CLINICAL INVESTIGATIONS

Transient Hypoxemia in Firemen Following Inhalation of Smoke*

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Mild to moderately severe hypoxemia was documented in 19 of 21 mostly asymptomatic firemen who were exposed to dense smoke containing polyvinylchloride and other pulmonary irritants. The hypoxemia was transient, with nearly complete reversibility within 24 hours. Subsequent tests for pulmonary function one month later demonstrated that this transient hypoxemia was not related to previous underlying pulmonary disease. The potential for serious complications of inhalation of smoke, particularly smoke from burning plastics, is heightened by the frequent lack of symptoms associated with this type of exposure, despite the development of moderately severe hypoxemia in addition to carboxyhemoglobinemia. Precautionary measures should include uninterrupted use of an effective breathing apparatus by firemen exposed to smoke and to noxious fumes and temporary oxygen supplementation, even in asymptomatic firemen, following exposure to dense smoke.

Inhalation of smoke is known to cause a broad spectrum of adverse respiratory effects, from mild irritation of the upper airways to severe tracheobronchitis, bronchospasm, pulmonary edema, and bronchopneumonia, often resulting in pulmonary insufficiency and death.[1] The duration of the exposure to the smoke and the occurrence of the exposure in a confined space are two of the factors that help determine the severity of the pulmonary consequences of inhalation of smoke.[2] Additional factors are the nature and quantity of the products of combustion of the materials consumed in the fire and the degree to which these products are inhaled along with the smoke.[3] These latter factors have assumed particular significance in recent years, with the increased use of synthetic plastic materials in the construction of buildings. The particular hazard of the toxicity of polyvinylchloride in fires has recently been discussed.[4]

For editorial comment, see page 438

The present report documents the appearance of moderately severe hypoxemia in firemen after exposure to smoke from fire in an office building, in which large quantities of polyvinylchloride materials were burned.

On Nov 12, 1974, a fire broke out on the eighth floor of a high-rise office building in the Century City area of Los Angeles. The fire was extensive and extremely smokey, requiring several hours to extinguish. After the fire had been brought under control, two firemen who initially had experienced a moderately severe burning sensation in the throat and upper portion of the chest were brought to the emergency room at the University of California, Los Angeles. On arrival at the emergency room, one of the firemen was no longer symptomatic, and the other complained only of a mild sensation of burning in the throat. Findings from physical examinations were normal, and chest x-ray films in the posteroanterior and lateral projections were within normal limits; however, since arterial blood gas levels determined in these two firemen revealed hypoxemia and hyperventilation (arterial oxygen pressure [PaO_2], 68 to 72 mm Hg; and arterial carbon dioxide pressure [$PaCO_2$], 25 to 29 mm Hg), they were hospitalized for further observation.

Because of the finding of hypoxemia in these two patients, despite a relative paucity of symptoms, the Fire Department was notified, and most of the firemen who had been engaged in the front line of the fire were requested to report to the emergency

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room at the University of California, Los Angeles, for evaluation for possible adverse pulmonary effects of exposure to some noxious combustion products involved in the fire.

Materials and Methods

Over the next ten hours a total of 19 additional firemen were seen in the emergency room. These subjects were all asymptomatic at the time of their evaluation, and none of these firemen complained of any unusual symptoms during their involvement in the fire. Routine physical examinations and chest x-ray films in the posteroanterior and lateral projections were performed in all subjects, and the findings were all normal. Approximately 4 ml of arterial blood were withdrawn following percutaneous puncture of the radial artery for determination of pH, $PaCO_2$, and PaO_2 using standard electrodes (acid-base digital analyzer, Radiometer model PHM 72). In addition, venous blood was collected anaerobically for determinations of levels of carboxyhemoglobin in three subjects, using a spectrophotometric technique.

Approximately one month later, all 21 firemen who were initially studied returned for further evaluation of their respiratory status, including administration of a respiratory questionnaire[4] and detailed studies of pulmonary function.

Results

The initial arterial blood gas values of the 21 firemen evaluated are indicated in Table 1. The values for PaO_2 in 14 subjects were less than or equal to 76 mm Hg and were more than two standard deviations below the predicted value (based on the data of Sorbini et al[5]), despite the presence of hyperventilation ($PaCO_2$, 25 to 36 mm Hg), which should have increased the alveolar oxygen pressure (P_AO_2) and consequently the PaO_2. These subjects were admitted to the hospital for further observation and received supplemental therapy with oxygen for approximately two hours. Although the other seven firemen had higher values for PaO_2 ($\geq$ 79 mm Hg), these patients were also hyperventilating ($PaCO_2$, 24 to 37 mm Hg), with the result that the alveolar-arterial oxygen pressure difference ($P[A\text{-}a]O_2$) estimated by assuming a respiratory quotient of 0.8 was abnormally widened in six of these subjects. These subjects were not hospitalized.

By the following morning the two firemen who

Table 1 — *Arterial Blood Gas Levels in 21 Firemen following Exposure to Dense Smoke*

Group and Fireman	Age, yr	Within 2-10 hr of Exposure			Predicted PaO_2, mm Hg*	Approximately 20 hr after Exposure		
		pH	$PaCO_2$, mm Hg	PaO_2, mm Hg		pH	$PaCO_2$, mm Hg	PaO_2, mm Hg
Hospitalized								
1**†	53	7.47	26	68	81.2	7.40	35	77
2	40	7.44	39	62	86.7	7.44	40	84
3	52	7.46	29	54	81.7	7.40	36	84
4	44	7.40	34	60	85.0	7.44	32	93
5‡	59	7.40	36	60	78.7	7.42	38	87
6	48	7.43	33	76	83.3	...	...	...
7	36	7.45	28	66	88.4	7.45	34	90
8**§	30	7.41	29	73	90.9	7.39	34	104
9	34	7.42	33	58	89.2	7.44	34	86
10	26	7.45	33	68	92.6	7.44	34	89
11	57	7.42	36	51	79.6	7.44	36	91
12	44	7.46	31	73	85.0	7.41	34	92
13	59	7.41	26	67	78.7	7.43	36	81
14	40	7.42	32	62	86.7	7.42	38	85
Group mean ± SD	44 ± 11	7.43 ± 0.02	32 ± 4	64 ± 7	84.8 ± 4.5	7.42 ± 0.02	35 ± 2	88 ± 7
Not hospitalized								
15	24	7.47	33	81	93.4	7.43	27	105
16	43	7.47	25	83	85.4	7.43	32	100
17	27	7.44	24	82	92.2	7.39	40	85
18	37	7.47	34	82	87.9	7.42	33	96
19	29	7.43	37	79	91.3	...	...	...
20	27	7.46	34	102	92.2	7.46	28	108
21	27	7.50	30	91	92.2	7.43	35	90
Group mean ± SD	31 ± 7	7.46 ± 0.02	31 ± 5	86 ± 8	90.7 ± 2.9	7.42 ± 0.02	32 ± 2	97 ± 9
Total mean ± SD	40 ± 12	7.44 ± 0.03	31 ± 4	71 ± 13	86.8 ± 4.9	7.42 ± 0.02	34 ± 3	91 ± 8

*Predicted according to Sorbini et al[5]: PaO_2 = 103.5 − 0.42 × age (yr) ± 3.75 mm Hg (SD); $PaCO_2$ = 40 mm Hg.
**Initially symptomatic firemen.
†Carboxyhemoglobin, 15 percent saturated.
‡Carboxyhemoglobin, 6 percent saturated.
§Carboxyhemoglobin, 5 percent saturated.

had initially been symptomatic recovered completely, and the other hospitalized firemen remained asymptomatic. Repeated studies of arterial blood gas levels performed less than 24 hours after the original measurements showed improvement in PaO_2 in all of the 13 hospitalized subjects in whom repeated measurements were made. In addition, the estimated $P(A\text{-}a)O_2$ improved in all five of the firemen with an initially abnormal value who were not hospitalized but returned to the emergency room for repeated studies of blood gas levels (Table 1). The average individual improvement in PaO_2 in those patients who originally had significant hypoxemia was 24.7 mm Hg, and since the values from repeated determinations of $PaCO_2$ had returned to or toward normal in most of the subjects, the mean decrease in the estimated $P(A\text{-}a)O_2$ was probably even greater. Although the values from repeated determinations of arterial PaO_2 were within the predicted normal limits for age in all subjects in whom repeated measurements were made, in three of the hospitalized patients (patients 1, 9, and 10), the estimated $P(A\text{-}a)O_2$ was still slightly abnormally widened. All subjects were released within 24 hours of hospitalization.

One month later, all 21 firemen were asked to complete a detailed respiratory questionnaire and underwent a repeat physical examination and a battery of pulmonary function studies. The results of these studies, which will be reported separately, showed no apparent relationship between a history of cigarette smoking, the presence of chronic respiratory symptoms, or abnormalities of pulmonary function and the degree of hypoxemia that developed following the episode of inhalation of smoke.

Because of the possibility that the transient hypoxemia observed in these firemen was related to inhalation of noxious chemicals released during the combustion of materials burned in the fire, the chemistry laboratory of the Los Angeles Fire Department collected representative uncombusted samples of the same materials as those consumed in the fire and analyzed the products released during the burning of these samples. Representative materials found at the scene of the fire are listed in Table 2, along with the major toxic chemical products of combustion. It is of note that several of the latter are well-known pulmonary irritants.

Table 2 — *Data on Toxic Products of Combustion*

Material	Use	Major Toxic Chemical Products of Combustion*
Polyvinyl-chloride	Wall and floor covering; telephone cable insulation	Hydrogen chloride (P); phosgene (P); carbon monoxide
Polyurethane	Upholstery	Isocyanates (P) (toluene 2,4-diisocyanate); hydrogen cyanide
Lacquered wood veneer; wallpaper	Wall covering	Acetaldehyde (P); formaldehyde (P); oxides of nitrogen (P); acetic acid
Acrylic	Light diffusers	Acrolein (P)
Nylon	Carpet	Hydrogen cyanide; ammonia (P)
Acrilan	Carpet	Hydrogen cyanide; acrolein (P)
Polystyrene	Miscellaneous	Styrene; carbon monoxide

*P, Pulmonary irritant.

Discussion

Because of the finding of mild to moderately severe hypoxemia in nearly all of the firemen who were in the front line of the high-rise fire in the Century City area on Nov 12, 1974, it was obvious that definite respiratory irritation had occurred, despite the general lack of respiratory symptoms. Therefore, an effort was made to discover the source of the pulmonary irritants. Plastic material containing polyvinylchloride was present in relatively large quantities as floor coverings (tiles), wall coverage (0.021 inch), and telephone cable (0.031 inch) in the burned out section of the office building (Table 2). One of the hazards of fires occurring in buildings containing materials made of polyvinylchloride is the production of a high-density smoke which may be 4 to 14 times more dense than that which develops in fires involving common constructional timber under similar conditions.[7] Vinyl-based coverings can release relatively high concentrations of hydrogen chloride gas when combusted. Each kilogram of polyvinylchloride can produce, upon complete combustion, about 0.4 kg of hydrogen chloride gas.[7] The polyvinylchloride plastic starts to evolve hydrogen chloride gas at relatively low temperatures (200°C to 300°C). Since the fire properties of surface coverings are known to be substrate-dependent, the generation of smoke and production of noxious gases, as well as the surface flammability, will depend on the material with which the polyvinylchloride or other substances are in contact.[8] Polyvinylchloride also produces moderate amounts of phosgene and high concentrations of carbon monoxide.[4,9]

In addition to polyvinylchloride, the fire properties of which have been the most intensively studied, other plastics and synthetic materials, including acrylics, Acrilan, and nylons, were involved in the present fire (Table 2). On overheating, these substances can decompose and emit acrolein, ammonia,

and oxides of nitrogen, all of which are capable of causing pulmonary injury,[9,10] especially under conditions of poor ventilation, when the local concentrations of these irritating substances are increased.

Although the firemen all used a self-contained breathing apparatus while fighting the fire in the Century City area, some admitted that they removed the breathing masks for short periods of time when they visually estimated that the smoke conditions were not hazardous. The fact that these firemen nearly all exhibited hypoxemia and hyperventilation two to ten hours after exposure to the fire is of particular interest, since all but one of the firemen were essentially asymptomatic, and all had normal chest x-ray films and normal findings on physical examinations. The short-term changes in blood gas levels undoubtedly represented subclinical respiratory irritation, most likely from noxious chemicals inhaled at the scene of the fire, resulting in abnormalities in gas exchange and stimulation of airway or pulmonary receptors, or both, with increased alveolar ventilation. Less than 24 hours later, oxygenation had improved in all subjects, although residual mild widening of the $P(A\text{-}a)O_2$ in three subjects may have reflected either underlying chronic obstructive pulmonary disease (two of the three subjects were regular smokers and were the only firemen who complained of chronic cough) or the residual effects of respiratory irritation, or both.

Although studies have not been performed in large numbers of firemen to determine the presence and extent of arterial hypoxemia after exposure to smoke from an ordinary fire, we have demonstrated that significant hypoxemia does occur in asymptomatic firemen without underlying respiratory disease or pulmonary functional impairment after exposure to smoke containing pulmonary irritants produced by the combustion of plastics and other synthetic materials. Although the hypoxemia which developed was often moderately severe, it was fortunately short-lived; however, a longer duration or a greater intensity of exposure to the same irritants, or both, might have resulted in less readily reversible pulmonary changes. Moreover, the concomitant occurrence of carboxyhemoglobinemia secondary to the inhalation of carbon monoxide would be expected to magnify the impairment in oxygen transport resulting from hypoxemia, thereby increasing the risk of development of acute cardiac or cerebral complications of curtailed delivery of oxygen to the tissues. A significantly higher resting level of carboxyhemoglobin has been found in Oklahoma City firemen, even during fire-free intervals, compared with a matched group of nonfiremen.[11] That these findings probably have clinical significance is suggested by the demonstration of a high incidence of ischemic response to a standard near-maximal exercise test in Los Angeles firemen, when compared to a comparable group of nonfiremen.[12] Consequently, preventive measures, such as the uninterrupted use of an effective breathing apparatus should be scrupulously observed by firemen exposed to smoke and noxious fumes, particularly from burning polyvinylchloride and other plastics, and temporary oxygen supplementation should be considered as a precautionary therapeutic measure in even asymptomatic firemen following any intense exposure to smoke. Additional studies, including measurements of arterial blood gas levels and carboxyhemoglobin determinations, are required to ascertain the short-term pulmonary effects of exposure to the products of combustion of different types of materials used in the construction of buildings.

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Respiratory Status of Los Angeles Firemen*

One-Month Follow-Up after Inhalation of Dense Smoke

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A standardized respiratory questionnaire and detailed pulmonary function tests were administered to 21 Los Angeles firemen one month following exposure to the combustion products of polyvinylchloride, which had produced transient hypoxemia in 19 of the firemen. The results of these studies were compared with those obtained in a sample of nonfiremen residing in the Los Angeles area who were matched by computer with the firemen for anthropomorphic characteristics and smoking status. The frequency of respiratory symptoms, the results of spirometric and plethysmographic studies, and the single-breath nitrogen washout were similar in the firemen, compared with the matched sample, whereas closing volume was higher in the matched controls. These findings suggest that although fighting fires may result in acute pulmonary injury secondary to discrete episodes of inhalation of smoke, it does not appear to predispose to the development of chronic respiratory symptoms or chronic functional respiratory impairment.

Recent publications have suggested an increased prevalence of chronic nonspecific respiratory disease in Boston firemen[1] who also developed a greater decrement in measurements of pulmonary function when compared with a similar group of

For editorial comment, see page 438

men matched for age, smoking habits, and ethnic background.[2] Analysis of data on pulmonary function in Boston firemen also revealed a slightly lower ventilatory capacity in nonsmokers in all age categories, compared with age-adjusted predicted values for healthy nonfiremen, although these differences were not statistically significant.[3] From these findings, the authors[1-3] concluded that the occupation of fighting fires constitutes a significant risk factor for the development of chronic pulmonary disease and pulmonary functional impairment, although more recent data obtained in a subgroup of the same cohort of firemen suggests that factors of selection may have confounded the earlier findings.[4]

An earlier study of 4,379 Los Angeles firemen indicates that they experience, on the whole, substantially lower age-adjusted death rates than their peer group selected either nationwide or from Los Angeles (observed deaths/expected deaths × 100 = 55 and 69, respectively).[5] A decrement in general health should be reflected to some extent in higher mortality. A substantially lower mortality in Los Angeles firemen is, therefore, at variance with the suggestion of a higher prevalence of chronic nonspecific respiratory disease and impaired pulmonary function due to exposure to fighting fires.

We recently studied 21 Los Angeles firemen, 19 of whom developed transient acute hypoxemia following exposure to a fire in a high-rise office building, in which large amounts of polyvinylchloride were combusted.[6] These same firemen were reevaluated one month following the fire to ascertain any possible effects on pulmonary function as a result of this episode of inhalation of smoke. In the light of previous studies suggesting impairment in pulmonary function as a consequence of fighting fires,[1-3] we were surprised to find that our group of Los Angeles firemen had relatively few respiratory symptoms, as well as remarkably normal pulmonary function, compared with published predicted values. Therefore, we matched these firemen by computer with nonfiremen residing in the Los Angeles area to ascertain whether or not differences could be detected in respiratory symptoms and pulmonary function, controlling for variables other than fighting fires, including age, sex, race, cigarette smoking, and geographic and climatic differences. We now report our findings.

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Responses to the questionnaire and the absolute values for pulmonary function obtained in each of these 21 firemen were also compared with those recently obtained in individuals residing in the Los Angeles basin who were administered the same interview and tests of pulmonary function in a mobile laboratory as part of a population study on chronic obstructive respiratory disease.[18] These individuals were matched by computer program as closely as possible to the firemen for age, sex, and tobacco-smoking history; individuals with a history of hazardous occupational exposure were excluded.

The validity of this comparison is supported by studies of validation previously performed in our laboratory, which showed good agreement ($r = 0.82$ to 0.91) between spirometric values obtained by a mobile field laboratory in the population from which the matched sample was drawn and those obtained by our laboratory in a 1 percent probability sample of randomly selected individuals from the same population.[18] Values obtained in the matched sample were adjusted for the slight differences observed between the field and validation laboratories using appropriate regression equations.[18] Differences between the results from studies of pulmonary function in the firemen and their matched controls were tested for statistical significance using Student's *t*-test for paired data; mean differences were considered significant for probability values less than 0.05.

Results

Physical examination of the 21 firemen showed no abnormalities with respect to the heart and lungs. The smoking history and the respiratory symptoms of both the firemen and the matched sample of nonfiremen are indicated in Table 1. Seven firemen were currently regular cigarette smokers, three were occasional smokers (less than one cigarette per day per year), six were former smokers (had discontinued smoking for at least the previous year), and five were nonsmokers. Only two of the 21 firemen in this report complained of cough on most days for three months per year for two or more years, and only one of these subjects had associated production of sputum. One additional patient raised phlegm more than three months out of the year for more than two years but did not admit to cough. Only one fireman complained of definite wheezing (on more than 19 days per year) unassociated with dyspnea, and no fireman reported shortness of breath on exertion. Of the matched group of nonfiremen, two gave a significant history of cough, and both of these individuals had associated phlegm. One of the matched controls had wheezing without shortness of breath, and two others complained of exertional dyspnea.

The results of studies of pulmonary function in the 21 firemen and their matched controls are shown

Table 2—*Data on Pulmonary Function*

Fireman and Match	Fireman/Matched Control: Percent of Predicted Value* FVC	FEV1	FEV1/FVC	FEF25-75%	Gaw/VL, L/sec/cm H2O/L	Raw, cm H2O/L/sec	Thoracic Gas Volume, L	Dsb, percent of predicted**	Single-Breath Nitrogen Washout, percent	CV/VC% Observed	CV/VC% Predicted
1	86/95	84/92	117/105	108/64	0.18/0.07	1.70/2.94	3.28/5.05	83	0.2/1.5	36/14	19
2	119/125	100/123	90/106	68/124	0.28/0.20	1.26/1.32	2.85/3.82	90	0.2/0.1	0/22	15
3	97/118	99/118	115/109	120/99	0.22/0.20	1.85/1.55	2.56/3.27	100	0.1/0.2	0/16	19
4	101/110	92/124	96/122	75/142	0.20/0.21	1.47/1.97	3.25/2.45	86	0.1/0.1	12/16	16
5	126/120	125/112	106/100	132/65	0.27/0.30	1.03/0.93	3.66/3.61	105	0.6/1.5	23/14	22
6	109/101	103/101	100/108	95/94	0.19/0.13	1.53/2.68	3.44/2.82	86	0.2/0.5	19/8	18
7	113/117	119/109	111/101	139/151	0.19/0.30	1.61/1.58	3.31/2.12	108	0.1/0.1	0/13	13
8	121/136	116/136	98/107	91/135	0.25/0.21	1.54/1.90	2.64/2.57	106	0.1/1.0	0/44	11
9	101/81	89/76	93/100	60/138	0.08/0.32	3.85/0.90	3.28/3.53	94	1.0/2.0	0/9	13
10	97/110	106/103	113/102	122/78	0.21/0.13	1.52/2.34	3.13/3.38	110	0.1/0.1	0/17	10
11	100/113	76/97	83/93	44/64	0.17/0.24	1.71/1.03	3.53/4.08	89	1.0/1.0	0/38	21
12	94/95	96/93	111/106	106/99	0.28/0.28	1.41/1.08	2.72/3.34	100	1.0/0.1	19/6	16
13	117/102	107/83	104/86	74/35	0.15/0.20	2.57/1.96	2.61/2.56	130	0.1/0.1	0/28	22
14	117/113	103/108	93/104	75/46	0.20/0.24	1.76/0.89	3.00/4.76	100	0.1/0.1	0/1	15
15	122/101	112/117	94/125	87/138	0.15/0.20	2.22/1.82	2.98/2.76	103	0.1/1.5	0/18	9
16	123/117	114/120	100/111	107/142	0.21/0.26	1.62/1.13	2.99/3.39	140	0.2/0.5	8/14	16
17	122/115	112/109	95/103	93/82	0.27/0.09	0.90/2.90	4.09/3.83	124	0.1/0.1	0/11	10
18	127/115	98/108	81/102	56/88	0.09/0.29	3.00/0.95	3.87/3.65	109	0.2/1.5	0/14	14
19	104/109	96/111	96/109	87/106	0.28/0.23	1.27/1.30	2.78/3.32	100	0.1/0.2	0/7	11
20	120/117	105/103	94/110	92/117	0.21/0.26	1.28/1.13	3.86/3.37	95	0.1/0.1	0/12	10
21	92/102	91/108	101/114	103/121	0.25/0.31	1.20/1.74	3.39/1.86	118	0.1/0.1	20/4	10
Mean	110/110	102/107	100/106	92/101	0.21/0.22	1.73/1.62	3.19/3.31	104	0.3/0.6	7/16	15
SD	12/12	12/14	10/9	25/34	0.06/0.07	0.69/0.66	0.43/0.79	15	0.3/0.6	11/10	4

*Predicted values for FVC, FEV_1, and FEF25-75% are based on regression equations of Morris et al;[19] and predicted values for FEV_1/FVC, Dsb, and CV/VC are based on regression equations of Berglund et al,[20] of Kory et al,[14] of Hammer and Meade as reported by Cotes,[18] and of Buist and Ross,[17] respectively.

**Values of Dsb were not obtained in matched sample.

Materials and Methods

Twenty-one firemen who had developed transient hypoxemia following exposure to fire in an office building in Los Angeles were studied approximately one month after the fire. Studies consisted of administration of a detailed respiratory questionnaire modified from the Medical Research Council of Great Britain's questionnaire on respiratory symptoms,[7] physical examination, and studies of pulmonary function. The latter consisted of the following: spirometric studies using a 13.5-L water-sealed spirometer (Warren E. Collins, Inc.), with calculation of forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and mean forced expiratory flow during the middle half of the FVC (FEF25-75%); determinations of airway resistance (Raw) and thoracic gas volume using a 600-L constant-volume whole-body plethysmograph (Warren E. Collins, Inc.),[8,9] with calculation of specific airway conductance ($Gaw/V_L = 1/Raw/thoracic\ gas\ volume$); measurements of single-breath nitrogen washout between 750 and 1,250 ml of the FVC and closing volume (CV), using a method modified from that of Anthonisen et al;[10] and single-breath diffusing capacity for carbon monoxide (Dsb).[11] Spirometric studies were performed using five trials with the subject standing with nose clips in place. The breath used for analysis was that associated with the greatest FEV_1 if the FVC was within 10 percent of the greatest FVC. Maneuvers for determining CV were performed in triplicate, and the values obtained from satisfactory tracings (expiratory vital capacity [VC] within 5 percent of the inspiratory VC and expiratory flow rates less than 0.5 L/sec) were averaged. Plethysmographic measurements were performed in quintuplicate, and the results were averaged.

Spirometric indices, CV, and Dsb were expressed as a percent of published predicted values.[12-16] Spirometric indices and Dsb were considered normal if greater than 80 percent of the predicted value, except for FEF25-75%, which was considered normal if greater than 70 percent of the predicted value. The lower limit of normal for Gaw/V_L was considered to be 0.15 L/sec/cm H_2O/L, based on data previously obtained in our laboratory. The upper limit of normal for the single-breath nitrogen washout was considered to be 1.8. The CV was considered normal if it did not exceed two standard deviations above the predicted value of Buist and Ross[17] for nonsmoking men.

Table 1 — *Historical Data in 21 Firemen and Their Matched Controls**

Fireman	Years as Fireman	Occupation of Matched Control	Fireman/Matched Control: Age, yr	Height, cm	Smoking History*	Cough	Phlegm	Wheezing >10 days per year	Shortness of Breath
1	26	Technician	53/53	175/175	Current	+/0	+/0	0/0	0/+
2	14	Technician	40/43	178/180	Occasional	0/0	0/0	0/0	0/0
3	28	Technician	52/49	178/178	Former	0/0	0/0	0/0	0/0
4	17	Skilled laborer	44/41	190/185	Former	0/0	0/0	0/0	0/0
5	28	Machine operator	59/58	179/180	Former	0/0	0/0	0/0	0/0
6	25	Skilled laborer	48/48	189/188	Current	0/+	0/+	0/0	0/0
7	5	Skilled laborer	36/37	175/173	Never	0/0	0/0	0/0	0/0
8	5	Skilled laborer	30/28	175/175	Current	0/+	0/+	0/+	0/0
9	13	Technician	34/34	180/180	Current	+/0	0/0	0/0	0/0
10	3	Lesser professional	26/22	188/188	Never	0/0	0/0	0/0	0/0
11	28	Administrative personnel	57/53	190/180	Occasional	0/0	0/0	0/0	0/0
12	12	Farmer	44/44	168/170	Current	0/0	0/0	0/0	0/0
13	33	Major professional	59/59	173/173	Former	0/0	+/0	0/0	0/+
14	11	Skilled laborer	40/40	189/188	Former	0/0	0/0	0/0	0/0
15	2	Skilled laborer	24/24	175/173	Occasional	0/0	0/0	0/0	0/0
16	18	Skilled laborer	43/41	182/178	Former	0/0	0/0	0/0	0/0
17	3	Administrative personnel	27/29	182/180	Never	0/0	0/0	0/0	0/0
18	12	Clerical/sales	37/36	172/173	Current	0/0	0/0	+/0	0/0
19	5	Machine operator	29/28	183/185	Never	0/0	0/0	0/0	0/0
20	4	Semiprofessional	27/25	180/180	Never	0/0	0/0	0/0	0/0
21	6	...	27/30	187/191	Current	0/0	0/0	0/0	0/0
Mean	14	...	40/39	180/180	...	...	...	...	...
SD	10	...	12/11	7/6	...	...	...	...	...

*See text for explanation of smoking history. Smoking history was same for each fireman and his matched control.