Environmental Health Perspectives
Vol. 11, pp. 247–250, 1975

Pulmonary Function Defects in Nonsmoking Vinyl Chloride Workers

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Pulmonary function was assessed by spirometry and maximum expiratory flow-volume curves to determine whether exposure to an occupational environment contaminated with vinyl chloride (VC) fumes and poly(vinyl chloride) (PVC) dust is associated with an increased risk of respiratory impairment. Data were analyzed for smoking, duration of exposure, and age. The high prevalence of impaired flow (57.5%) could not be attributed to smoking. Prevalence in nonsmokers was 36.4% when exposure was less than 10 yr, 42% when exposure was between 10 and 20 yr, and 80% when exposure exceeded 20 yr. The last is virtually the same rate as for smokers exposed more than 20 years. The same trend is shown with incrasing age. Unlike younger workers, when smokers and nonsmokers ≥ 40 years of age are compared, prevalence rates of air flow impairment are not statistically different. The present investigation is one of the few in which the effects of occupational exposure could be separated from and were found to predominate over the effects of smoking.

In any investigation of air flow, cigarette smoking must be considered. In most previous studies, the effects of cigarette smoking predominated over any effect attributable to atmospheric pollution or occupational exposure. As stated by Ferris and Anderson in their comprehensive survey of Berlin, New Hampshire, a city selected because its major industry is a pulp mill, "the smoking variable is so strong it overwhelms the possible effect of atmospheric pollution. Surveys of non-smokers and never-smokers may have to be undertaken to study the effect of atmospheric pollution and occupational exposure as causative factors in chronic nonspecific respiratory disease" (*1*).

Air flow was assessed by spirometry and maximum expiratory flow volume curves in 348 workers exposed to vinyl chloride fumes and poly(vinyl chloride) dust in a polymerization plant in Niagara Falls, N. Y. The effects of exposure to this occupational environment could be separated from those attributable to smoking, since significant prevalence rates of impairment were noted in nonsmoking workers, especially ≥ 40 yr of age, i.e., those with > 20 yr of exposure.

History of Nonsmoking

In all, 76 of the 348 workers tested in Niagara Falls (21.8%) had never smoked cigarettes and 78 (22.4%) had discontinued. Younger workers (≤ 29 yr) were twice as likely never to have smoked. There was no difference in prevalence of air flow impairment between current (119 of 194 or 61%) and previous (44 of 78 or 57%) smokers; both groups were considered as one category for further analysis.

Mean values for the three tests of air flow are shown in Table 1, related to age and smoking. As expected, values for smokers are lower both in the younger and older age groups, although the differences are not always significant.

Prevalence of reduced values for these three tests is shown in Table 2, related to age and

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Table 1. Mean ventilatory values related to age and smoking.[a]

Age group	$FEV_1/FVC \times 100$		MMF, % of predicted		$FEF_{25}/FVC \times 100$[b]	
	Smokers	Nonsmokers	Smokers	Nonsmokers	Smokers	Nonsmokers
≤39 yr	76.3±7.0[c] (n=139)	79.4±5.3 (n=43)	78.8±18.6[d] (n=100)	85.8±18.6 (n=32)	30.3±11.0[d] (n=66)	34.8±14.2 (n=18)
≥40 yr	71.9±9.1[e] (n=132)	73.3±7.0 (n=33)	65.6±26.4[f] (n=90)	77.6±25.9 (n=25)	21.6±10.3[g] (n=61)	23.5±10.6 (n=14)
All	74.2±8.4 (n=271)	76.6±6.8 (n=77)	72.1±26.7 (n=190)	82.2±22.3 (n=57)	25.7±11.7 (n=127)	30.4±14.4 (n=32)

[a] All values ±1 SD.
[b] All subjects tested; 65 of the 159 were tested because they had abnormal FEV_1 or MMF.
[c] Statistically significant, $p<0.01$.
[d] Not statistically significant, $p<0.2$.
[e] Not statistically significant, $p<0.5$.
[f] Statistically significant, $p<0.05$.
[g] Not statistically significant, $p<0.6$.

Table 2. Prevalence of flow impairment by three different tests related to age and smoking.

Age group	FEV_1/FVC[a]			MMF, % of predicted[a]			FEF_{25}/FVC[a, b]		
	Smokers and nonsmokers	Smokers	Nonsmokers	Smokers and nonsmokers	Smokers	Nonsmokers	Smokers and nonsmokers	Smokers	Nonsmokers
≤39 yr	61/182[c] 34%	52/139 38% ($p<0.05$)	9/43 21%	61/132 46%	53/100 53% ($p<0.01$)	8/32 25%	20/46 44%	18/36 50%	2/10 20%
≥40 yr	93/165 56%	78/132 59% ($p<0.1$)	15/33 45%	70/115 61%	56/90 62% ($p>0.5$)	14/25 56%	36/48 75%	30/40 75%	6/8 75%
All	154/347 45%	130/271 48%	24/76 32%	131/247 53%	109/190 57%	22/57 39%	56/94 60%	48/76 63%	8/18 44%

[a] Random patients.
[b] p values are not shown for FEF_{25}/FVC because of the large standard deviation.
[c] The denominator indicates the number of subjects tested in each category.

smoking. While prevalence of impairment is statistically different for smokers and nonsmokers ≤ 39 yr, smoking is not a significant factor beyond this age.

The relationship of age and smoking to prevalence of air flow impairment, an abnormality of any of the three tests being used as the criterion, is summarized in Table 3. For all subjects, 57.5% were abnormal. For those ≤ 39 yr of age, 53% of smokers and 28% of nonsmokers manifested reduced air flow. This difference is significant ($p < 0.01$). For those aged ≥ 40 yr, the prevalance of impairment in smokers (71%) is not significantly different ($p > 0.5$) from the prevalance in nonsmokers (64%). In each smoking category, the prevalence of air flow impairment is significantly higher among older workers ($p < 0.01$).

Volume impairment was noted in only 16 or 4.6% of the group. Prevalence was similar in smokers and nonsmokers.

Duration of Occupational Exposure

The mean age for the 265 current workers was 37.8 yr (range, 19–65 yr). Mean ventilatory values are shown in Table 4 and the prevalence of air flow impairment in Table 5, related to duration of exposure and smoking. On using MMF or FEF_{25}, prevalence of impairment in both smoking categories (smokers and nonsmokers) taken together increased from 48% when exposure was less than 10 yr to 56% when exposure was 10–20 yr, to 84% when

Table 3. Summary of prevalence of flow impairments related to age and smoking.[a]

Age group	Smokers and nonsmokers	Smokers		Nonsmokers
≤39 yr	85/182 (47%)	73/139 (53%) ($p<0.01$)[c]	($p<0.01$)[b]	12/43 (28%) ($p<0.01$)[c]
≥40 yr	115/166 (69%)	94/133 (71%)	($p<0.5$)[b]	21/33 (64%)
All (mean age 38.86 yr)	200/348 (57.5%)	167/272 (61%)		33/76 (43%)

[a] By any test.
[b] Comparing smokers with nonsmokers in the same age group.
[c] Comparing workers ≤39 yr of age with those ≥40 yr of age in the same smoking category.

Table 4. Mean ventilatory values in current workers related to duration of exposure and smoking.[a]

Duration of exposure, yr	$FEV_1/FVC \times 100$		MMF, % of predicted		$FEF_{25}/FVC \times 100$[b]	
	Smokers	Nonsmokers	Smokers	Nonsmokers	Smokers	Nonsmokers
<10	75.8±6.9 (n=102)	78.1±6.3 (n=41)	73.8±23.3 (n=68)	81.3±19.0 (n=30)	30.5±11.3 (n=54)	28.5±15.2 (n=20)
10–20	74.6±7.3 (n=64)	74.4±8.1 (n=13)	72.0±22.9 (n=49)	87.2±30.4 (n=10)	25.0±9.4 (n=27)	25.5±10.5 (n=4)
>20	70.3±9.6 (n=35)	74.6±4.6 (n=8)	59.9±21.4 (n=19)	78.0±34.7 (n=4)	22.6±12.3 (n=21)	22.8± 6.9 (n=5)

[a] All values ±1 SD.
[b] All subjects tested, see Table 1.

Table 5. Prevalence of flow impairment in current workers related to duration of exposure and smoking.

	Smoking category	Duration of exposure		
		<10 yr	10–20 yr	>20 yr
Mean age, yr	Smokers	32.1±9.4	42.1±7.4	51.9±7.4
	Nonsmokers	29.6±9.4	42.9±10.1	50.6±7.2
	All subjects	31.4 (range 19–58)	42.2 (range 31–61)	51.7 (range 39–65)
Decrease in MMF or FEF_{25}/FVC	Smokers	56/103 (54%)	37/64 (58%)	30/35 (86%)
	Nonsmokers	13/42 (31%)	6/13 (46%)	6/8 (75%)
	All subjects	69/145 (48%)	43/77 (56%)	36/43 (84%)
Decrease in FEV_1/FVC	Smokers	45/103 (44%)	28/64 (44%)	24/35 (69%)
	Nonsmokers	10/32 (31%)	4/13 (31%)	4/8 (50%)
	All subjects	55/145 (38%)	32/77 (42%)	28/43 (65%)

exposure exceeded 20 yr. This increase in prevalence with progressive duration of exposure was true for both the smokers and the nonsmokers. The difference in prevalence between smokers and nonsmokers narrowed from 23% ($p < 0.02$) when exposure was less than 10 yr to 11% ($p < 0.5$) when exposure exceeded 10 yr. Any difference between smokers and nonsmokers cannot be attributed to age, since there is no significant difference in age at any duration of exposure.

For a more conventional measurement of air flow, FEV_1/FVC, the frequency of impairment (≤ 74%) among all workers was also high, although 10% lower than for the MMF or FEF_{25}. An increase in prevalence for both smokers and nonsmokers is noted when their exposures exceed 20 yr.

In summary, the present investigation demonstrated a high prevalence of air flow impairment in VC–PVC workers which cannot be attributed to smoking. Prevalence in nonsmokers (past and current workers) was 36.4% when occupational exposure to VC–PVC was less than 10 yr, 42% when exposure was between 10 and 20 yr, and 80% when exposure exceeded 20 yr. The last is virtually the same rate as for smokers exposed more than 20 yr

(Table 5). The same trend is shown with increasing age. Unlike younger workers, when smokers and nonsmokers ≥ 40 years of age are compared, prevalence rates of air flow impairment are not statistically different (Tables 2 and 3).

Discussion

These rates of air flow impairment are higher than the rates in the literature for most other occupational groups. In a control population of farm and marble workers in Spain, 12% had abnormal FEV_1 (15.6% of those ≥ 40 yr of age) (*2*), compared to 45 and 56% of the VC–PVC workers, respectively. In a different control group, prisoners and guards (mean age about 43 yr), 7.4% demonstrated a decreased $FEV_{0.75}$ (*3*), while 10% of men in rural Denmark, where cigarette smoking is relatively uncommon, had an $FEV_{0.75}$ less than 2 liters (*4*).

The survey of Chilliwack, a small Canadian town with low levels of air pollution, showed that 12.6% of the men had severe obstructive lung disease. About 70% of these had an $FEV_1/FVC \leq 60\%$ for a prevalence of severe impairment of about 9% (*5*). The most recent survey, of English civil servants ≥ 40 yr of age, revealed 26.4% to have an $FEV_1/FVC < 75\%$ (*6*). While this figure is higher than the others cited, it is considerably lower than the 56% for VC–PVC workers of comparable age (Table 2). In an investigation of male bank employees ≥ 40 yr of age, Bower noted that 19% had a diminished MMF (*7*), compared to 61% of VC–PVC workers of the same age.

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