

Comparison of measured and predicted ventilatory volumes in selected groups of industrial workers

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ŠARIĆ M, GOMZI M, HRUSTIĆ O. Comparison of measured and predicted ventilatory volumes in selected groups of industrial workers. *Scand j work environ health* 8 (1982): suppl 1, 111—116. A follow-up study of ventilatory volumes [forced vital capacity (FVC), forced expiratory volume in 1 s (FEV_{1.0}) and maximum expiratory flow at 50 % of the FVC (MEF₅₀)] was conducted for selected groups of workers from two plants involving the electrolytic extraction of aluminum (two groups with 95 and 38 workers, respectively), a cement industry (50 workers with chronic bronchitis and 96 healthy workers) and a shipyard (38 workers) during a period of 3 or 4 a. In the workers from the aluminum plant, particularly in those who were older and exposed longer to respiratory irritants, the fall in FVC was much higher than expected. Cement workers also showed a tendency towards more decreased FVC values than expected, and the fall in MEF₅₀ was particularly pronounced. The cement workers with chronic bronchitis had a slightly higher annual fall in the ventilatory volumes than the healthy cement workers. The observed fall in the MEF₅₀ of the shipyard workers without a specific occupational exposure to dusts or respiratory irritants was unexpectedly high. An analysis of the relative values of the ventilatory volumes within the groups indicated individual differences among the exposed workers in regard to a possible chronic effect of occupational exposure to respiratory irritants. A drop in the ventilatory volumes during the follow-up period was not found to be directly dependent on the initial volume values. In the evaluation of the results, selection factors and ambient exposure to irritants were taken into account.

Key terms: cement production, chronic bronchitis, electrolytic extraction of aluminum, individual susceptibility, smoking habit.

The control of occupational exposure to various respiratory irritants involves assessing the relationship between measured and predicted values of ventilatory volumes and following the changes (decrease) per unit of time in comparison with the expected decrease in the general population of the same age. On the basis of the results of this procedure a risk of respiratory impairment can be estimated for a particular exposure. The estimation poses several problems however. It is questionable for instance how "adequate" normal values are for comparison with measured

ones. An ever present problem concerns selection — from job selection, change of job because of possible hypersensitivity, to disability due to exposure-induced respiratory impairments or to other reasons, all of which naturally affects the realistic estimation of the biological significance of exposure. Another problem is how much the established decrease in ventilatory volumes during a limited period of follow-up may be extrapolated to a longer time period. There is also a question of a correct interpretation of results with regard to smoking habit, socioeconomic factors, ambient exposure to irritants, respiratory susceptibility, and the reproducibility of applied tests.

The purpose of this paper is to illustrate some of these problems with several examples.

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Sample and method

Five groups of workers were examined. Two groups were from plants involving the electrolytic extraction of aluminum (Alu-Swiss process), with exposure to fluoride and sulfur dioxide. In the plant from which the first group (I) was chosen, the concentrations of hydrogen fluoride

and particulate fluorides, measured on several occasions, ranged from 0.3 to 3.2 mg/m³ and 0.02 to 2.4 mg/m³, respectively, while that of sulfur dioxide was between 0.8 and 4.6 mg/m³. In the second plant (group II) the measured concentrations varied between 0.2 and 2.3 mg/m³ for hydrogen fluoride, between 0.06 and 0.7 mg/m³ for particulate fluorides, and be-

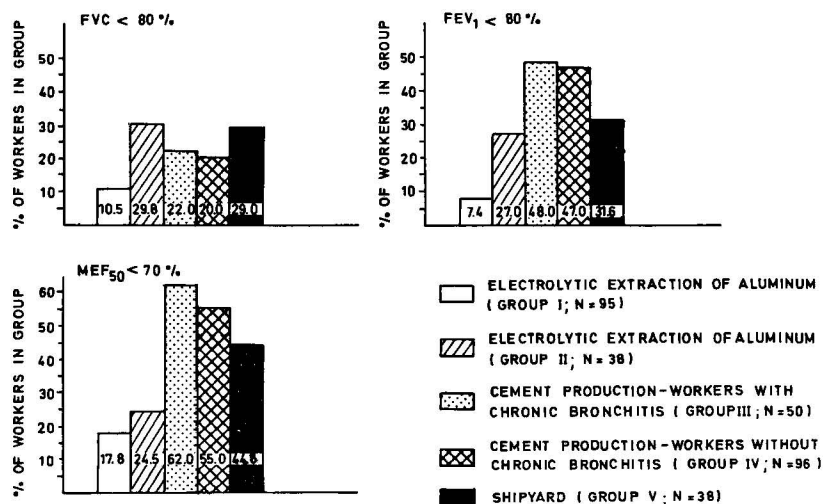


Fig 1. Percentage of workers with decreased respiratory volumes in the examined groups. (FVC = forced vital capacity, FEV_{1.0} = forced expiratory volume in 1 s, MEF₅₀ = maximum expiratory flow at 50 % of the FVC)

Table 1. General characteristics of the compared groups of workers.

Group	N	Age (a)		Height (cm)		Present smokers (%)	Past smokers (%)	Length of exposure to irritants & dusts (a)	
		Mean	SD	Mean	SD			Mean	SD
I — Electrolytic extraction of aluminum	95	30.2	8.2	175.2	7.3	40.1	12.9	1.9	0.7
II — Electrolytic extraction of aluminum	38	41.4	7.6	172.0	6.6	38.5	15.5	12.4	5.6
III — Cement production (workers with chronic bronchitis)	50	51.6	10.2	175.2	7.1	64.0	24.0	22.7	6.3
IV — Cement production (workers without chronic bronchitis)	96	48.3	9.5	173.2	7.0	36.5	27.1	20.1	6.7
V — Shipyard	38	45.6	9.4	173.2	7.1	44.7	10.6	—	—

tween 0.6 and 1.0 mg/m³ for sulfur dioxide.

Two groups (III & IV) of workers were from a portland cement factory with exposure to cement dust which varied from 55 to 228 mg/m³ for total dust and from 2 to 28 mg/m³ for the respirable fraction.

The fifth group (V) was chosen from a shipbuilding industry (storehouse and transportation workers) without specific exposure to respiratory irritants.

One of the two groups of workers from cement production (group III) was selected on the basis of the presence of respiratory symptoms (chronic bronchitis syndrome), while the absence of these symptoms was the criterion for selecting the other (group IV). The other groups were randomly selected from workers holding relevant jobs in the plants where the study was conducted.

The following ventilatory volumes were measured: forced vital capacity (FVC) forced expiratory volume in 1 s (FEV_{1.0}), and maximum expiratory flow at 50 % of the FVC (MEF₅₀). FVC and FEV_{1.0} were determined on a waterless spirometer (Pulmonor), and the MEF₅₀ curves were recorded on a digital pneumotachograph (Vertek). At least three measurements were taken. While performing a respiratory maneuver, the workers were in a standing position, and a nose clip was used. From one of two identical or similar tracings, FVC, FEV_{1.0}, and MEF₅₀ were measured. The measurements were made under field conditions. The recorded FVC and FEV_{1.0} values were compared with the predicted values by means of the nomograms developed by Morris and his co-workers (9). MEF₅₀ was calculated according to Lapp's equation (7). The volumes were followed for 3 a, except for the group of cement workers without symptoms of chronic bronchitis and the shipyard workers, for whom the follow-up lasted 4 a. During the follow-up period the measured values were compared with the initial values determined at first measurement.

Results

Data concerning the number and general characteristics of the workers under study

and their length of exposure to respiratory irritants are listed in table 1. The two groups from the aluminum plant differed in age and average length of exposure, group II being older and exposed longer. The workers in cement production were the oldest. The percentage of smokers among them was much higher for those with than those without the symptoms of chronic bronchitis.

Fig 1 shows the percentage of examined workers with decreased ventilatory volumes. Of the two groups from the aluminum plant, group II, the older men with longer exposure, had a greater percentage of values lower than 80 % of the predicted FVC and FEV_{1.0} than group I, as well as more MEF₅₀ values lower than 70 % of the predicted. In group IV, cement workers without symptoms of chronic bronchitis, there were slightly fewer workers with FVC and FEV_{1.0} values below 80 % of the expected level, and fewer workers with MEF₅₀ values lower than 70 % of the predicted level, than in the group with chronic bronchitis (group III). The shipyard workers had fewer FEV_{1.0} values below 80 % and MEF₅₀ values below 70 % of the expected level than the cement workers, but they had more FVC values below 80 % of the expected (29 %).

Table 2 shows the mean initial values and mean drop in the ventilatory volumes over a 3-a period for groups I and II, workers from the aluminum plant. The corresponding values for groups III and IV (cement workers) and group V (shipyard workers) are given in table 3. The decrease in ventilatory volumes during the period of observation was higher in group I, the older aluminum workers with a longer exposure to irritants and lower initial volumes, than in group II, the younger aluminum workers from the same type of production but with a shorter exposure and higher initial volumes. In both groups of cement workers, with (group III) and without (group IV) chronic bronchitis, a similar drop in the ventilatory volumes was noted, except that, in the group without bronchitis the decrease in FEV_{1.0} was slightly smaller. In group V (shipyard workers) the FVC was less reduced than in groups III and IV (cement workers), but the decrease in FEV_{1.0} and MEF₅₀ was almost the same.

Table 2. Initial values and annual decrease in the ventilatory volumes of groups I and II, workers from the electrolytic extraction of aluminum, group II being older and with longer exposure.

Ventilatory volume ^a	Group I			Group II		
	Initial values		Mean annual decrease (l)	Initial values		Mean annual decrease (l)
	Mean	SD		Mean	SD	
FVC (l)	4.84	0.88	0.190	4.56	0.69	0.252
FVC (%)	93.3	13.1	—	94.7	16.6	—
FEV _{1.0} (l)	3.95	0.59	0.021	3.47	0.61	0.110
FEV _{1.0} (%)	95.5	14.1	—	96.1	18.1	—
MEF ₅₀ (l/s)	4.89	1.01	0.052	4.00	1.30	0.100
MEF ₅₀ (%)	62.5	15.8	—	78.2	19.8	—

^a FVC = forced vital capacity, FEV_{1.0} = forced expiratory volume in 1 s, MEF₅₀ = maximum expiratory flow at 50 % of the FVC.

Table 3. Initial values and annual decrease in the ventilatory volumes of the cement workers with (group III) and without (group IV) chronic bronchitis and the shipyard workers (group V).

Ventilatory volume ^a	Group III			Group IV			Group V		
	Initial values		Mean annual decrease (l)	Initial values		Mean annual decrease (l)	Initial values		Mean annual decrease (l)
	Mean	SD		Mean	SD		Mean	SD	
FVC (l)	4.72	0.80	0.160	4.93	0.75	0.136	4.51	0.78	0.091
FVC (%)	98.4	15.8	—	105.1	14.7	—	94.0	12.8	—
FEV _{1.0} (l)	3.34	0.71	0.080	3.68	0.60	0.042	3.37	0.67	0.093
FEV _{1.0} (%)	91.2	16.9	—	99.7	13.6	—	91.8	15.7	—
MEF ₅₀ (l/s)	3.69	1.38	0.268	4.08	1.91	0.218	4.10	1.73	0.208
MEF ₅₀ (%)	69.2	6.0	—	75.2	38.5	—	77.7	31.2	—

^a FVC = forced vital capacity, FEV_{1.0} = forced expiratory volume in 1 s, MEF₅₀ = maximum expiratory flow at 50 % of the FVC.

Discussion

The results point to a strong tendency for workers in the electrolytic extraction of aluminum to have lower FVC values, particularly under conditions of longer exposure. In relation to reference values for the fall in FVC and FEV_{1.0} of 0.02–0.03 l/a [based on the nomogram developed by Morris et al. (9)], the mean annual decrease in FVC was, in both groups, much higher than expected. If an even more liberal criterion for the expected annual fall in FVC — up to 0.12 l/a (1, 5) is used, the observed decrease in FVC was higher than expected, particularly in the group of aluminum workers who were older and exposed longer. The drop in FEV_{1.0} and MEF₅₀ was less pronounced. The observed annual decrease in FEV_{1.0} in the group of younger aluminum workers with shorter exposure was within the expected range,

while in the group of older workers with longer exposure it was higher than expected even if the criterion of up to 0.80 l (6, 8) was applied for the expected fall per year. The MEF values were similarly lowered in both groups from this plant. However, based on Lapp's nomogram of the expected fall of 0.018–0.02 l/a (7), the annual fall observed for this volume in both groups, particularly in the group of older workers with a longer exposure, was higher than expected.

For the workers exposed to cement dust, the mean annual decrease in FVC was also higher than expected in both groups (with and without chronic bronchitis). The observed fall in FEV_{1.0} was less pronounced, ie, it was nearer the expected annual fall, whereas the annual decrease in MEF₅₀ was much higher than expected. On the whole the group of cement workers with chronic bronchitis had a slightly higher annual

fall in the volumes measured when they were compared with the group of cement workers without chronic bronchitis.

In the group of shipyard workers, who were not exposed to any specific respiratory irritants, the percentage of those with reduced volumes was unexpectedly high. In this group there were even more workers with reduced FVC than in the two cement worker groups, but those with lower FEV_{1.0} and MEF₅₀ were fewer. The mean annual fall in the ventilatory volumes of this group was also higher than expected, particularly in the case of MEF₅₀.

After a comparison of the results of our study, we come to the question of selection and, in the case of the shipyard workers, perhaps even of the influence of ambient exposure to cement dust. Namely, it may be assumed that the fluctuation of workers in cement production was higher because of a great number of those who retired for reasons of respiratory disability than was the case with shipyard workers. On the other hand environmental measurements showed that the shipyard workers from whom our group was selected, despite the absence of a specific exposure to respiratory irritants, were exposed to increased concentrations of cement dust emitted by a nearby cement works. Measurements showed values of 128—315 $\mu\text{g}/\text{m}^3$ for volatile particles and 35—144 $\mu\text{g}/\text{m}^3$ for sulfates (SO_4).

It is interesting to note that the analysis within the compared groups of workers revealed no direct dependence of ventilatory volumes on the rate of smoking.

An analysis of the relative values of the ventilatory volumes showed a rather large scatter in almost all the groups, from volumes within the expected limits or even higher to volumes considerably below the expected. This finding points to a possibility of different susceptibility to the same type of exposure, in other words, to individual differences in volume decrease under the same exposure conditions. Such individual differences were observed in the plants for the electrolytic extraction of aluminum, where 10—12% of the workers were found to be hyperreactors, ie, they showed acute bronchoconstrictive symptoms due to exposure (12, 13).

The follow-up of changes in ventilatory volumes per unit of time also raises the

question of the relationship between drop in volume and initial volume value. Although the ventilatory volumes were more reduced in the older aluminum workers with a longer exposure and lower initial values, it may not be concluded that a linear decrease will hold for a longer period of time. For example, for the studied aluminum workers who were 10 a older and whose average exposure was about five times longer, the mean FVC % and FEV_{1.0} % values were only slightly lower than for those of the younger group from the same plant, whereas the mean MEF₅₀ % of the younger group with the shorter exposure was a little more than one-fourth higher than that of the older group. It is true, however, that the percentage of workers with FVC and FEV_{1.0} values below 80 % of the predicted was about three to four times higher in the older group than in the younger one. Differences in MEF₅₀ (less than 70 % of the predicted values) between the two groups were far smaller. However, the possibility of selection must not be forgotten. A number of workers with a higher degree of ventilatory impairment may have quit doing this type of work or retired as disabled. Accordingly, the group of older workers with a longer exposure might have been partly freed from those who had developed more serious respiratory disorders.

Differences in susceptibility to exposure seem to be evident also from the relationship between the fall in volumes and their initial values. A linear drop was more noticeable for the "more sensitive workers" regardless of the initial volume values.

The problem is that very often the fall of ventilatory volumes is not followed from the very beginning, nor is it necessarily continuous, so that predictions of the course of the disease should be made with caution. Most researchers have examined the course of chronic obstructive lung disease when the disease was already in a developed phase (1, 5, 10, 11). Only a few studies have followed chronic bronchitis prospectively, from the earliest stages (3, 4). A stable FEV_{1.0}, even if it is low, is considered to be a good prognostic sign (9). Emirgil & Sabol (2) claim that the rate of deterioration in ventilatory volumes differs from person to person, but that it is relatively fixed for individuals.

There are several types of decrease in initial $FEV_{1.0}$, ie, linear, exponential and phasic. The last-mentioned usually includes three phases: (i) nearly normal and unchanged $FEV_{1.0}$, (ii) a sudden drop, and (iii) the "plateau" phase. A continuously reduced lung function is regarded to be more characteristic of emphysema, but a stepwise, possibly reversible drop as more characteristic of bronchitis. A change in function may differ from year to year, and the variability may be due to reasons other than chronic nonspecific lung disease, eg, to subclinical infections, therapy with bronchodilators, smoking, or air pollution. Deterioration of the disease in our workers during the follow-up period had mainly a continuously progressive course. A stepwise course, ie, improvement, is attributed to the reversibility of bronchitis or to different exposures.

In summary, our analysis of changes in the ventilatory volumes of five groups of industrial workers over a period of 3–4 a indicates that the type of ventilatory impairment depends partly on the type and duration of exposure. Obstructive disorders were the most prominent in cement workers, but a pronounced fall in FVC values was also noted among workers involved with the electrolytic extraction of aluminum. A comparison of the relative values of the ventilatory volumes with the expected values led us to assume that there are great individual differences among exposed workers also in regard to a possible chronic effect of occupational exposure to irritants. It was not possible to evaluate the relationship between the fall in volumes and their initial values with sufficient accuracy. The analysis showed that two factors might not have been under sufficient control and might have therefore affected the results, ie, selection and ambient exposure to irritants.

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