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Respiratory health of brickworkers in Cape Town, South Africa. Appropriate dust exposure indicators and permissible exposure limits.

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Respiratory health of brickworkers in Cape Town, South Africa

Appropriate dust exposure indicators and permissible exposure limits

by Jonathan E Myers, MD¹

MYERS JE. Respiratory health of brickworkers in Cape Town, South Africa: appropriate dust exposure indicators and permissible exposure limits. *Scand J Work Environ Health* 1989;15:198–202. The predictive value for respiratory abnormalities of dust indicators was assessed for 268 brickworkers. The subjective/objective correlations were poor ($r = 0.09$). The subjective indicators were found to be predictive of early/mild abnormalities, while the objective indicators were better for more severe abnormalities. The respirable/total dust correlations were high ($r = 0.99$). Length of service was a good proxy predictor for most respiratory abnormalities, while respirable dust was a good proxy for respirable free silica. Simple screening measures with potential application in less-developed settings, like subjective questionnaire responses and total dust measurement, are suggested. The American Conference of Governmental Industrial Hygienists' threshold limit values for free silica and "nuisance" particulates appear to be too high to prevent the occurrence of abnormalities. The World Health Organization's health-based limit for respirable free silica (1 mg/m^3) and hygienic standards of well below 5 mg/m^3 would have prevented much of the respiratory abnormality found. Hygienic standards for dust and the concept of "nuisance" dust need to be reevaluated by further research.

Key terms: bricks, dust, hygienic standards, nuisance dust, threshold limit value.

Studies of brickworkers' work environments (1) and respiratory health status (2, 3) have been described previously. This article presents the results of comparisons between the subjective and objective dustiness indicators. Intercorrelations and the ability to predict abnormal respiratory outcomes are examined. Comparisons between objective dust indicators, including length of service as a proxy for cumulative dust exposure and respirable dust as a proxy for respirable free silica, have been made. The concept of "nuisance" dust, defined in relation to pulmonary fibrosis, has been in use for many years (4, 5). There appear to be no published reports examining this concept from the standpoint of other aspects of respiratory morbidity. Data from this study suggest that the threshold limit values (TLV) of the American Conference of Governmental Industrial Hygienists (ACGIH) for free silica and respirable dust (4–7) are inadequate for the prevention of respiratory morbidity.

Subjects and methods

The methods used in this study have been described elsewhere (1–3) and are similar to those used to com-

pare interreader variation for the radiographs (3) and in the examination of predictors of abnormal respiratory outcomes (2) on a prioritized basis.

The subjective indicators "subjective dustiness in current job," "subjective dustiness in the job prior to the current job," and "subjective dustiness in the second last job" in brickworks were obtained from questionnaire responses to inquiries about whether these jobs were not at all dusty, dusty, or very dusty. The objective indicators "objective dustiness in current job," "objective dustiness in the job prior to the current job," and "objective dustiness in the second last job" are based upon respirable dust values attributable to the three dustiness levels that were determined by previous analyses of brickworks jobs (1). These six variables each have three levels corresponding to high, medium, and low levels of dustiness. Cumulative respirable dust exposure was the other objective indicator, the derivation of which has been explained previously (1).

The mean dust exposure levels and the respiratory abnormality prevalence were examined in relation to the ACGIH TLV for respirable dust (5 mg/m^3) (4) and respirable free silica (1.8 mg/m^3 of respirable dust) (6), given the average free-silica content of brickworks dust (1). A measure of the weighted average level over different jobs of respirable dust exposure, in milligrams per cubic meter, was obtained for each worker by dividing the cumulative level of the respirable dust exposure by the length of service (in years).

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Results

Comparison of the subjective and objective dustiness indicators

Table 1 shows the results of a comparative analysis of the subjective dustiness versus objective dustiness indicators for three levels of jobs in the brick factories. The consistencies (equal ranking for dustiness) were generally low with marked biases in favor of the subjective indicator. The correlations were very poor indeed. Agreement increased and biases decreased as the analysis proceeded backwards in time over previous jobs.

Table 2 shows the relative contributions of three dustiness variables in the stepwise logistic regression analysis to the variance in the different symptom outcome variables. When the strength of association (P-values) between the objective and subjective dustiness indicators and symptoms were compared, a pattern of a stronger association between objective indicators with more severe or long-standing symptoms and between the subjective indicator with milder or earlier symptoms within the symptom groups emerged.

Table 2 shows that subjective dustiness in the current job was better for predicting the cough symptom group than objective dustiness in the current job. This latter was, in turn, better than cumulative respirable dust exposure. There was a clear pattern in that the progressively more objective dust indicators predicted the progressively more severe cough symptoms. A similar pattern may be observed with regard to the phlegm group of symptoms. Severe breathlessness was the only one of the breathlessness group of symptoms to be strongly associated with a dust indicator (cumulative respirable dust exposure). No indicator was significantly associated with past medical history or physical signs.

Table 1. Subjective versus objective dustiness categories. (Subjdust/objdust = subjective/objective dustiness in current job, subjdust-1/objdust-1 = subjective/objective dustiness in the job prior to the current job, subjdust-2/objdust-2 = subjective/objective dustiness in the second last job)

	Current job (subjdust versus objdust)	Previous job 1 (subjdust-1 versus objdust-1)	Previous job 2 (subjdust-2 versus objdust-2)
Consistency	28 %	39.4 %	50 %
Bias	54.8 % to subjective indicator	46.5 % to subjective indicator	33 % to subjective indicator
Bias score	79.3 % to subjective indicator	66.1 % to subjective indicator	52.7 % to subjective indicator
Correlation	r = 0.09	r = 0.08	r = 0.22

Table 2. Comparison of dust indicators as contributors to respiratory symptoms. [FEV% = (100 × forced expiratory volume in 1 s)/forced vital capacity]

Outcome variable	F to enter		
	Subjective dustiness in current job	Objective dustiness in current job	Cumulative respirable dust exposure
Cough in the mornings	4.08**	2.28	0.38
Cough most days	5.41***	2.72*	1.14
Cough for ≥three months of the year	4.66***	3.46**	1.93
Cough for ≥three months of the year for ≥three years	4.54***	3.54**	3.4 *
Cough for ≥three months of the year for ≥three years with FEV% at <75	3.52**	5.38***	5.05**
Phlegm production in the mornings	6.01****	0.73	0.00
Phlegm production most days	2.71*	1.43	1.4
Phlegm production for ≥three months of the year	1.28	2.41*	2.66
Phlegm production for ≥three months of the year for ≥three years	2.56*	3.92**	4.91*
Phlegm for ≥three months of the year for ≥three years with FEV% at <75	2.84*	3.96**	5.07***
Shortness of breath	2.47*	1.67	0.54
Shortness of breath when compared with peers	1.66	0.84	1.16
Dyspnea at effort (grades II and III)	1.97	1.76	6.8***
Tightness of the chest	4.28**	3.13**	6.46***
Wheezing	1.07	0.40	0.18

* P<0.1, ** P<0.05, *** P<0.01, **** P<0.001.

Comparisons between the objective dustiness indicators

The correlation between cumulative total dust exposure and cumulative respirable dust exposure was very high, the correlation coefficient being $r = 0.9941$. Throughout the regression analysis cumulative respirable dust exposure was always selected before total dust exposure on account of its marginally higher F-to-enter value and lower associated P-value.

Length of service as a proxy for cumulative dust exposure did not appear to be as good a predictor of symptoms as more precise measures of dust exposure. Subjective dustiness in current job, objective dustiness in current job, and cumulative respirable dust exposure were generally selected over length of service (2). The contribution of length of service to the variances in the stepwise logistic regressions, as measured by the F-to-enter and associated P-values, was generally less than the more precise dust indicator variables. Table 3 shows that the logistic regression of pneumoconiosis status still included length of service when it was used as the only dust indicator, but the association was a little weaker than when cumulative respirable dust exposure was the dust indicator. When length of service was used as the indicator of dust exposure in a multiple linear regression analysis instead of cumulative respirable dust exposure, the effect of dust exposure on forced expiratory volume in 1 s ($FEV_{1.0}$) was lost altogether. The dust effect on forced vital capacity (FVC) remained unchanged, while the effect on radi-

ographic changes was diminished but still present. Length of service was therefore a somewhat poorer predictor than the other objective dust indicators of short- and long-term effects of dust exposure.

Average dust exposure levels, threshold limit values and permissible exposure levels

Table 4 shows a cross-classification of selected respiratory abnormalities with average exposure level. It is apparent that about half of the pneumoconiosis cases could have been "prevented" at a hygienic standard of below 2 mg/m^3 (the ACGIH TLV for this study). There was no association between wheezing and average dust level. The prevalence of chest tightness declined at levels below 5 mg/m^3 . For both chronic bronchitis and chronic obstructive bronchitis there was a clear diminution of the group prevalence at well below 5 mg/m^3 . The analysis of covariance showed the mean $FEV_{1.0}$ and FVC, adjusted for height and age, to be significantly different only above and below a cutoff level of 5 mg/m^3 .

Discussion

A problem with subjective measures of dustiness relates to the difficulty of cross-job comparisons of intensity of dust exposures. While a machine would differentiate on an objective basis, the differential experience of workers in other departments, in addition to that of their current department, would limit or enhance their ability to classify dust exposure correctly. This possibility may explain why agreement between these indicators was so low (table 1). Another explanation relates to the high prevalence of dusty workplaces according to both types of indicator. This result will have the effect of reducing agreement between the indicators. The subjective indicators of dustiness in the current job may, in a sense, be argued to be more precise than objective indicators, as dust monitoring may not adequately or representatively capture the personal specificity of each job. In addition host factors like atopy or bronchial reactivity to dust may enhance the

Table 3. Multiple regression of the lung function values and radiographic abnormality on length of service (years) as the dust indicator. [$FEV_{1.0}$ = forced expiratory volume in 1 s, FVC = forced vital capacity, $FEV\% = (100 \times FEV_{1.0})/FVC$, SEE = standard error of the estimate, R = multiple correlation coefficient]

$FEV_{1.0} = -1.4376 + 0.0403 \times \text{height} - 1.4197 \times \log(\text{age})$
R = 0.5261
SEE = 0.5318
$FVC = -4.7388 + 0.0534 \times \text{height} - 0.4097 \times \log(\text{age})$
$- 0.2522 \times \log(\text{years})$
R = 0.5752
SEE = 0.5633
$FEV\% = 113.3680 - 22.5148 \times \log(\text{age})$
R = 0.3709
SEE = 7.16

Table 4. Group size by average exposure level to respirable dust.

	People with respiratory abnormality in exposure group													
	<0.5 mg/m ³		0.5–1 mg/m ³		1–2 mg/m ³		2–3 mg/m ³		3–4 mg/m ³		4–5 mg/m ³		>5 mg/m ³	
	N	% ^a	N	% ^a	N	% ^a	N	% ^a	N	% ^a	N	% ^a	N	% ^a
Pneumoconiosis	—	0	2	2	3	3	—	0	—	0	3	25	2	6
Wheezing	4	26	23	26	25	27	4	29	2	22	3	25	12	33
Chest tightness	1	7	22	25	24	26	3	21	2	22	4	33	15	41
Chronic bronchitis	—	0	5	6	7	7	2	14	—	0	—	0	4	11
Chronic obstructive bronchitis	—	0	1	1	4	4	1	7	—	0	—	0	3	8
Dyspnea	—	0	6	7	10	11	2	14	1	11	1	8	4	11
Total	15		88		94		14		9		12		36	

^a Percentages of total.

sensitivity of subjective indicators of dustiness to the early onset of respiratory abnormalities in the current job.

A possible interpretation of the findings in table 2 is that subjective indicators are useful as early warning signals, while objective indicators are better predictors of more advanced symptomatology and respiratory abnormality. This assumption implies that for preventive purposes it is important to "listen to the workers." This procedure may have considerable preventive value, especially in less developed settings, in that it is easy to obtain information about symptoms in terms of time, accessibility, and resources. As the milder symptoms notionally precede the more severe ones in time, monitoring of the early symptoms could be valuable and serve as an indicator as to whether or not there is a need for more objective measurements. Dose-response effects with high prevalences indicate the need for further investigation and control. If early symptom prevalences are low and no dose-response relation with subjective dustiness indicators is detected for them, further investigation may not be necessary.

A further preventive health implication relates to the fact that objective measures of dustiness are good mainly for predicting the more severe symptoms. Initial industrial hygiene screening of uninvestigated workplaces might proceed by way of determining the prevalence of more severe symptoms, which although difficult to elicit, is much easier to ascertain than performing time-consuming and expensive dust measurements. It would appear that total dust measurement is almost as good a predictor of respiratory abnormality as respirable dust. This finding may have some value in the rough and ready monitoring or crude screening situation in that relatively expensive cyclones for obtaining the respirable dust fraction could be dispensed with given adequate prior validation of this type of screening mechanism against a more comprehensive "gold standard" for dust levels in a particular industry.

Information on length of service also appears to be a reasonable crude screening measure for investigating dust relationships when it is not possible to do expensive and time-consuming measurements. However, some sensitivity is lost when this method is compared with a more precise indicator of dust exposure, and this loss may have serious consequences when attempts are made to detect early, mild, or infrequent effects or diseases with short latency like asthma.

Table 4 shows that, to "prevent" most pneumoconiosis cases, a hygienic standard of less than half the ACGIH TLV (6) would have to be used. Thus the health-based limit of the World Health Organization (8) appears to be better as a standard. Table 4 also shows respiratory ill effects at average respirable dust exposure levels below 5 mg/m^3 , the TLV for "nuisance" particulates (4). As the numbers in the various categories are small, these patterns should be

treated with some caution. Very few subjects were exposed below an average exposure level of 0.5 mg/m^3 , and it is not possible to discuss this part of the exposure spectrum with any confidence. It would nevertheless seem reasonable to argue that preventive benefits would accrue if the "nuisance" dust standard were lowered for situations in which there is a decreasing trend for prevalence below 5 mg/m^3 . This is the case for chronic bronchitis, chronic obstructive bronchitis, chest tightness, and, to a less extent, dyspnea. The current TLV (4) appears adequate for preventing reductions in lung function.

The ACGIH defines "nuisance" particulates in the following way: "In contrast to fibrogenic dusts which cause scar tissue to be formed in the lungs when inhaled in excessive amounts, so-called 'nuisance' dusts have a long history of little adverse effect on lungs and do not produce significant organic disease or toxic effect when exposures are kept under reasonable control" (5). The definition also refers to the absence of effects enumerated in the definition of pneumoconiosis (9). Neither respiratory symptoms nor a reduction in lung function has therefore been taken into account by this definition. The data suggest that the concept of "nuisance" dust is too narrow and should be reconsidered in the light of a well-established and increasing body of literature demonstrating the association between dusty work and respiratory abnormality other than pneumoconiosis.

It would appear from these results that an average dust exposure level set at a more conservative level than 5 mg/m^3 would have a more effective preventive value for respiratory abnormalities as a whole. It should also be borne in mind that respirable dust levels of near 5 mg/m^3 of respirable dust in the breathing zone create, from a purely subjective point of view, a very unpleasant environment in which to work.

More specific research is strongly indicated in this area, both in the documentation of respiratory effects below currently accepted permissible exposure levels and in establishing and validating cost-efficient screening technologies which are particularly appropriate to less-developed settings.

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