next in underground non-face workers, and least in surface workers whereas prevalence of OCB is greatest in underground non-face workers and the same in face and surface workers. Analysis of the age distribution and smoking habit distribution of bronchitis, however, shows that an occupational effect must be sought with these two factors held constant. Age distribution by bronchitis grade is shown in table 2 and age by site of work in table 3. SCB and OCB prevalence increases with age and the underground non-face and surface workers have a higher proportion of older men.

SMOKING

Prevalence of bronchitis is strongly related to smoking (table 4). Prevalence of all bronchitis is 25% in smokers, 12.4% in ex-smokers, and 6.7% in lifelong

non-smokers. Preliminary analysis showed a non-significant effect of amount smoked in a current smoker, probably because of uniform smoking patterns in coal workers, and smoking was thus classified into three categories: current smokers, ex-smokers, and lifelong non-smokers.

Table 5 shows the prevalence of SCB and OCB by age, site of work, smoking, and alcohol consumption. Generally, prevalence of SCB increases with age, smoking, alcohol consumption, and dust exposure. Prevalence of OCB trends are similar but not as clear. The increase with age is lagged behind that of SCB and workplace selection has probably caused some men with disability to move from face work, thus obscuring dust exposure effects.

The logistic transform:

$$z = \log_e((R + 1/2)/(n - R + 1/2))$$

with variance

$$v = \frac{(n + 1)(n + 2)}{n(R + 1)(n - R + 1)}$$

where R = frequency was applied to SCB + OCB and OCB alone. Tables 6 and 7 show the transformed data. We analysed mucus hypersecretion (SCB + OCB) and airflow obstruction (OCB) as separate entities.

Factorial analysis enabled all effects of interest to be tested for significance. Tables 8 and 9 show selected logistic factorial standardised contrasts. In these contrasts the three levels of smoking and work site were assumed to be equally spaced.

It may be seen for SCB + OCB (table 8) that all main linear effects are highly significant ($p < 0.0001$). The odds ratio for smoker:non-smoker is 4.23:1,

Table 5 Prevalence (%) of simple chronic bronchitis (SCB) and obstructive chronic bronchitis (OCB)

Site	Alcohol consumption (g/week)	Age (years)						
		21-30			31-40			
		Non	Ex	S	Non	Ex		
Face	< 300	SCB	9 (2.3%)	4 (3.8%)	63 (12.2%)	29 (7.2%)	20 (9.0%)	
		OCB	0 (0.0%)	1 (0.9%)	0 (0.0%)	1 (0.2%)	2 (0.9%)	
	n	383	104	515	405	223		
		> 300	SCB	3 (12.5%)	2 (11.8%)	15 (16.1%)	2 (4.8%)	7 (11.3%)
			OCB	0 (0.0%)	0 (0.0%)	2 (2.1%)	0 (0.0%)	1 (1.6%)
		n	24	17	93	42	62	
Underground non-face	< 300		SCB	9 (2.6%)	3 (3.6%)	28 (12.1%)	10 (3.5%)	6 (4.7%)
		OCB	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.7%)	
	n	352	83	232	287	129		
		> 300	SCB	0 (0.0%)	1 (10.0%)	5 (13.2%)	2 (7.7%)	4 (16.0%)
			OCB	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
		n	16	10	38	26	25	
Surface	< 300		SCB	3 (1.5%)	1 (2.1%)	10 (4.8%)	8 (2.9%)	3 (2.3%)
		OCB	0 (0.0%)	0 (0.0%)	1 (0.5%)	1 (0.4%)	1 (0.8%)	
	n	203	47	210	277	130		
		> 300	SCB	0 (0.0%)	0 (0.0%)	2 (6.5%)	1 (3.6%)	5 (12.8%)
			OCB	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
		n	11	9	31	28	39	

Non = Lifelong non-smoker. Ex = Current ex-smoker. S = Current smoker. n = Number in classification cell.

Table 6 Logistically transformed frequency data (SCB + OCB)

Site	Alcohol consumption (g/week)	Age (years)											
		21-30			31-40			41-50			51-60		
		Non	Ex	Smoker	Non	Ex	Smoker	Non	Ex	Smoker	Non	Ex	Smoker
Surface	< 300	z -3.674	-2.895	-1.964	-2.510	-2.192	-1.775	-2.334	-2.047	-0.959	-1.684	-1.402	-0.277
	v 0.1029	0.1784	0.0179	0.0350	0.0486	0.0119	0.0333	0.0437	0.0085	0.0351	0.032	0.012	
Underground non-face	> 300	z -1.815	-1.825	-1.475	-2.785	-1.858	-1.038	-1.236	-1.699	-0.261	-1.582	-0.909	0.576
	v 0.3078	0.4191	0.0693	0.3662	0.1293	0.0296	0.0943	0.1349	0.0176	0.1556	0.1030	0.0328	
Surface	< 300	z -3.588	-3.135	-2.369	-3.274	-2.793	-1.979	-2.735	-2.636	-0.981	-1.946	-1.421	-0.353
	v 0.1032	0.2665	0.0266	0.0948	0.1342	0.0224	0.0714	0.0900	0.0130	0.0426	0.0313	0.0129	
Underground non-face	> 300	z -3.497	-1.846	-1.807	-2.282	-1.564	-1.045	-1.726	-1.155	-0.321	-1.052	-0.676	0.464
	v 1.125	0.660	0.2012	0.3877	0.2553	0.0527	0.1739	0.1127	0.0271	0.0921	0.1036	0.0310	
Surface	< 300	z -4.048	-3.434	-2.853	-3.342	-3.336	-2.367	-3.116	-2.482	-1.742	-2.371	-1.539	-0.493
	v 0.2562	0.5324	0.0888	0.1040	0.2095	0.0333	0.0875	0.0780	0.0251	0.0524	0.0371	0.0144	
Underground non-face	> 300	z -3.135	-2.944	-2.468	-2.909	-1.836	-1.212	-3.296	-1.457	-0.523	-1.669	-1.144	0.202
	v 1.182	1.222	0.3785	0.555	0.2002	0.0659	0.5372	0.1413	0.0321	0.1757	0.0899	0.0340	

$\lambda = \log((R + 1/2)/(n - R + 1/2))$ $\nu = (n + 1)(n + 2)/(n(R + 1)(n - R + 1))$
 Where R = number with SCB + number with OCB, n = number in classification cell.

Table 7 Logistically transformed frequency data (OCB)

Site	Alcohol consumption (g/week)	Age (years)											
		21-30			31-40			41-50			51-60		
		Non	Ex	Smoker	Non	Ex	Smoker	Non	Ex	Smoker	Non	Ex	Smoker
Surface	< 300	z -6.642	-4.234	-6.938	-5.597	-4.484	-3.748	-4.392	-3.506	-2.766	-3.463	-2.972	-2.036
	v 1.0052	0.5145	1.0038	0.5037	0.3394	0.0641	0.2033	0.1481	0.0304	0.1484	0.1059	0.0285	
Underground non-face	> 300	z -3.892	-3.555	-3.600	-4.443	-3.714	-3.422	-3.135	-3.574	-2.384	-2.809	-1.830	-1.245
	v 1.0833	1.1176	0.3479	1.0476	0.5244	0.1736	0.3565	0.5281	0.0549	0.3654	0.1672	0.0434	
Surface	< 300	z -8.860	-5.118	-6.142	-6.354	-4.450	-4.313	-4.545	-4.733	-2.652	-3.454	-2.909	-1.827
	v 1.0057	1.0241	1.0086	1.0069	0.5117	0.1695	0.3390	0.5088	0.0413	0.1484	0.0966	0.0259	
Underground non-face	> 300	z -3.497	-3.044	-4.344	-3.970	-3.932	-3.643	-4.443	-3.433	-2.168	-2.438	-2.424	-1.515
	v 1.1250	1.2000	1.0526	1.0769	1.0800	0.3473	1.0476	0.5324	0.0703	0.2232	0.2815	0.0493	
Surface	< 300	z -6.009	-4.554	-4.939	-5.217	-4.458	-5.015	-4.336	-3.892	-3.575	-3.434	-2.536	-1.863
	v 1.0098	1.0425	0.5071	0.5054	0.5116	0.3368	0.2547	0.2573	0.1147	0.1298	0.0777	0.0290	
Underground non-face	> 300	z -3.135	-2.944	-4.143	-4.043	-4.369	-5.130	-4.418	-4.489	-2.457	-2.093	-2.512	-1.299
	v 1.1818	1.2222	1.0645	1.0714	1.0513	1.0238	1.0488	1.0455	0.0998	0.2327	0.2216	0.0495	

$\lambda = \log((R + 1/2)/(n - R + 1/2))$ $\nu = (n + 1)(n + 2)/(n(R + 1)(n - R + 1))$
 Where R = number with OCB, n = number in classification cell.

S	41-50		S	51-60	
	Non	Ex		Non	Ex
82 (12.2%)	28 (7.6%)	19 (8.6%)	127 (21.8%)	27 (12.7%)	108 (31.7%)
15 (2.2%)	4 (1.1%)	6 (2.7%)	34 (5.8%)	6 (2.8%)	39 (11.4%)
572	367	222	582	213	341
40 (23.1%)	11 (18.6%)	7 (13.0%)	81 (35.2%)	5 (11.6%)	55 (41.9%)
5 (2.9%)	2 (3.4%)	1 (1.8%)	19 (8.3%)	2 (4.6%)	29 (22.1%)
173	59	54	230	43	131
45 (10.8%)	12 (5.1%)	10 (5.8%)	80 (20.7%)	20 (9.5%)	88 (27.5%)
5 (1.2%)	2 (0.8%)	1 (0.6%)	25 (6.5%)	6 (2.8%)	44 (13.7%)
115	237	171	386	211	320
23 (23.7%)	6 (14.3%)	10 (21.3%)	48 (32.0%)	10 (18.2%)	11 (26.2%)
2 (2.1%)	0 (0.0%)	1 (2.1%)	15 (10.0%)	4 (7.3%)	24 (17.8%)
97	42	47	150	55	135
30 (7.9%)	8 (3.0%)	10 (5.7%)	38 (12.2%)	13 (5.4%)	72 (24.6%)
2 (0.5%)	3 (1.1%)	3 (1.7%)	8 (2.6%)	7 (2.9%)	39 (13.3%)
378	270	174	311	239	293
19 (22.6%)	1 (2.4%)	8 (18.2%)	39 (29.5%)	2 (5.0%)	40 (33.8%)
0 (0.0%)	0 (0.0%)	0 (0.0%)	10 (7.6%)	4 (10.0%)	25 (21.2%)
84	41	44	132	40	118

Table 8 Selected logistic factorial standardised contrasts (SCB + OCB). (*u* is a standard normal deviate)

	<i>u</i>	<i>p</i>	Odds ratios
Age (linear effect)	11.72	< 0.0001	51-60 : 41-50 = 2.11:1 41-50 : 31-40 = 1.69:1 31-40 : 21-30 = 1.61:1
Age (quadratic effect)	1.34	NS	
Site (linear effect)	4.75	< 0.0001	Face : surface = 1.78:1 Face : underground = 1.19:1 Underground : surface = 1.50:1
Site (quadratic effect)	-1.14	NS	
Smoking (linear effect)	12.69	< 0.0001	Smoker : non-smoker = 4.23:1 Smoker : ex-smoker = 2.42:1 Ex-smoker : non-smoker = 1.75:1
Smoking (quadratic effect)	-1.48	NS	
Alcohol main effect	7.65	< 0.0001	Alcohol > 300 g/wk : alcohol < 300 g/wk = 2.13:1
Site (linear) × age (linear)	1.27	NS	
Site (linear) × age (quadratic)	0.03	NS	
Site (linear) × smoking (linear)	-0.89	NS	
Site (linear) × alcohol	-0.31	NS	
Smoking (linear) × age (linear)	1.93	NS	
Alcohol × age (linear)	-0.45	NS	
Smoking (linear) × alcohol	0.58	NS	
Age (linear) × smoking (linear) × alcohol	0.79	NS	
Site (linear) × smoking (linear) × alcohol	-0.71	NS	
Age (linear) × site (linear) × alcohol	-0.40	NS	
Age (linear) × site (linear) × smoking (linear)	-0.51	NS	
Age (linear) × site (linear) × smoking (linear) × alcohol	0.52	NS	

compared with 1.78:1 for face : surface and 2.13:1 for heavy drinker : light drinker. No interactions or non-linear effects tested were significant. The data thus are consistent with a hypothesis of additive effects of age, smoking, dust, and alcohol on the development of chronic mucus hypersecretion.

When OCB was considered separately (table 9), the

linear age effect was highly significant ($p < 0.0001$) and in addition there was a positive quadratic effect ($p < 0.01$) reflecting the sharper increase in OCB in the higher age group. The smoking effect was highly significant but the odds ratio less than that for SCB + OCB, possibly reflecting discontinuation of smoking habit by those affected. The alcohol effect was more

Table 9 Selected logistic factorial standardised contrasts (OCB). (*u* is a standard normal deviate)

	<i>u</i>	<i>p</i>	Odds ratios
Age (linear)	10.23	< 0.0001	51-60 : 41-50 = 3.44:1 41-50 : 31-40 = 2.35:1 31-40 : 21-30 = 1.34:1
Age (quadratic)	2.75	< 0.01	
Age (cubic)	-0.24	NS	
Site (linear)	0.51	NS	
Site (quadratic)	1.05	NS	
Smoking (linear)	4.81	< 0.0001	Smoker : non-smoker = 2.66:1 Smoker : ex-smoker = 1.31:1 Ex-smoker : non-smoker = 2.02:1
Smoking (quadratic)	-1.17	NS	
Alcohol main effect	6.24	< 0.0001	Alcohol > 300 g/wk : alcohol < 300 g/wk = 2.91:1
Site (linear) × age (linear)	0.73	NS	
Site (linear) × age (quadratic)	2.04	< 0.05	
Site (linear) × smoking (linear)	1.02	NS	
Site (linear) × alcohol	0.89	NS	
Smoking (linear) × age (linear)	2.03	< 0.05	
Smoking (linear) × age (quadratic)	-0.78	NS	
Alcohol × age (linear)	-3.12	< 0.002	
Alcohol × age (quadratic)	2.50	< 0.02	
Smoking (linear) × alcohol	-1.95	~ 0.05	
Smoking (linear) × site (linear) × alcohol	0.51	NS	
Age (linear) × smoking (linear) × alcohol	1.40	NS	
Age (quadratic) × smoking (linear) × alcohol	-0.67	NS	
Age (linear) × site (linear) × alcohol	0.22	NS	
Age (quadratic) × site (linear) × alcohol	0.02	NS	
Age (linear) × site (linear) × smoking (linear)	-0.23	NS	
Age (quadratic) × site (linear) × smoking (linear)	-0.73	NS	
Age (linear) × smoking (linear) × site (linear) × alcohol	-0.94	NS	
Age (quadratic) × smoking (linear) × site (linear) × alcohol	1.34	NS	

pronounced than that for SCB + OCB. The borderline interactions between age and smoking and age and site may be ignored as some data cells contain small numbers or are empty and this affects the accuracy of the approximations involved in the analysis. The interaction between alcohol and age (linear and quadratic) may be seen from inspection of table 5 to result from no fixed pattern of association and we regard it as spurious. There is a borderline negative interaction between smoking and alcohol and again this probably is spurious. (Some ex-smokers appear to have less risk of obstructive disease if they drink more.)

The main difference between the separate analysis of OCB and that of SCB + OCB is the lack of significant site effect. Inspection of table 5 shows that in those aged 51–60 OCB prevalence is fairly uniform in different sites, being slightly greater in surface workers. This is a healthy worker effect common to studies of this type. Following the suggestion of Peto *et al.*,²¹ we looked at the age groups 31–40, 41–50, and then the gradient face-underground non-face-surface of OCB prevalence is more apparent (table 5)—that is, the healthy worker effect has not yet operated but FEV₁ loss has occurred. Even in these restricted age groups, however, the site gradient was not statistically significant ($p > 0.05$).

Discussion

This study provides evidence for a dust exposure related aetiology for SCB and, to a lesser extent, for OCB in coal miners. It is the first reported total population study of these conditions in an industry population and the population studied is larger than the largest sample survey so far available. It is also the first major report on these conditions from the Australian coal industry. The results are consistent with the findings of Rogan *et al* and Rae *et al* in the British

coal industry^{2,3} and those of Kibelstis *et al* and Hankinson *et al* in the United States.^{5,7} The overall prevalence of SCB and OCB is lower in Australia and this may be related to better dust conditions in the coal mines and less atmospheric pollution in coal mining areas. The New South Wales coal industry is only now introducing personal gravimetric dust sampling and has previously maintained a particle count dust monitoring system. Although it may have been possible to obtain better estimates of individual exposure from industrial history and average mine dust counts, this would have been a difficult exercise and we thought that any increased accuracy obtained would not justify the effort. The study would still be subject to the criticism that only respirable particles are counted and the inevitable confounding of exposure with age. With an estimated dust exposure for each individual it might have been possible to carry out a more quantitative study using either clinical SCB grade or actual FEV₁ as the dependent variable and dust exposure, smoking, alcohol, age, and height as independent variables.

This would have implied an accuracy of history taking greater than justified, however, and interpretation would have been made difficult by correlations between smoking, drinking, age, and exposure. We thought it better to use "bronchitis" diagnosis by occupational physicians rather than FEV₁ for the dependent variable as minor degrees of FEV₁ loss may have been due to other lung conditions. Although a cross sectional study cannot provide data on the natural history of a disease, the results of this study are consistent with the hypothesis that OCB is a sequel to SCB. When OCB is analysed separately (table 5) the prevalence in all smoking groups is lower than that of SCB, and increases with age and smoking. The increase with age is lagged behind SCB. The gradient with site of work is less clear than with SCB but the difference between face

Table 10 Changes in prevalence* of SCB, OCB, and pneumoconiosis with time

	1948	1954	1957–60	1963–5	1971–4	1974–7	1977–80
All chronic bronchitis (SCB + OCB) (%)	33.0‡	38.0‡	25.0	21.0	17.6	13.6	12.8
Obstructive chronic bronchitis (OCB) (%)	9.0‡	14.0‡	10.0	6.0	4.6	3.3	2.8
Smokers (%)	NA	62	65	62	72	67	63
Pneumoconiosis (%) ILO \geq 1/0	16.0	8.7	3.6	3.0	3.0	2.9	2.0
% NSW total work force examined†	10%	10%§	85%	60%	100%	100%	100%

*For consistency with earlier surveys, prevalence figures relate to populations with new entrants included.

†Average total work force 17 000.

‡OCB assessed by clinical criteria.

§Southern district (Wollongong) only.

||10% sample.

NA = Not available.

and surface work is apparent in each age group except the oldest. Prevalence differences in this group have been obscured by smoking and work force movements which would be in a direction such as to underestimate work site effects.

Recently published longitudinal studies on smaller groups than that in the present study now appear to show that chronic mucus hypersecretion and airflow obstruction should be regarded as two distinct conditions with a common aetiology (mainly smoking),²¹⁻²³ and our data are also consistent with this hypothesis.

The prevalence of SCB and OCB in non-smoking surface workers may be taken to estimate the community prevalence without smoking or dust effects. For comparison with other studies, over all age groups, this was 4.6%. Jacobsen found that the prevalence ratio between smoking low dust exposed workers and non-smoking low dust exposed workers was 34%/9% (all ages).²⁴ The comparable figures in this study are 27.4%/4.8% for surface workers (table 5) giving a ratio 5.7:1 comparable with Jacobsen's ratio of 3.8:1. Among all smokers, the prevalence of SCB + OCB was 25.0% compared with 6.7% for lifelong non-smokers (3.7:1, cf Jacobsen 44% compared with 18%, 2.4:1).

The low prevalence of cough and sputum plus infection (chronic bronchitis grade 2) is probably related to the generally affluent living conditions that miners enjoy outside work and the low atmospheric pollution in New South Wales mining areas. Miners with grades 4 and 5 chronic bronchitis would be disabled from work in general and the low prevalence in the working population is due to retirement.

The alcohol effect has not been previously reported in a coal mining population but similar findings have been reported by Lebowitz.¹⁴ He found the "bronchitis" prevalence ratio between "heavy" (>6.25 US oz, (184 g)) and light or moderate drinking in lifelong non-smokers was 21.5%/15.2% (aged adjusted) compared with 19.6%/11.9% in the 51-60 age group and 14.1%/6.8% in the 41-50 age group in the present study. We thought that to define heavy drinking as >184 g/wk would be too low a criterion for an all male heavy industry population and chose higher limits accordingly.

Sample and total population surveys of bronchitis prevalence in New South Wales coal miners have been carried out since 1948.^{11 12 25} Table 10 shows that SCB and OCB prevalence has been falling continuously whereas smoking habits have not changed significantly. Pneumoconiosis prevalence has also been falling, reflecting better dust control (as well as work force redeployment). A sharp fall in prevalence around 1960 coincided with the elimination of shot firing in coal mines and its associated nitrogen oxides.

This time trend is also consistent with an industrial aetiology for bronchitis.

There is significant large airways obstruction in coal workers. Hankinson *et al* found better relations between indices of large rather than small airways obstruction and dust exposure.⁷ Postmortem measurements from this institution show that gland/wall ratio and wall internal to cartilage/lumen ratio in large bronchi correlated well with symptoms and signs of OCB.²⁶ The prevalence of gland/wall ratio >0.4 in the postmortem sample is 46% and gland/wall ratio is not correlated with postmortem pneumoconiosis.^{18 19}

In other necropsy studies significant relations between coal mine dust exposure, smoking, and bronchial gland enlargement were found by Douglas *et al*.²⁰

We are currently carrying out retrospective studies similar to those of Love and Miller⁴ relating quantified aetiological factors in individuals to the progression of simple and obstructive chronic bronchitis (mucus hypersecretion and airflow obstruction). We hope, however, that in future reduced smoking habit and maintained dust control will keep industrial bronchitis in the New South Wales coal industry to a minimum. The Queensland coal industry has started a medical surveillance scheme identical to that of New South Wales and data will soon be available for comparison. It should be noted, however, that with increased use of long wall mining techniques and possible increased dust production, constant epidemiological monitoring of industrial lung disease will be required.

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