Differences in lung function and prevalence of pneumoconiosis between two kaolin plants

M E BASER, T P KENNEDY, R DODSON, W RAWLINGS JR, N V RAO, J R HOIDAL

From the Department of Environmental Health Sciences, Johns Hopkins School of Hygiene and Public Health, Baltimore, Maryland, Pulmonary Medicine Division, University of Tennessee, Memphis, Tennessee, and Department of Environmental and Cell Biology, University of Texas Health Sciences Center, Tyler, Texas, USA

ABSTRACT To investigate the origin of differences in previously published pulmonary function studies of workers in kaolin plants in Georgia, spirometric and radiographic data collected in a cross sectional survey of two large plants were analysed. As compared with workers in plant 2, workers in plant 1 had a 2-7-fold greater prevalence of pneumoconiosis and a mean 0-36 l decrement in adjusted forced vital capacity. Our previous finding that exposure to kaolin was not associated with a decrement in lung function may have resulted from failure to consider differences between the plants.

Kaolin is a commercially valuable form of clay primarily composed of kaolinite, a non-fibrous hydrated aluminum silicate with low quartz content.1 Kaolin is cytotoxic to erythrocytes2 and macrophages3 in vitro. Middleton first reported radiographic abnormalities in kaolin processing workers in 1936.4 Pathological and mineralogical studies have confirmed the fibrogenic potential of kaolinite.5-10 Epidemiological studies in the British, American, and Egyptian industries have found that the prevalence of opacities is related to duration of employment or to age.11-18

Three pulmonary function studies in the American industry have yielded different results. Sepulveda et al found differences in mean adjusted forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and peak flow between exposed and non-exposed workers.6,17 Altekruse et al found that FEV1 % predicted and FVC % predicted declined with increasing years of employment in production, and that FEV1 % predicted and FVC % predicted were lower in production workers with pneumoconiosis as compared with production workers without pneumoconiosis.18 By contrast to these studies, which found that decrement in lung function was related to exposure to kaolin and to pneumoconiosis, Kennedy et al found no differences in mean adjusted FEV1 or FVC between workers with and without pneumoconiosis.15

In the present study we used previously collected data to test two hypotheses for the discrepant pulmonary function results. Plant differences in prevalence of pneumoconiosis and pulmonary function might result from qualitative or quantitative differences in exposure to kaolin. In addition, Sepulveda et al16,17 and Altekruse et al18 examined the relation between exposure and lung function but Kennedy et al did not.15 Therefore, the discrepant results might be due to an independent association of exposure to kaolin with opacities and decrement in lung function (fig).

Methods

We reanalysed data from the two largest plants (n = 181 and 244) studied by Kennedy et al, the only study of the American industry which included more than one plant.15 A third plant was excluded owing to its small workforce (n = 34). Since the plants were near each other, lifetime work histories were collected to determine if workers currently employed in one plant had been previously employed in the other.

The crude relations of independent variables to dependent variables were tested using the chi-squared test with continuity correction for discrete variables and the two tailed t test for continuous variables. Multiple regression was used to simultaneously adjust

暴露与功能之间的关系

暴露：功能

暴露与功能之间的关系

功能：暴露

暴露与功能之间的关系

暴露与功能之间的关系

Open line represents weak associations, dotted line a weak association.

Accepted 19 December 1988

773
for potential explanatory and confounding variables.  

Multiple linear regression was used for the continuous dependent variables (FEV₁ and FVC). The distributions of regression residuals were tested for normality and constant variance.  

Multiple logistic regression was used for the dichotomous dependent variable (presence or absence of opacities). The chi-squared goodness of fit test was used to test fit to the regression model.  

Plant membership was included as an independent variable in the linear and logistic regressions to test for interplant differences in lung function and the prevalence of pneumoconiosis.  

The independent variables in the multiple linear regression equations with FEV₁ and FVC as the dependent variables were plant, years in production, age, height, race, and smoking status. Years in production was included to test the exposure-lung function hypothesis. Race and smoking status were included as independent variables because separate race and smoking status specific regression equations would have been based on small numbers of subjects.  

The independent variables in the multiple logistic regression with presence of pneumoconiosis as the dependent variable were plant, age (dichotomised by greater or less than 55), and years in production. Age over 55 was an independent correlate of the prevalence of pneumoconiosis, a finding believed to reflect higher historical dust concentrations. Employment in production, but not in maintenance, mine, laboratory, or administration, was associated with opacities.  

Results  

Table 1 compares the crude distributions of demographic and exposure variables by plant. Compared with workers in plant 2, workers in plant 1 were significantly younger and had been employed for fewer years in production. There were no differences between plants in the crude distributions of height, smoking status, race, or pneumoconiosis. Only one person in plant 2 had been previously employed in plant 1.  

Table 2 presents the results of the multiple logistic regression with presence of pneumoconiosis as the dependent variable. The chi-squared goodness of fit test was not

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Demographic and exposure variables by plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variable</td>
<td>Category</td>
</tr>
<tr>
<td>Age (y)</td>
<td>18-34</td>
</tr>
<tr>
<td>Height (in)</td>
<td>62-67</td>
</tr>
<tr>
<td>Smoking status</td>
<td>Never</td>
</tr>
<tr>
<td>Race</td>
<td>White</td>
</tr>
<tr>
<td>Employment in production (y)</td>
<td>0-9</td>
</tr>
<tr>
<td>Pneumoconiosis</td>
<td>Yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Regression coefficients (b) and standard errors (SEb) for multiple logistic regression with presence of pneumoconiosis as the dependent variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Independent variable</td>
<td>b</td>
</tr>
<tr>
<td>Years in production (%)</td>
<td>50-65</td>
</tr>
<tr>
<td>Age†</td>
<td>0.591</td>
</tr>
<tr>
<td>Plant‡</td>
<td>0.987</td>
</tr>
</tbody>
</table>

*The odds ratio is calculated as e^b.
†Subjects older than 55 compared with those aged 55 or under.
‡Plant 1 compared with plant 2.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Regression coefficients (b) and standard errors (SEb) for multiple linear regressions with FEV₁ and FVC as dependent variables</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FEV₁ (l)</td>
</tr>
<tr>
<td>Independent variable</td>
<td>b</td>
</tr>
<tr>
<td>Age (l/y)</td>
<td>-0.034</td>
</tr>
<tr>
<td>Height (l/in)</td>
<td>0.087</td>
</tr>
<tr>
<td>Race*</td>
<td>-0.394</td>
</tr>
<tr>
<td>Smoking status†</td>
<td>Current</td>
</tr>
<tr>
<td>Ex</td>
<td>-0.098</td>
</tr>
<tr>
<td>Years in production (l/y)</td>
<td>-0.004</td>
</tr>
<tr>
<td>Plant‡</td>
<td>-0.112</td>
</tr>
</tbody>
</table>

*Black compared with white.
†As compared with never smokers.
‡Plant 1 compared with plant 2.
Differences in lung function and prevalence of pneumoconiosis between two kaolin plants

significant (p = 0.125). The adjusted prevalence of pneumoconiosis was 1.8-fold greater in workers older than 55 as compared with workers aged 55 or under (p = 0.028). The adjusted prevalence of pneumoconiosis increased 1.1% for each year in production (p < 0.001), so that workers with 20 years employment in production would be expected to have an adjusted prevalence of 22%. Even after adjusting for age and years in production, workers in plant 1 had a 2.7-fold greater prevalence than workers in plant 2 (p < 0.001).

Table 3 presents the results of the multiple linear regressions with FEV, and FVC as the outcomes. The regression residuals were normally distributed and had constant variance. The independent variables accounted for 48.8% of the variance in FEV, and 47.1% of the variance in FVC. There was no relation between years in production and adjusted FEV1 or adjusted FVC. There was, however, a strong association of plant with adjusted FVC (p < 0.001) but not with adjusted FEV1 (p < 0.072). Relative to workers in plant 2, workers in plant 1 had a mean 0.368 l decrement in adjusted FVC.

Discussion

Although years in production was not independently associated with opacities and decrement in lung function, workers in plant 1 (who were younger and had been employed for fewer years in production than workers in plant 2) had a significantly higher adjusted prevalence or pneumoconiosis and lower adjusted FVC. Possibly the regression procedures incompletely adjusted for the interplant differences in the distributions of years in production and age (table 1). If this were true, however, workers in plant 2 would have had a higher adjusted prevalence of pneumoconiosis and lower adjusted FVC.

The smoking histories did not include information on pack-years of smoking. Owing to the age differences between plants (table 1), the distributions of pack-years of smoking might differ even though the distributions of smoking status were similar. This may be important for several reasons. Impaired mucociliary clearance in smokers may result in increased dust retention and risk of pneumoconiosis. There was no relation, however, between smoking status and prevalence of pneumoconiosis. Oldham has suggested the use of interaction terms between age and smoking status when detailed smoking histories are not available. In these data interaction terms (between age and ex-smoking and between age and current smoking) did not explain variance in either FEV, or FVC in addition to that explained by other independent variables. In addition, cigarette smoking is more closely associated with obstructive than with restrictive pulmonary function changes, and we found a difference between plants in adjusted FVC but not in adjusted FEV1 (table 3). Thus it is unlikely that the lack of detailed smoking histories biased these results.

The results of this study differ from those of other studies reporting "mill effects" in the coal26 and cotton27 industries because the findings of both restrictive pulmonary function changes and an increased prevalence of pneumoconiosis in one plant suggest a responsible agent. Historically, 15–20% of the production of plant 1 has been calcined kaolin, whereas plant 2 has produced only hydrous clay (Production managers plants 1 and 2, personal communications). High temperature processing methods, such as those used to calcine kaolin or to make refractory brick, produce mineralogical changes in hydrous kaolin. When quartz is heated to temperatures between 867°C and 1470°C it is converted to cristobalite, which has a greater fibrogenic potential. Concentrations of cristobalite in air samples as high as 8-9% have been reported from a Missouri firebrick factory using kaolin.

Information on respirable particle size and concentration for calcined versus hydrous kaolin is lacking, and detailed information on output of calcined kaolin for the companies under study could not be obtained from the governmental agencies which routinely collect these data for the industry as a whole. Further studies of the industry should include this information, which is necessary for the attribution of differences in pulmonary function or radiographic abnormalities to historical exposures.

Supported by grant OH02264-02 from the National Institute of Occupational Safety and Health.

References

2 Middleton EL. Industrial pulmonary disease due to the inhalation of dust. Lancet 1936;i:59-64.


