TIME DOMAIN SPIROGRAM INDICES OF SILICA EXPOSED WORKERS

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ABSTRACT

Time domain spirogram indices had been shown to be sensitive indicators of small airway function. The aim of this study is to assess the small airway function of 110 silica-exposed workers using these indices.

The workers were subdivided into high, moderate and low exposure groups, based on their occupational history. Their spirograms were digitized electronically and conventional indices as well as time domain indices (MTT—mean transit time, COVTT—coefficient of variation of transit time and IOSTT—index of skewness of transit time) were derived.

With adjustment for age, height and smoking status the FEV_1 and FVC did not differ significantly among the groups whereas all the time domain indices showed significant differences. $FEF_{75\%}$ and $FEF_{75-85\%}$ were also significantly lower in the high exposure group although the difference in $FEF_{75\%}$ in the moderate and high exposure groups was not statistically significant.

Separate analysis were performed for smokers and non-smokers, while excluding all those with FEV_1/FVC ratio of less than 0.75. Similar trend of greater small airways obstruction in the higher exposure groups was also seen. The most significant differences were seen with time domain indices, $FEF_{75-85\%}$ and $FEF_{75\%}$.

This preliminary study supports the presence of small airway dysfunction among silica exposed workers. Furthermore, time domain spirogram indices appear to be more sensitive to small airway dysfunction.

INTRODUCTION

Airway resistance of the lungs can be partitioned into central and peripheral components. The peripheral component is composed of the resistance from airways of less than 2mm in internal diameter down to the gas exchange areas. This region is commonly termed as the small airways. Since small airways resistance contribute only 10–15% of total airway resistance, it is possible for a subject to have significant diffuse obstruction in the small airways while the total airway resistance are essentially normal.[1,2] In normal individuals, maximum expiratory flow at large lung volumes like the peak flow and the forced expiratory volume in one second (FEV_1), depend mainly on flow in the larger airways whereas maximum flow at small lung volumes reflect predominantly the function of small airways.[3,4,5]

Several spirometric indices especially flow rates at low lung volumes may reflect the status of small airways. These would include forced expiratory flow at 50% and 75% of forced vital capacity ($FEF_{50\%}$ and $FEF_{75\%}$), forced expiratory flow between 25 and 75%, 75 and 85% of forced vital capacity ($FEF_{25-75\%}$, $FEF_{75-85\%}$).[6-8] Time domain indices by using moments analysis of the volume time spirogram have also been shown to be sensitive indicators of small airways obstruction.[4,9-15]

The mean transit time (MTT) is an index of the average rate of emptying of the vital capacity. It is influenced by all parts of the spirogram. Mathematically, this is the first moment about the origin (see appendix 1). The coefficient of variation of transit times (CoVTT), represents the amount of variation between the initial and the terminal slower portion of the VC. It is derived from the second moment about the mean. The index of skewness of transit times (IoSTT), is a measure of the 'slow finish' at the terminal end of the expiration. This is derived from the third moment about the mean. Some workers analyzed moments about the origin rather than moments about the mean.[9-11,16] As an index of dispersion, these authors used the moment ratio (MR).

There had been few studies utilizing time domain indices to assess the small airways function of dust exposed workers. In this study we have applied the various spirometric indices as well as time domain indices on a group of granite quarry workers to evaluate their small airways function in relation to their dust exposure.

METHODS

Subjects

The volume-time spirograms of 132 currently employed granite quarry workers were selected. Each spirogram had

at least 3 satisfactory tracings. The tracing with the highest FVC was digitized using an electronic digitizer. The digitized data is stored into a micro-computer and volume-time as well as flow-volume curves are plotted on the computer screen for visual checking. Flow was calculated by least square regression using pairs of volume-time data in an interval of 0.05 seconds on either side of a given time point. This method of digitizing volume-time tracings had been shown to be an accurate and useful way of deriving volume-time and flow-volume indices from volume-time tracings.[17,18] Early termination increases the error in indices at low lung volumes.[6] Early truncation increases the variability of time domain indices.[16,19] Hence only spirograms that had a flow rate of less than 0.05 l/s in the last 0.5 s were selected for further analysis.[20] Of the 132 spirograms, only 110 satisfy the above criteria. The FEV_1, FVC, $FEF_{50\%}$, $FEF_{75\%}$, $FEF_{25-75\%}$, $FEF_{75-85\%}$, MTT, CoVTT, IoSTT and MR were calculated.

Detailed information including age, height measurement, smoking habits and a lifetime history of occupational exposure to dust were recorded for each worker. The 110 workers were divided into three dust exposure groups based on occupational history and environmental assessment of personal dust exposure by job categories. The average quartz content in the respirable dust was 28%. The low exposure group comprised those who were in the administrative section all of their working life. The moderate exposure group consists of transport and maintenance workers. The high exposure group were those who were past or current drillers and crusher workers for most years of their working life. Recent full-sized chest radiographs taken of each worker had been read independently by three experienced readers according to the International Labour Organization Standard Classification of Radiographs of Pneumoconiosis. None of the 110 workers had radiological films with profusion of small opacities greater than 1/0.

Statistics

The data was processed on an IBM 3033 mainframe computer using statistical procedures from Statistical Analysis System (SAS). Adjustment for group differences in age, height and smoking was done using analysis of co-variance and separate analysis for smokers and non-smokers.

RESULTS

Description of Study Population

There were 50 non-smokers and 60 smokers in the study population. Non-smokers were younger (41.0 compared with 47.6 years for smokers). The mean height were similar (1.66 m for non-smokers and 1.64 m for smokers). 15 (25%) of the smokers have a FEV_1/FVC ratio of less than 0.75 whereas all the non-smokers have a ratio of greater than 0.75.

The mean age, height, duration of exposure as well as the proportion of smokers in the three exposure groups are significantly different (Table I). The high exposure group had the longest duration of employment while the low exposure group had the shortest. The high exposure group can therefore be expected to have the greatest dose of dust and the low exposure group, the lowest dose. Age and duration of employment was highly correlated ($r=0.78$ for non-smokers, $r=0.67$ for smokers).

Lung Function

With adjustment for age, height and smoking status the FEV_1 and FVC did not differ significantly among the groups whereas all the time domain indices showed significant differences (Table II). $FEF_{75\%}$ and $FEF_{75-85\%}$ were also significantly lower in the high exposure group although the difference in $FEF_{75\%}$ between the moderate and high exposure groups was not statistically significant.

Table I
General Characteristics of Study Population

	Exposure			
	Low	Moderate	High	p value
Number	26	39	45	
Age (years)	36.4	44.1	48.7	0.0001
Height (m)	1.67	1.64	1.63	0.0232
Duration of exposure (years)	7.9	13.2	15.9	0.0215
Smokers (%)	27	62	64	< 0.05

Table II

Age, Height and Smoking Status Adjusted Lung Function Parameters of the Three Exposure Groups*

PARAMETER	EXPOSURE GROUPS			p VALUES		
	L	M	H	L vs M	L vs H	M vs H
FEV1 (l/s)	2.77 (0.08)	2.69 (0.06)	2.65 (0.06)	0.3868	0.2607	0.7078
FVC (l)	3.16 (0.09)	3.23 (0.07)	3.26 (0.07)	0.5359	0.4301	0.8042
$FEF_{25-75\%}$ (l/s)	3.40 (0.17)	3.09 (0.13)	2.86 (0.13)	0.1582	0.0188	0.1995
$FEF_{75-85\%}$ (l/s)	1.35 (0.08)	0.93 (0.06)	0.75 (0.06)	0.0001	0.0001	0.0283
$FEF_{50\%}$ (l/s)	3.98 (0.21)	3.86 (0.16)	3.61 (0.15)	0.6475	0.1722	0.2423
$FEF_{75\%}$ (l/s)	1.88 (0.10)	1.35 (0.08)	1.14 (0.07)	0.0001	0.0001	0.0572
MTT (s)	0.51 (0.03)	0.63 (0.02)	0.71 (0.02)	0.0019	0.0001	0.0202
CoVTT	1.00 (0.04)	1.22 (0.03)	1.45 (0.03)	0.0001	0.0001	0.0001
IoSTT	0.88 (0.26)	1.58 (0.20)	3.21 (0.19)	0.0367	0.0001	0.0001
MR	1.42 (0.03)	1.59 (0.02)	1.77 (0.02)	0.0001	0.0001	0.0001

* Adjusted for age, height and smoking status using analysis of covariance

( ) - standard error of adjusted means

Exposure groups :
L - Low exposure
M - Moderate expsoure
H - High exposure

Separate analysis were performed for smokers and non-smokers, while excluding all those with FEV_1/FVC ratio of less than 0.75. Except for FEV_1 and FVC in the low exposure group, all the other parameters showed that the smokers have greater degree of airway obstruction than the non-smokers (Tables III and IV). Similar trend of greater small airways obstruction in the higher exposure groups was also seen. The most significant differences were seen with time domain indices, $FEF_{75-85\%}$ and $FEF_{75\%}$.

Table III

Age and Height Adjusted Lung Function Parameters of the Three Exposure Groups in Non-Smokers

PARAMETER	EXPOSURE GROUPS			p VALUES		
	L	M	H	L vs M	L vs H	M vs H
FEV1 (l/s)	2.81 (0.10)	2.93 (0.10)	2.79 (0.10)	0.4182	0.8522	0.3224
FVC (l)	3.15 (0.12)	3.38 (0.12)	3.32 (0.13)	0.1818	0.3347	0.7421
FEF25-75% (l/s)	3.72 (0.20)	3.57 (0.22)	3.25 (0.22)	0.6301	0.1500	0.3062
FEF75-85% (l/s)	1.49 (0.11)	1.19 (0.12)	0.87 (0.12)	0.0753	0.0007	0.0547
FEF50% (l/s)	4.25 (0.25)	4.34 (0.26)	4.10 (0.27)	0.8192	0.7026	0.5356
FEF75% (l/s)	2.11 (0.13)	1.65 (0.14)	1.28 (0.14)	0.0225	0.0002	0.0733
MTT (s)	0.46 (0.03)	0.56 (0.04)	0.63 (0.03)	0.0519	0.0022	0.1720
CoVTT	0.99 (0.04)	1.16 (0.05)	1.46 (0.05)	0.0135	0.0001	0.0001
IoSTT	0.51 (0.26)	1.15 (0.27)	2.44 (0.27)	0.1009	0.0001	0.0014
MR	1.42 (0.03)	1.54 (0.02)	1.78 (0.02)	0.0164	0.0001	0.0001

* Adjusted for age, height and smoking status using analysis of covariance

( ) - standard error of adjusted means

Exposure groups :
L - Low exposure
M - Moderate expsoure
H - High exposure

Table IV

Age and Height Adjusted Lung Function Parameters of the Three Exposure Groups in Smokers

PARAMETER	EXPOSURE GROUPS			p VALUES		
	L	M	H	L vs M	L vs H	M vs H
FEV1 (l/s)	3.00 (0.12)	2.61 (0.07)	2.74 (0.08)	0.0076	0.0794	0.2213
FVC (l)	3.38 (0.13)	3.15 (0.08)	3.33 (0.08)	0.1318	0.7207	0.1311
$FEF_{25-75\%}$ (l/s)	3.47 (0.29)	3.04 (0.17)	2.96 (0.19)	0.2146	0.1563	0.7500
$FEF_{75-85\%}$ (l/s)	1.32 (0.13)	0.82 (0.08)	0.74 (0.08)	0.0017	0.0006	0.4923
$FEF_{50\%}$ (l/s)	4.22 (0.34)	3.91 (0.20)	3.64 (0.21)	0.4321	0.1658	0.3766
$FEF_{75\%}$ (l/s)	1.75 (0.18)	1.23 (0.10)	1.18 (0.11)	0.0161	0.0109	0.7266
MTT (s)	0.48 (0.05)	0.64 (0.03)	0.67 (0.03)	0.0074	0.0018	0.3912
CoVTT	1.04 (0.06)	1.29 (0.04)	1.51 (0.04)	0.0015	0.0001	0.0003
IoSTT	0.68 (0.46)	1.82 (0.27)	3.04 (0.29)	0.0381	0.0001	0.0041
MR	1.45 (0.05)	1.64 (0.03)	1.81 (0.03)	0.0024	0.0001	0.0002

* Adjusted for age, height and smoking status using analysis of covariance

( ) - standard error of adjusted means

Exposure groups :
L - Low exposure
M - Moderate expsoure
H - High exposure

DISCUSSION

A few studies have reported evidence suggestive of small airways obstruction in occupationally exposed groups. In coal worker's pneumoconiosis without evidence of large airway obstruction, frequency dependence of compliance was demonstrated suggestive of small airways obstruction.[21] Evidence of small airways abnormalities were also seen among asbestos exposed workers[22,23] as well as mineral dust exposure[24] and hard rock miners.[25] Among gold miners, those with silicosis had lower $FEF_{25-75\%}$ suggestive of small airways obstruction attributable to silica exposure.[26]

Our present study suggests that small airway obstruction is present among silica exposed workers in the absence of radiological evidence of silicosis. There was also evidence of a trend of increasing small airways obstruction in higher dust exposure group. Wiles and Faure[27] demonstrated an

exposure-effect relationship between dust exposure and $FEF_{25-75\%}$.

Smoking is known to affect both the larger and smaller airways.[28] As expected, smokers showed greater evidence of small airways obstruction even after excluding those with evidence of significant airway obstruction ($FEV_1/FVC < 0.75$). The amount of cigarettes smoked (number of sticks per day × number of years smoked) was not significantly different in the three groups. Hence the trend of small airways obstruction in smokers is suggestive of the effect of silica exposure.

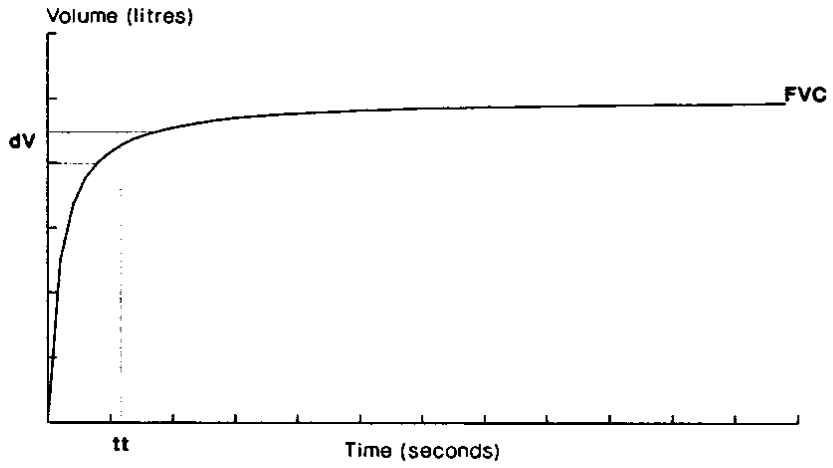
Our study also suggests that time domain indices are more sensitive to small airways obstruction. These indices give greater emphasis to the end of the forced expiratory manouvre and are hence more sensitive to events in the small airways.

The clinical and prognostic significance of early airways obstruction is still far from clear. Further studies would be required to evaluate its predictive value in identifying workers who will progress on to clinical airflow obstruction.

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APPENDIX I



$$M_1 \text{ (MTT)} = \Sigma \frac{dV \times tt}{FVC}$$

$$M_2 = \Sigma \frac{(dV \times tt)^2}{FVC}$$

$$MR = M_1/M_2$$

$$SDTT = \left[\Sigma \frac{(tt - M_1)^2 \times dV}{FVC} \right]^{1/2}$$

$$SKEWTT = \left[\Sigma \frac{(tt - M_1)^3 \times dV}{FVC} \right]^{1/3}$$

$$CoVTT = SDTT/MTT$$

$$IoSTT = SKEWTT/(SDTT)^{3/2}$$

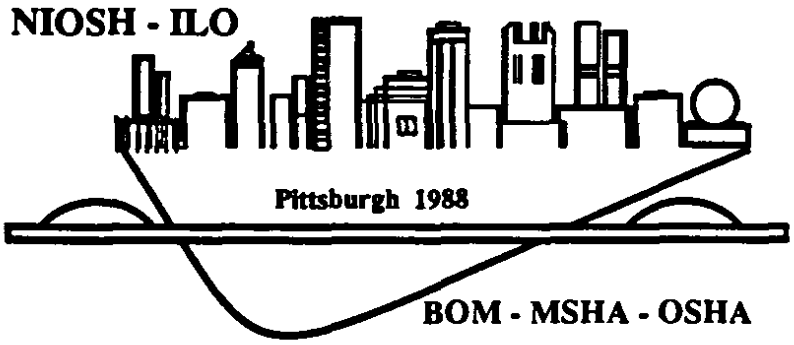
M_n : N^{th} moment about the origin

SDTT : Standard deviation of transit times

SKEWTT : Skewness of transit times

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