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Respiratory health of brickworkers in Cape Town, South Africa. Symptoms, signs and pulmonary function abnormalities.

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Respiratory health of brickworkers in Cape Town, South Africa

Symptoms, signs and pulmonary function abnormalities

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MYERS JE, CORNELL JE. Respiratory health of brickworkers in Cape Town, South Africa: symptoms, signs and pulmonary function abnormalities. *Scand J Work Environ Health* 1989;15:188-194. The respiratory health of 268 brickworkers in five brickworks was investigated by means of a questionnaire, a physical examination, and pulmonary function testing. The prevalence of respiratory symptoms ranged from 7 % for chronic bronchitis to 52 % for morning cough to 27 % for both chest tightness and wheeze and 9 % for dyspnea at effort. A stepwise logistic regression analysis showed the symptoms to be significantly predicted by combinations of smoking and exposure to dust, while a multiple linear regression showed an effect of dust exposure on forced vital capacity and forced expiratory volume in 1 s but no smoking effect. Smoking generally had less of an effect than dust and predicted early/mild symptoms only.

Key terms: bricks, dust, lung function, smoking.

A cross-sectional study was carried out to assess the prevalence of respiratory abnormalities among brickworkers. Details of the study background and methods, together with work environmental and radiographic findings, have been reported elsewhere (1, 2). Previous studies have been more in the nature of simple screenings based on chest radiography and limited occupational history data. Questionnaire methods for detecting symptoms have been nonstandard, and the interrelationships between radiographic abnormality, lung function, symptoms, and dust exposure have not been investigated. As a result of objective dust exposure measurements, detailed symptomatology data, lung function measurements, and chest radiographs, it has been possible to investigate these relationships (including dose-response relationships for symptoms and other abnormal findings) and whether or not current dust levels in brickworks are prejudicial to respiratory health independently of, or interactive with, any effect of smoking.

Subjects and methods

The study group comprised all black manual workers in five brickworks near Cape Town. A total of 575 workers were examined. This was the total work force at the time of the respiratory health survey in July

1985. Cases with missing data (N = 14) due to unreadable radiographs or inability to provide their age, those who had previously worked in a workplace exposed to siliceous dusty conditions for two or more years (N = 176), women (N = 28), those unable (N = 50) to produce acceptable spirometers meeting the criteria of the American Thoracic Society (3), and ex-smokers (N = 39) were excluded from the analysis. The findings for the remaining 268 workers are presented.

Symptomatology, physical findings, and lung function were determined by means of a cross-sectional prevalence survey utilizing internal controls based upon objective dust measurements. A modified version of the American Thoracic Society respiratory questionnaire (4) translated into vernacular languages (Xhosa and Afrikaans) was administered by trained interviewers. The questionnaire included questions relating to current and past occupational history in brickworks and all other jobs, subjective assessment of levels of dustiness in all jobs, history of respiratory diseases, present respiratory symptoms, and smoking habits. The physical examination was conducted blind as to exposure history and radiographic or lung function data by one of the authors (JEM). Included were auscultation of the chest, inspection of fingernails, and measurement of height, sitting height and weight. Spirometry was performed with the S-model bellows Vitalograph[®] for the measurement of forced expiratory volume in 1 s (FEV_{1.0}) and forced vital capacity (FVC). The machine was calibrated before and after each day's use; no significant differences were found. The subjects were measured sitting, without nose-clips. The FVC and FEV_{1.0} readings were taken from the best of three acceptable tracings (3). The best readings for the FEV_{1.0} and FVC were not necessarily taken

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from the same tracing. Readings were converted to BTPS (temperature 37°C, ambient pressure, saturated with water vapor at 37°C) conditions.

Workers were classified into subjective and objective dust exposure categories, the derivation of which has been explained elsewhere (1).

Data were analyzed using the BMDP statistical package (5). Cumulative respirable dust exposure, cumulative total dust exposure, length of service (in years), and age were not normally distributed and were therefore transformed logarithmically to yield log-normal distributions before the analysis commenced. Relationships between respiratory symptoms and signs, lung function values, dust exposure indicators, length of service, and the profusion of small radiographic opacities (2) were examined with the use of the analysis of covariance and the multiple linear regression for continuous response variables, and logistic regression for categorical response variables. Forced regression on confounding covariates was performed for standardization. Stepwise analysis was carried out as a means of assessing the relative priority of associations between multiple covariates. The strength of the association with the dependent variable and the order of inclusion of the predictor variables in the regressions are shown by their F-to-enter and related P-values, while the chi-squared improvement value, its degrees of freedom, and the associated P-value indicate the statistical significance of these variables when entered into the model.

Results

The population was overwhelmingly migrant (234 or 87.6 %) in nature, working on contract at the brickworks. Their principal residence was in the Transkei or the Ciskei, to which they returned after varying periods of work for varying periods of time. While working, they live in single-sex company hostels close to or inside the brickworks.

The mean log for age was 1.471 (SD 0.128), the geometric mean age was 29.58 years, and 53 % of the workers were younger than 30 years. The mean log for length of service was 0.694 (SD 0.392), the geometric mean of the length of service was 4.94 years, and 43 % of the workers had five or fewer years of service.

Of the total study group (including ex-smokers) numbering 307, 211 (68.7 %) were smokers, 39 (12.7 %) were ex-smokers, and 57 (18.6 %) were never smokers. Of the 211 smokers, 74.8 % smoked cigarettes, 17.6 % smoked a pipe, and 8.0 % smoked both. Of the 158 cigarette smokers, 64.6 % smoked less than 10 cigarettes/d, 30.3 % between 10 and 20 cigarettes/d, and only 4.8 % more than 20 cigarettes/d. Of the 47 pipe smokers, 25.5 % smoked less than 25 g of tobacco per week, 23.4 % between 25 and 50 g/week, and 51.1 % more than 50 g/week. The percentage of pipe smokers who inhaled the smoke was 61.7.

Table 1 shows the crude (unadjusted) prevalence rates for questionnaire-based symptom responses and physical signs of the study group. The results in the table indicate a high background prevalence of respiratory abnormalities. This was particularly the case for acute and milder respiratory symptoms and those irritative symptoms which might be thought to be related to a polluted work environment.

Inspection of the temporal patterns of chest tightness and wheezing symptoms provided some evidence of work-relatedness. This association was much weaker for the latter than for the former symptom. No pattern was evident with respect to day of the week among the 72 workers experiencing chest tightness. There was, however, some relationship with work, 31 persons (43.1 %) experiencing it after work, 21 (29.2 %) during work, 10 (13.9 %) before work, and another 10 (13.9 %) experiencing combinations of the possibilities. Of the 73 workers with wheezing, 67 (91.8 %) complained of associated attacks of shortness of breath. Forty-eight (65.7 %) had to take medicine or treatment for these attacks. Only 11 (15.1 %) had had these attacks before starting to work in the brickworks. Attacks were reportedly worse for only 38 (52 %) of the workers with wheezing symptoms on a particular day of the week.

Table 2 shows a pattern of work-relatedness for roughly half of the workers with asthmatic symptoms. About a quarter of these workers had patterns that clearly did not relate to work time at all, while more than half tended to associate attacks with the work week. Within this latter subgroup there was no obvious pattern with respect to different days of the week. Overall there did not appear to be a strong relationship between day of the week and asthmatic symptoms. Attacks were reportedly worse for 51 (70 %) workers at a particular time of day.

Table 3 shows an essentially bimodal distribution for the time of occurrence of wheezing attacks. They occurred principally during workhours and later at night, carrying over until the next morning. Forty-nine (67 %) said that the attacks were worse at certain times of the year. Of these 20 % were worse in summer, while 80 % were worse in winter. Fifty-one (70 %) said that there was a factor at work that made the attacks worse. This factor was generally identified as dust. Sixty (82 %) said that they suffered attacks while on vacation. Of these, 23.3 % reported that the attacks were of similar frequency, 58.3 % stated that the attacks were less frequent, 3.3 % said that they were more frequent, and 15 % reported that the attacks stopped altogether while they were on vacation.

Table 1 shows the results of the stepwise logistic regression analysis of the symptom and sign data as dependent or outcome variables on age, length of service, cumulative respirable dust exposure, cumulative total dust exposure, smoking status, objective dustiness in current job, and subjective dustiness in current job. The statistically significant contributions of the in-

Table 1. Crude abnormality prevalence and factors contributing to the presence of abnormalities. [FEV% = (100 × forced expiratory volume in 1 s)/forced vital capacity, df = degrees of freedom]

Abnormality outcome	Crude prevalence (%)	Independent variable	F for entry	P-value (<)	Improvement chi-squared	df	P-value (<)
Cough in the morning	51.5	Smoking status	6.32	0.05	6.27	1	0.05
		Subjective dustiness in current job	4.04	0.05	8.02	1	0.05
Cough most days	37.7	Subjective dustiness in current job	5.41	0.005	11.18	2	0.005
		Smoking status	6.91	0.01	7.12	1	0.01
Cough for ≥ three months of the year	31.0	Subjective dustiness in current job	4.66	0.05	9.80	2	0.01
Cough for ≥ three months of the year for ≥ three years	8.2	Objective dustiness in current job	2.95	0.1	6.92	2	0.05
		Length of service	3.89	0.05	3.96	1	0.05
Cough for ≥ three months of the year for ≥ three years with FEV% at < 75 %	4.1	Objective dustiness in current job	5.38	0.01	10.85	2	0.005
Phlegm production in the mornings	46.3	Subjective dustiness in current job	6.01	0.005	12.11	2	0.005
Phlegm most days	34.3	Smoking status	4.30	0.05	4.49	2	0.005
Phlegm production for ≥ three months of the year	28.4	Nil	-	-	-	-	-
Phlegm production for three months a year for ≥ three years	6.7	Objective dustiness in current job	3.92	0.05	6.84	2	0.05
		Length of service	4.90	0.05	5.01	1	0.05
Phlegm production for ≥ three months in the year for ≥ three years with FEV% at < 75 %	3.4	Objective dustiness in current job	3.96	0.05	7.94	2	0.05
Shortness of breath	14.6	Smoking	7.24	0.01	9.11	1	0.005
Shortness of breath when compared with persons the same age	9.0	Nil	-	-	-	-	-
Dyspnea at effort (grades II and III)	9.0	Length of service	8.03	0.005	8.00	1	0.005
		Smoking	3.26	0.1	4.00	1	0.05
		Subjective dustiness in current job	2.44	0.1	6.61	2	0.05
Chest tightness	26.9	Cumulative respirable dust exposure	6.46	0.05	6.42	1	0.05
		Subjective dustiness in current job	5.29	0.01	11.67	2	0.005
		Smoking	3.71	0.1	4.00	1	0.05
Wheezing	27.1	Nil	-	-	-	-	-
History of asthma	9.3	Smoking	4.96	0.05	6.63	1	0.01
Nasal symptoms	43.3	Nil	-	-	-	-	-
Eye symptoms	32.5	Smoking	7.50	0.01	7.99	1	0.005
		Age	5.94	0.05	5.82	1	0.05
Hay fever	48.9	Nil	-	-	-	-	-
Skin rash	30.6	Nil	-	-	-	-	-
History of tuberculosis	11.9	Age	5.56	0.05	5.22	1	0.05
		Subjective dustiness in current job	4.16	0.05	9.25	2	0.01
Current proved tuberculosis	1.8	Nil	-	-	-	-	-
Radiographic past or present tuberculosis	9.3	Age	19.33	0.0001	16.83	1	0.0001
Adventitious sounds present	7.5	Age	15.46	0.0001	13.55	1	0.0001
Rhonchi present	6.0	Age	8.73	0.005	7.83	1	0.005
		Cumulative respirable dust exposure	5.16	0.05	5.18	1	0.05
Crepitations present	1.1	Nil	-	-	-	-	-
Both rhonchi and crepitations present	0.7	Length of service	7.05	0.01	7.71	1	0.01

dependent variables to the outcome have been ranked in the order of priority of the predictor. Abnormality outcomes have been ranked from mild to severe within the groups. It appears from the table that the presence of the early or milder respiratory symptoms in the cough, phlegm, and breathlessness groups tended to be significantly predicted by smoking status and sub-

jective indicators of dustiness in the current job. As these symptoms progressed to more severe variants within the three groups, the objective dustiness indicators for the current job or total length of service became selected as significant predictors. Partial exceptions to this pattern were breathlessness and chest tightness, both of which were predicted by a combination

of objective and subjective dust indicators, together with smoking status. Chest tightness was sharply differentiated from wheezing in terms of the predictor variables included in the regression. Generally speaking, the grouping of historical conditions did not exhibit any associations of note with the independent variables. The role of age as a predictor was confined to physical signs and radiographic evidence of tuberculosis (past and present).

The lung function values are expressed as multiple linear regression equations for the study group in table 4, which shows the effect of height, age, smoking status, and cumulative respirable dust exposure upon lung function after height, age, and smoking were forced into the model for standardization. When the categorical variables subjective dustiness in the current job and objective dustiness in the current job were entered as independent variables, they were not selected before cumulative respirable dust exposure.

Table 5 shows the results of the stepwise logistic regression of symptoms and signs on the lung function parameters $FEV_{1.0}$, FVC, and $FEV\%$, ie, $(100 \times FEV_{1.0})/FVC$, after standardization for height, age, and smoking status. The $FEV\%$ appears to be negatively associated with most cough and phlegm symptoms, chest tightness, wheezing, a history of treatment for tuberculosis and current treatment for tuberculosis. The strength of these associations generally increased with the severity ranking within the symptom group concerned. $FEV_{1.0}$ was significantly negatively associated with a history of asthma and radiographic evidence of past or present tuberculosis according to readers 1 and 2. Breathlessness symptoms and physical signs were not associated with any lung function parameter.

Smoking status was investigated in relation to symptoms, signs, pulmonary functions, and radiographic changes (2). The findings presented in table 1 indicate that associations with smoking were restricted to mainly early or mild respiratory symptoms, while table 4 shows no effect of smoking on the pulmonary function values. A stepwise logistic regression of pneumoconiosis status on the various chronic respiratory symptoms revealed no significant associations. Similarly, there were no significant associations with $FEV_{1.0}$, FVC, or $FEV\%$ when dust exposure was forced into the regression after age and smoking status.

Discussion

The character of the study group is special in that it was a very young, short-serving, and mainly migrant work force. Under such circumstances it is debatable whether a cross-sectional study is any less effective than a longitudinal study. Since the turnover is likely to be very high, a longitudinal study would present difficulties, such as the loss of follow-up data over time of observation, which could seriously compromise the validity of results calculated from such data. On the other

Table 2. Distribution of wheezing attacks over the week.

Weekly wheezing pattern	Number of attacks	%
Monday through Sunday	2	5.3
Monday through Friday	9	23.7
Monday through Wednesday	12	31.6
Wednesday through Friday	7	18.4
Weekends only	2	5.3
Odd days	6	15.8
Total	38	100.0

Table 3. Distribution of wheezing attacks over time of day.

Daily wheezing pattern	Number of attacks	%
Before work	4	7.8
During work	19	37.3
At home after work	6	11.8
Much later in bed	14	27.5
Much later in bed and before work the next day	3	5.9
Bimodally — during work and much later in bed	5	9.8
Total	51	100.0

Table 4. Multiple linear regression of the lung function values on age, height, smoking status, and the dust indicators. [resp dust = cumulative respirable dust exposure, SEE = standard error of the estimate, R = multiple correlation coefficient, FVC = forced vital capacity, $FEV_{1.0}$ = forced expiratory volume in 1 s, $FEV\% = (100 \times FEV_{1.0})/FVC$]

$FVC = -4.7228 + 0.0535 \times \text{height} - 0.4671 \times \log(\text{age})$ $- 0.2200 \times \log(\text{resp dust})$ $R = 0.5741$ $SEE = 0.5606$
$FEV_{1.0} = -1.7167 + 0.0406 \times \text{height} - 1.1336 \times \log(\text{age})$ $- 0.1772 \times \log(\text{resp dust})$ $R = 0.5421$ $SEE = 0.5276$
$FEV\% = 113.7987 - 22.7851 \times \log(\text{age})$ $R = 0.3755$ $SEE = 7.1560$

hand, it is well-known that the attrition rate in industries with an unpleasant work environment may be high and may result in loss of workers, particularly those with symptoms of a work-related illness. A cross-sectional prevalence study would therefore underestimate indices of interest. This is one component of a healthy worker effect (6). Upon returning from their rural areas of residence, African workers undergo a pre-employment examination and periodic mini-radiographic examinations. This process would have the effect of depressing the prevalence of sputum-positive tuberculosis in the study group.

There is also an anticipated effect of excluding those workers who were unable to meet the requirements of the criteria established by the American Thoracic Society for pulmonary function tests (7). All these factors constitute potential biases towards the null in this study. Since ex-smokers are known to differ in unexpected ways from smokers and nonsmokers (ie, they

Table 5. Association between the presence of symptoms and the lung function values. [FEV_{1.0} = forced expiratory volume in 1 s, FEV% = (100 × FEV_{1.0})/forced vital capacity, df = degrees of freedom]

Outcome variable	Independent variable	F for entry	P-value (<)	Improvement chi-squared	df	P-value (<)
Cough in the mornings	— FEV%	4.55	0.05	4.63	1	0.05
Cough most days	Nil	.	.	.	.	.
Cough for ≥ three months of the year	— FEV%	5.47	0.05	5.34	1	0.05
Cough for ≥ three months of the year for ≥ three years	— FEV%	11.72	0.001	9.87	1	0.005
Cough for ≥ three months of the year for ≥ three years with FEV% at < 75 %	— FEV%	30.32	0.0001	21.66	1	0.0001
Phlegm production in the mornings	— FEV%	6.62	0.05	6.65	1	0.01
Phlegm production most days	— FEV%	7.51	0.01	7.38	1	0.01
Phlegm production for ≥ three months of the year	— FEV%	8.50	0.005	8.14	1	0.005
Phlegm production for ≥ three months of the year for ≥ three years	— FEV%	8.93	0.005	7.66	1	0.01
Phlegm production for ≥ three months of the year for ≥ three years with FEV% at < 75 %	— FEV%	23.88	0.0001	17.12	1	0.0001
Shortness of breath	Nil	.	.	.	.	.
Shortness of breath when compared with peers	Nil	.	.	.	.	.
Dyspnea at effort (grades II and III)	Nil	.	.	.	.	.
Tightness of the chest	— FEV%	6.37	0.05	6.24	1	0.05
Wheezing	— FEV%	5.68	0.05	5.52	1	0.05
History of asthma	— FEV _{1.0}	7.86	0.01	7.34	1	0.01
Nasal symptoms	Nil	.	.	.	.	.
Eye symptoms	Nil	.	.	.	.	.
Hay fever	Nil	.	.	.	.	.
Skin rash	Nil	.	.	.	.	.
History of tuberculosis	— FEV%	27.70	0.0001	22.53	1	0.0001
Current proved tuberculosis	— FEV%	8.77	0.005	4.94	1	0.05
Radiographic past or present tuberculosis	— FEV _{1.0}	47.08	0.0001	38.77	1	0.0001
Adventitious sounds present	Nil	.	.	.	.	.
Rhonchi	Nil	.	.	.	.	.
Crepitations	Nil	.	.	.	.	.
Rhonchi and crepitations	Nil	.	.	.	.	.

do not lie on a continuum from never smoking to smoking status) and since they were small in number, they were excluded from the study group in order to facilitate pure smoker-nonsmoker comparisons. After all the exclusions, however, there was still a sufficient number of long serving workers to afford internal comparisons and to obtain a perspective, however incomplete, of exposure-time relationships.

Generally speaking, the symptom prevalences were high, and these high prevalences indicate a substantial background burden of respiratory ill health in the study group. They are, however, comparable with prevalences found by us (8–10) and other investigators (11–14) among groups of workers exposed to high levels of asbestos, silica, or grain dust. The brickworks environment was heavily polluted with dust and sulfur dioxide fumes and constituted an extremely unpleasant work environment.

The cough and phlegm questions served as an internal check upon each other, and the results corresponded well. The prevalence gradient ranging from mild to severe symptoms was in agreement with the one expected and again serves as a check upon the quality of the questionnaire as a valid instrument.

It would also appear that a simple question seeking comparative information about dyspnea could be as good as more complicated inquiries into the grading of dyspnea. It is also much easier to ask. Most occupational epidemiology studies show low prevalences for dyspnea because of the healthy worker effect. The prevalence of nose, eye, and skin irritation was high but did not correlate with dust as a potential cause. These symptoms may have been attributable to other workplace pollutants such as fumes.

Chronic nonspecific lung disease has recently been reviewed by Abrams (15). This entity includes a cluster of symptoms associated with chronic bronchitis and

a reduction in lung function associated with obstructive lung disease. There has been much argument about dusty work environments as an etiologic factor. Morgan (16) found industrial bronchitis (dust-induced) to be unassociated with decreased pulmonary function values. Others have found that dust plays no role and have postulated instead that this condition is entirely attributable to the effects of smoking and age (17–19). Recent studies, however, provide strong evidence for the independent role of dust in the causation of this disease (20–27).

South African studies have shown excesses of chronic bronchitis among miners when compared with the levels among nonminers (28) and a reduction in lung function among miners with chronic bronchitis (29). These changes were independent of smoking and related to dust exposure. Similar findings have been reported elsewhere (30) for mine workers. The industrial causation of chronic obstructive airways disease has been granted statutory recognition in South Africa and is compensable for mine workers under the Occupational Diseases in Mines and Works Act of 1973.

The results of this study show clear associations between acute and chronic respiratory symptoms, dust exposure, and evidence of airflow limitation, independent of the effect of smoking. A high proportion of workers complained of chest tightness and wheezing. Attacks of wheezing were reported to be more frequent in the less dusty season (winter), a finding indicating a primarily nonwork-related etiology, with worktime exposure perhaps playing an aggravating role. Table 1 also indicates that chest tightness and wheezing represent different biological responses. Wheezing was not associated with any measured work exposure, while chest tightness was. Wheezing was perhaps more closely associated with nonwork-related stimuli, while chest tightness may have been a response to a work environment characterized by high levels of dust and fumes.

The past history of tuberculosis was within the expected range for black factory workers in South Africa at 11.9 % (8, 9) and agreed well with the radiographic prevalence. The 1.8 % prevalence of sputum positive tuberculosis was almost three times the average reported by tuberculosis screening authorities (31) despite regular screening. This finding possibly indicates the potentiating effect of a dusty work environment. There were, however, very small numbers of cases, and relationships could not be corroborated by findings of relationships between the dust exposure indicators and any tuberculosis index.

No assumptions have been made with respect to the normality, or otherwise, of any reference population of external controls for lung function values, which is problematic in the case of black South African workers (32). Internal controls based upon objective dust determinations have been used instead. This procedure has the advantage of reducing the heterogeneity of the comparison groups.

The multiple regression analysis of the lung function values showed a clear dose-response effect for both FVC and FEV_{1.0} with the most precise dust indicator (cumulative respirable dust exposure), and thus provided further corroboration for a deleterious dust-related effect on the respiratory system. Holness et al (33) found a similar dose-response relationship for FEV_{1.0} in a group of brickworkers serving as a reference group for workers exposed to cotton dust.

The associations between symptom prevalence and decreased lung function values in table 5 provide further objective validation for the questionnaire. Similarly, these findings tend to validate the dust-relatedness demonstrated for symptoms and signs in table 1. Respiratory abnormalities are a result of multiple etiologic factors. This phenomenon gives rise to difficulty in disentangling the influence of various factors contributing to their presence. This study has been able to control for smoking, a known contributor, and it demonstrated statistically significant associations between the outcome variables of interest and dust exposure. Smoking contributed to some symptom prevalences, and the contribution was more marked for the early/milder symptoms with the exception of severe dyspnea at effort, for which it also played a role. In general, smoking played less of a role than dustiness in the determination of respiratory symptoms. Smoking was not associated with the diminution of the lung function values or with the prevalence or severity of pneumoconiosis (2). This finding was partly due to the fact that the population studied was not made up of heavy smokers. These findings are not unexpected for black workers in South Africa (8, 9, 34). In summary it may be said that the results from the analysis of symptoms and lung function changes in relation to dust exposure add further weight to the body of evidence connecting industrial dust exposure to objective and subjective respiratory ill effects other than pneumoconiosis. These findings are unlikely to be confined to brickworkers and could very probably be generalized to those working in environments characterized by similar general dust and free-silica levels.

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