# The Incidence, Prevalence, and Severity of Sarcoidosis in New York City Firefighters

David J. Prezant, Atheya Dhala, Andrew Goldstein, Denise Janus, Felipe Ortiz, Thomas K. Aldrich and Kelly J. Kelly

*Chest* 1999;116;1183-1193
DOI 10.1378/chest.116.5.1183

# The Incidence, Prevalence, and Severity of Sarcoidosis in New York City Firefighters*

*David J. Prezant, MD, FCCP; Atheya Dhala, MD; Andrew Goldstein, MD, FCCP; Denise Janus, MD; Felipe Ortiz, MD; Thomas K. Aldrich, MD, FCCP; and Kelly J. Kelly, MD*

***Objective:*** **The etiology of sarcoidosis is unknown, but epidemiology suggests that environmental agents are a factor. Because firefighters are exposed to numerous toxins, we questioned whether sarcoidosis was increased in this cohort.**

***Setting:*** **The New York City Fire Department (FDNY), employing > 11,000 firefighters and nearly 3,000 emergency medical services (EMS) health-care workers (HCWs).**

***Design:*** **In 1985, FDNY initiated a surveillance program to determine the incidence, prevalence, and severity of biopsy-proven sarcoidosis in firefighters. In 1995, EMS HCWs were added as control subjects.**

***Results:*** **Between 1985 and 1998, 4 prior cases and 21 new cases of sarcoidosis were found in FDNY firefighters. Annual incidence proportions ranged from 0 to 43.6/100,000, and averaged 12.9/100,000. On July 1, 1998, the point prevalence was 222/100,000. For EMS HCWs, annual incidence proportions were zero. Radiographic stage 0 or stage 1 sarcoidosis was found in 19 firefighters (76%), and stage 3 was found in 1 firefighter (4%). Pulmonary function (FVC, $FEV_1$, and diffusing capacity for carbon monoxide) was normal in 17 firefighters (68%), and reduced to ≤ 65% predicted in 2 firefighters (8%). Maximum oxygen consumption ($M\dot{V}O_2$) was normal in 10 of 17 firefighters (59%), and reduced to 65% predicted in 3 firefighters (12%). Five of seven firefighters (71%) with abnormal $M\dot{V}O_2$ had gas exchange abnormalities, and none had $O_2$ desaturation. All returned to fire fighting.**

***Conclusions:*** **Annual incidence proportions and point prevalence were increased in FDNY firefighters as compared to EMS HCWs and historical controls. Radiographs and physiologic measurements demonstrated only minimal impairment.** ***(CHEST 1999; 116:1183–1193)***

**Key words:** exercise testing; firefighters; pulmonary function; sarcoidosis

**Abbreviations:** DLCO = diffusing capacity for carbon monoxide; EMS = emergency medical services; FDNY = NYC Fire Department; FRC = functional residual capacity; HCW = health-care worker; HMO = health maintenance organization; HR = heart rate; $M\dot{V}O_2$ = maximum $\dot{V}O_2$; NYC = New York City; $PETCO_2$ = end-tidal $PCO_2$; PFT = pulmonary function test; RER = respiratory exchange ratio; VC = vital capacity; $\dot{V}CO_2$ = carbon dioxide production; VD/VT = estimated dead space to VT ratio; $\dot{V}E/\dot{V}CO_2$ = ventilatory equivalent for carbon dioxide; $\dot{V}E/\dot{V}O_2$ = ventilatory equivalent for oxygen; $\dot{V}O_2$ = oxygen consumption; VT = tidal volume; VT/VC = ventilatory pattern

Sarcoidosis is a multisystem, noncaseating, granulomatous disorder that typically presents with bilateral hilar adenopathy and pulmonary infiltration. The incidence rates are highest among young to middle-age adults, varying both geographically and among populations of different backgrounds.[1–10] In the United States, the incidence of sarcoidosis ranges from 2.5 to 7.6/100,000 for white men and from 13.2 to 81.8/100,000 for African-American men.[11,12] In New York City (NYC), point prevalence has been reported at 17/100,000 for whites and 64/100,000 for nonwhites.[10] The etiology(s) of sarcoidosis remains unknown. Genetic influences may play a role since sarcoidosis is more common in subjects of African-American and Puerto Rican descent than among white or Asian descent, and it is slightly more common in women than men.[1–3,9,11,12] Rare familial clusters have been reported.[1,3] Environmental exposures to infectious agents (*Chlamydia pneumoniae*

*From the New York City Fire Department, Bureau of Health Services (Drs. Prezant and Kelly), and The Albert Einstein College of Medicine, Montefiore Medical Center (Drs. Prezant, Dhala, Janus, Ortiz, and Aldrich), Department of Medicine, Pulmonary Division, Bronx, NY.

Manuscript received September 9, 1998; revision accepted May 6, 1999.

*Correspondence to: David J. Prezant, MD, FCCP, Montefiore Medical Center, Pulmonary Division, Centennial 423, Bronx, NY 10467*

and Mycobacteria) and allergens (forests, wood fuel) have been implicated.[3,4,13–15] Occupational clusters, with presumptive toxic or infectious exposures, have been reported for sarcoidosis, or diseases pathologically similar to sarcoidosis, in health-care workers,[2,4,16] United States Navy enlisted men serving on aircraft carriers,[12] and beryllium workers.[17]

Few occupations are more at risk for toxic exposures than fire fighting. In 1993, Kern et al[18] reported a cluster of three cases of sarcoidosis in firefighters from Rhode Island. Pulmonary functions were not studied, so severity cannot be assessed, but their findings suggest that firefighters may be at increased risk for sarcoidosis. The NYC Fire Department (FDNY) is the largest fire department in the United States, employing about 11,000 firefighters. In 1985, a pulmonary surveillance program was initiated at FDNY. A major goal was to determine the incidence and severity of biopsy-proven sarcoidosis in this work force. For historical context, point prevalence was also calculated. At diagnosis, severity was assessed based on physiologic measures of flow rates, diffusing capacity, lung volumes, airway hyperreactivity (cold air challenge), and maximum oxygen consumption ($M\dot{V}O_2$). In 1995, this program was expanded to include a control group of emergency medical services (EMS) prehospital health-care workers (HCWs). We report here our results from 1985 to 1998.

## Materials and Methods

### *Case Ascertainment*

FDNY firefighters with sarcoidosis were identified in five ways. First, in 1986, a chart review of all currently employed FDNY firefighters was completed to identify firefighters having sarcoidosis diagnoses prior to 1985. Second, beginning in 1985, all FDNY firefighters with signs or symptoms of pulmonary disease were referred to a pulmonary specialist at the FDNY Bureau of Health Services for prospective evaluation and database collection. We report on the period from January 1, 1985 to December 31, 1998. Third, all routine chest radiographs taken during wellness medical evaluations were prospectively reviewed. This review was accomplished as follows: (1) all films were routinely interpreted by a board-certified radiologist without knowledge that a research study was in progress; and (2) if the radiographic findings as evaluated by the radiologist were abnormal, the chest radiograph was reviewed by our board-certified pulmonologist, who was aware that a pulmonary surveillance study (for all lung disease, not just sarcoidosis) was in progress. FDNY firefighters have a wellness medical evaluation at the FDNY Bureau of Health Services prior to employment and approximately every 3 years thereafter. During this study (from 1985 to 1998), all FDNY firefighter had at least two wellness medical evaluations. Fourth, all disability leave and retirement applications were reviewed. Finally, health and safety representatives of the unions representing FDNY firefighters were told of this initiative and of our interest in evaluating firefighters with sarcoidosis.

The control group consisted of NYC EMS HCWs (both emergency medical technicians and paramedics). EMS merged with FDNY in 1995. Prior to that time, EMS employees were followed by the EMS Health Service, and since that time they have been followed by the FDNY Bureau of Health Services. With the merger in 1995, all current and newly hired EMS HCWs were enrolled in the FDNY wellness medical evaluation program and in the FDNY pulmonary surveillance program. The methods used for case ascertainment were the same as above. Complete medical records from the EMS Health Service, including chest radiograph reports, were available to FDNY physicians for review. Since the merger, all EMS HCWs have had at least two wellness examinations, including chest radiographs.

### *Population at Risk*

For annual incidence proportions, the population at risk was the number employed on July 1 of each year. The FDNY firefighter population totals were as follows: 12,211 (1985); 12,397 (1986); 12,386 (1987); 12,214 (1988); 12,990 (1989); 11,860 (1990); 11,545 (1991); 11,482 (1992); 11,433 (1993); 11,299 (1994); 11,436 (1995); 11,319 (1996); 11,348 (1997); and 11,315 (1998). EMS HCW totals were as follows: 2,844 (1995); 2,746 (1996); 2,909 (1997); and 2,689 (1998). The demographic representation has remained relatively stable throughout the study, with white men accounting for approximately 94% of the firefighters and 44% of the EMS FDNY workforce. In 1998, FDNY firefighter demographics included the following: 10,609 white men (93.8%); 342 African-American men (3%); 314 Hispanic men (2.8%); 14 Asian men (0.1%); 34 white women (0.3%); and 2 African-American women (0.01%). In 1998, EMS HCW demographics included the following: 1,181 white men (43.9%); 430 African-American men (15.9%); 412 Hispanic men (15.3%); 46 Asian men (0.2%); 10 not-identified men; 293 white women (10.9%); 179 African-American women (6.6%); 124 Hispanic women (4.6%); 4 Asian women; and 10 not-identified women.

### *Radiographic Staging*

In all firefighters and EMS HCWs suspected of having sarcoidosis, chest radiographs and CT scans were obtained. Radiographic staging followed the guidelines of Siltzbach.[19] To determine if there was evidence of sarcoidosis prior to employment, we reviewed preemployment medical evaluations (history, physical, and ECG); an independent radiologist, without knowledge of the study or diagnosis in question, reviewed the preemployment chest radiograph. Pulmonary function tests (PFTs) were not part of the preemployment evaluation. We expected to find few if any cases of preemployment sarcoidosis because, prior to 1995, this diagnosis definitely excluded employment as an FDNY firefighter and may have excluded employment as an EMS HCW.

### *Case Definition*

Firefighters and EMS HCWs who were suspected of having sarcoidosis underwent a biopsy of the most accessible involved organ or, when their private physician insisted, a Kveim biopsy. One firefighter and one EMS HCW refused a biopsy and were excluded from the study. Inclusion in this study required pathologic evidence of noncaseating granulomas.

### *Pulmonary Functions*

At the time of diagnosis, physiologic assessment of severity included spirometry (pre- and postbronchodilator), lung volumes (helium dilution), and single breath diffusing capacity for carbon

monoxide (DLCO). Predicted values were based on published norms,[20] and testing adhered to American Thoracic Society standards.[21,22] For this study, normal FVC, $FEV_1$, DLCO, and functional residual capacity (FRC) were defined as ≥ 80% of predicted. This cutoff is consistent with prior sarcoidosis studies[23,24] and recommendations in the literature at the time of study design.[20] Tests that were performed after 1985 were obtained using a pulmonary function system (model DSII; Collins; Braintree, MA). Post-bronchodilator spirometry was assessed 15 min after albuterol inhalation and was considered significant if there was a > 12% improvement in $FEV_1$.

*Airway Hyperreactivity*

Starting in 1985, all firefighters (but not EMS HCWs) having sarcoidosis diagnoses underwent isocapnic cold air provocative challenge testing to assess airway hyperreactivity. On a separate day, spirometric measurements before and after isocapnic cold air challenge were obtained every 2 min until there was a 20% reduction in the $FEV_1$, or until 12 min had elapsed.[25] Significant bronchial hyperreactivity was defined as a reduction in $FEV_1$ ≥ 20% of baseline.

*Exercise Performance*

Starting in 1985, most firefighters (but not EMS HCWs) shortly after diagnosis underwent a symptom-limited, incremental, maximal exercise test in which workload was increased every minute using cycle ergometry (Cardio2 Exercise System, CPX-D max series 2; Medical Graphics; St. Paul, MN). The exception was firefighter #2, whose exercise test was performed 10 years after diagnosis. BP, heart rate, ECG, $\dot{V}O_2$, and pulse oximetry were recorded throughout rest and exercise. Pulse oximetry (Biox model 3700; Ohmeda; Louisville, CO) was measured with a fingertip probe. Variables measured or calculated included the following: work rate (in watts); minute ventilation ($\dot{V}E$); respiratory rate; tidal volume (VT); ventilatory pattern (VT/vital capacity [VC]); oxygen consumption ($\dot{V}O_2$) adjusted for body weight (mL/kg/min); carbon dioxide production ($\dot{V}CO_2$); respiratory exchange ratio (RER); ventilatory equivalent for oxygen ($\dot{V}E/\dot{V}O_2$), and carbon dioxide ($\dot{V}E/\dot{V}CO2$); heart rate (HR); $O_2$ pulse ($\dot{V}O_2$/HR); and estimated dead space to VT ratio (VD/VT). Breath-by-breath measurements were averaged during the final 30 s of each minute. As arterial blood gases were not sampled, the estimated VD/VT was calculated using $PaCO_2$ estimated from end-tidal $PCO_2$ ($PETCO_2$) and VT using the equation of Jones et al,[26] where estimated $PaCO_2$ is $5.5 + (0.90 \times [PETCO_2 - 0.0021]) \times VT$. VD/VT was calculated using the modified Bohr equation, where $VD/VT = ([PaCO_2 - PETCO_2]/PaCO_2)$ – mouthpiece dead space/VT.

Criteria for a maximal or near-maximal exercise test were a peak HR ≥ 85% of predicted maximum, an RER ≥ 1.12, or an end-exercise plateau in $\dot{V}O_2$ (an increase of ≤ 50 mL/min over 1 min despite a work rate increase of ≥ 10 W).[27] Normal exercise test results were defined[27] as follows: $\dot{V}O_2$ at peak exercise, ≥ 75% predicted maximum $\dot{V}O_2$ ($M\dot{V}O_2$); anaerobic threshold, ≥ 40% predicted $M\dot{V}O_2$; ventilatory reserve at peak exercise, ≤ 80% maximum voluntary ventilation; VT/VC at peak exercise, 0.50 to 0.60; $VE/\dot{V}CO_2$ at anaerobic threshold, ≤ 34; $VE/\dot{V}O_2$ at anaerobic threshold, ≤ 31; VD/VT at rest, ≤ 0.40; VD/VT at peak exercise, ≤ 0.25; and $O_2$ saturation at peak exercise, < 4% decrease from rest.

## *Statistical Analysis*

All values are presented as means ± SD. The annual incidence proportion was defined as the number of firefighters who had sarcoidosis diagnosed over the prior year, divided by the number of firefighters at risk (the number currently employed minus the number currently employed with previously diagnosed sarcoidosis). Point prevalence was defined as the number of firefighters employed as of July 1, 1998 (who had sarcoidosis diagnosed either before and after 1985) and had sarcoidosis still present on chest radiograph on July 1, 1998, divided by the total number of firefighters employed on that date (n = 11,315). For the control group, the same definitions applied, but surveillance started on January 1, 1995, and the number of EMS HCWs employed on July 1, 1998 was 2,689. Significant correlations were assessed using Spearman correlation for rank-ordered variables (for example, radiographic staging); and Pearson correlation for continuous variables (for example, tenure, pulmonary functions, and exercise parameters). Significant differences were assessed by *t* test. All statistics were analyzed using appropriate software (Statgraphics version 6.1, 1993; STSC; Rockville, MD). Significance was defined using an overall type I error of 0.05.

# RESULTS

Twenty-five FDNY firefighters (Table 1) and 1 EMS HCW had biopsy-proven sarcoidosis diagnosed. All 25 were male, and 1 firefighter was an African American (#5). A retrospective chart review for those who were currently employed and had sarcoidosis diagnosed prior to 1985 found four firefighters with sarcoidosis diagnosed after employment, and one EMS HCW with sarcoidosis diagnosed before employment. For the 25 FDNY firefighters, the preemployment candidate medical chart was reviewed and did not suggest the presence of sarcoidosis or other cardiopulmonary disease or limitation. The preemployment chest radiograph was originally interpreted as normal for all 25 firefighters, but when reevaluated for this study, it showed findings suggestive of sarcoidosis in 2 firefighters (#1,2). Both conditions were diagnosed prior to 1985 and thus were not counted as incidence cases. The preemployment chest radiograph of the one EMS HCW also showed findings consistent with stage 2 sarcoidosis, but this disease was already known at the time of employment. At the end of this study on July 1, 1998, all 25 firefighters and the 1 EMS HCW remained as full-duty employees and continued to have stable chest radiograph findings that were consistent with the diagnosis of sarcoidosis.

For FDNY firefighters, annual incidence proportions over the course of this study (from 1985 to 1998) ranged from 0 to 43.6/100,000 and averaged 12.9/100,000 (Fig 1). For EMS (from 1995 to 1998), annual incidence proportions were zero. During the same period (from 1995 to 1998), incidence proportions in FDNY firefighters averaged 11/100,000. On July 1, 1998, the point prevalence for FDNY firefighters was 222/100,000, and for EMS HCWs it was 35/100,000. For white male FDNY firefighters, the annual incidence proportion of sarcoidosis ranged

**Table 1—*Sarcoidosis in FDNY Firefighters: Characteristics at Diagnosis**

| Subject | Age, yr | Date Hired | Date of Diagnosis | Unit | Symptom | CXR Pre-Hire | CXR | Chest CT | Biopsy Site |
|---|---|---|---|---|---|---|---|---|---|
| 1† | 30 | 1963 | 1972 | Ladder | None | 1 | 1 | 2 | Kveim |
| 2‡ | 44 | 1970 | 1977 | Engine | None | 0 | 2 | 2 | Lung wedge |
| 3 | 35 | 1968 | 1982 | Ladder | None | 1 | 1 | 1 | Kveim |
| 4 | 34 | 1970 | 1983 | Engine | Hemoptysis | 0 | 0 | 0 | Lung wedge |
| 5†§ | 37 | 1977 | 1986 | Ladder | DOE | 0 | 2 | 2 | Lung |
| 6‡ | 34 | 1984 | 1988 | Engine | Fatigue | 0 | 1 | 1 | Node |
| 7†‡ | 33 | 1982 | 1989 | Ladder | None | 0 | 1 | 1 | Lung |
| 8†‡ | 32 | 1987 | 1989 | Ladder | None | 0 | 1 | 1 | Lung |
| 9‡ | 38 | 1979 | 1991 | Engine | Chest pain | 0 | 1 | 1 | Lung |
| 10‡ | 33 | 1981 | 1991 | Engine | None | 0 | 1 | 1 | Node |
| 11 | 28 | 1990 | 1991 | Ladder | None | 0 | 1 | 1 | Node |
| 12‡ | 30 | 1985 | 1991 | Ladder | None | 0 | 1 | 1 | Node |
| 13 | 36 | 1978 | 1992 | Ladder | Chest pain | 0 | 1 | 1 | Lung |
| 14† | 36 | 1981 | 1992 | Ladder | None | 0 | 2 | 2 | Node |
| 15† | 31 | 1990 | 1992 | Ladder | Arthralgias | 0 | 1 | 1 | Node |
| 16 | 30 | 1989 | 1992 | Engine | None | 0 | 1 | 1 | Node |
| 17 | 26 | 1990 | 1992 | Ladder | None | 0 | 1 | 1 | Node |
| 18† | 41 | 1977 | 1993 | Engine | Arthralgias | 0 | 2 | 2 | Lung |
| 19†§ | 33 | 1990 | 1993 | Engine | Chest pain | 0 | 3 | 3 | Lung |
| 20 | 49 | 1977 | 1994 | Engine | Arthralgias | 0 | 1 | 1 | Lung wedge and node |
| 21 | 36 | 1983 | 1995 | Ladder | Chest pain | 0 | 1 | 1 | Lung |
| 22 | 37 | 1988 | 1995 | Engine | Hepatitis | 0 | 1 | 1 | Liver |
| 23 | 40 | 1981 | 1996 | Ladder | None | 0 | 2 | 2 | Lung |
| 24 | 33 | 1990 | 1997 | Engine | None | 0 | 1 | 1 | Node |
| 25§ | 38 | 1985 | 1997 | Engine | Arthralgias | 0 | 1 | 1 | Node |

*CXR (chest radiograph) and Chest CT results refer to radiographic staging; Lung = transbronchial biopsy unless otherwise noted.
†Abnormal PFT (FVC, $FEV_1$, or DLCO).
‡Abnormal $M\dot{V}O_2$.
§Corticosteroid treatment.

from 0 to 46.4/100,000 and averaged 13.7/100,000. On July 1, 1998, the point prevalence for sarcoidosis in white male FDNY firefighters was 226/100,000. If the two firefighters who may have had sarcoidosis on chest radiograph prior to employment were excluded, then the point prevalence was 207/100,000. For African-American male FDNY firefighters, the point prevalence was 292/100,000. However, as African-American males represent only 3% of FDNY firefighters and only 1 case, this is for descriptive rather than statistical comparison.

Table 1 details characteristics of the 25 firefighters at the time of diagnosis. Their average age was 35 ± 5 years old, and only one firefighter admitted to using tobacco (#12; an ex-smoker with a 5-pack-year history). Six firefighters presented for evaluation of a medical complaint (*ie*, dyspnea on exertion, chest pain, hemoptysis, arthralgias, or fatigue) and were then found to have an abnormal chest radiograph. 19 firefighters were referred for evaluation of an abnormal chest radiograph performed at routine FDNY wellness medical evaluations. On evaluation, 6 of the 19 firefighters reported medical complaints (*ie*, dyspnea on exertion, chest pain, arthralgias, or fatigue). None were identified from the evaluation of disability retirement applications. At the time of diagnosis, duration of employment as an FDNY firefighter averaged 9 ± 5 years (range, 1 to 17 years). No unit assignment more specific than fire fighting could be identified as a common factor within this cohort. Firefighters with sarcoidosis diagnoses were nearly evenly divided among those in engine units (whose primary task is extinguishing the fire) and those in ladder units (whose primary task is interior fire search, rescue, venting, and overhaul); this remained true when expressed relative to the number of firefighters who were assigned to engine and ladder units.

Chest radiographs obtained at diagnostic evaluation revealed stage 0 (normal radiograph; n = 1) or stage I (hilar adenopathy without apparent parenchymal involvement; n = 18) for a total of 19 cases (76%). Chest CT results correlated with radiographic staging in all cases except #1 (stage 1 on radiograph; stage 2 on CT). There was no significant correlation between radiographic staging and years employed as a firefighter ($r = 0.08$; $p = 0.69$). There was no significant difference in radiographic staging between firefighters assigned to engine or ladder units (*t* test, $p = 0.41$).

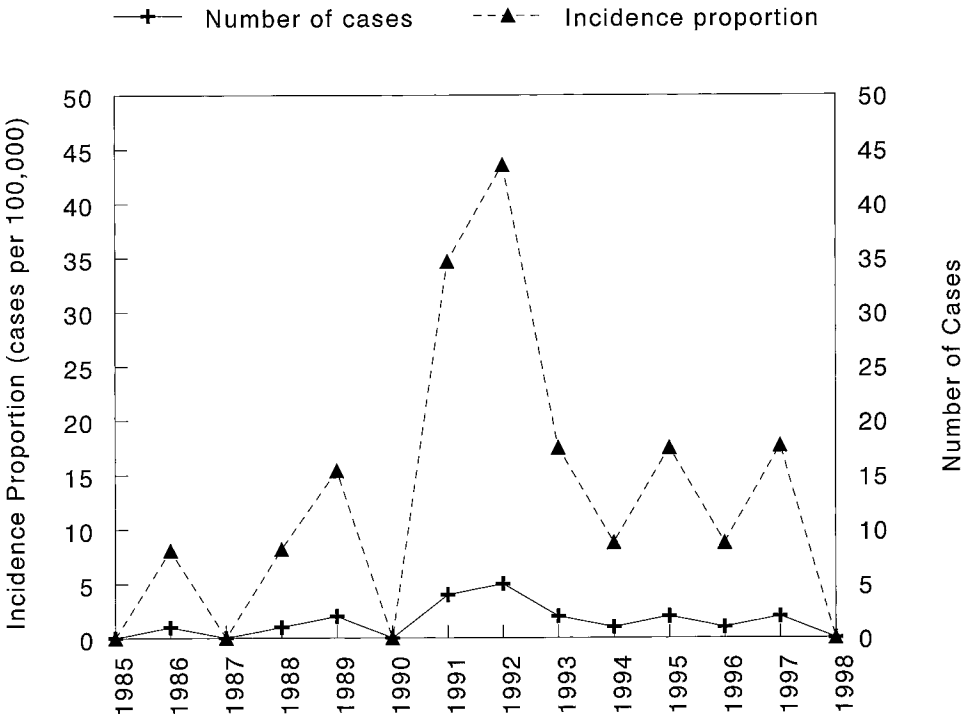


FIGURE 1. The number of cases of biopsy-proven sarcoidosis in FDNY firefighters during the study years from 1985 to 1998. For FDNY firefighters, incidence proportions ranged from 0 to 43.6/100,000 and the average annual incidence proportion was 12.9/100,000. For EMS HCWs, the annual incidence (from 1995 to 1998) was zero (not shown).

Twelve firefighters had a positive finding (noncaseating granulomas) on lung biopsy. Two subjects had a negative finding on lung (transbronchial) biopsy with a positive result on mediastinal node biopsy. Fourteen firefighters had biopsy sites that did not involve the lung, including 2 firefighters with a positive result from a Kveim biopsy and 1 firefighter with a positive result from a liver biopsy (Table 1). The one EMS HCW had a positive result from a transbronchial biopsy. Angiotensin converting enzyme measurements were not part of our assessment protocol, but were elevated in six of seven firefighters (86%) who had levels drawn.

Table 2 and Figure 2 summarize the pulmonary functions in FDNY firefighters at the time of diagnosis. Both the FVC and $FEV_1$ were normal ($\geq$ 80% predicted) in 20 firefighters (80%). An FVC and/or $FEV_1$ $\leq$ 65% predicted were found in only one firefighter (#5). No firefighter had a significant bronchodilator response. No firefighter tested (n = 22) showed evidence of airway hyperreactivity as assessed by isocapnic cold air challenge testing. FRC was normal ($\geq$ 80% predicted) in 14 firefighters (56%). An FRC $\leq$ 65% predicted was found in eight firefighters. DLCO was normal ($\geq$ 80% predicted) in 17 firefighters (68%). A DLCO $\leq$ 65% predicted was found in only one firefighter. No significant correlations were found between pulmonary functions and years employed as a firefighter (FVC, $r = 0.01$, $p = 0.95$; $FEV_1$, $r = 0.03$, $p = 0.9$; FRC, $r = -0.11$, $p = 0.6$; and DLCO, $r = 0.07$, $p = 0.75$). There were no significant differences in pulmonary functions between firefighters assigned to engine and ladder units (FVC, $p = 0.79$; $FEV_1$, $p = 0.1$; FRC, $p = 0.82$; and DLCO, $p = 0.23$). The one EMS HCW had normal pulmonary functions (FVC, 86%; $FEV_1$, 88%; FRC, 80%; and DLCO, 84%).

Because obesity may influence the decrease in FRC, we excluded lung volume from analysis and considered pulmonary function to be abnormal when FVC, $FEV_1$, or DLCO were $<$ 80% predicted. We considered pulmonary function to be moderately reduced when any of the above were $\leq$ 65% predicted. Based on these criteria, pulmonary function was abnormal in eight firefighters (32%) and moderately reduced in only two firefighters (8%; #1,5). Pulmonary function did not significantly correlate with radiographic staging ($r = 0.28$; $p = 0.17$), but there was a trend with abnormal pulmonary function in 5 of 7 firefighters (71%) with stage 2 or 3 disease, but only 3 of 18 firefighters (17%) with stage 0 or 1 disease.

Exercise performance is shown in Tables 3 and 4. Of the 17 firefighters tested, 3 did not achieve a HR

**Table 2—*Sarcoidosis in FDNY Firefighters: Pulmonary Functions***

| Subject | FVC, L | | $FEV_1$, L | | FRC, L | | DLCO, mL/min/mm Hg | | Cold Air % Change |
|---|---|---|---|---|---|---|---|---|---|
| | Absolute | % | Absolute | % | Absolute | % | Absolute | % | |
| 1* | 5.77 | 128 | 3.20 | 76 | 3.45 | 87 | 26.80 | 65 | |
| 2† | 3.73 | 110 | 3.41 | 107 | 3.57 | 114 | 26.55 | 106 | 4 |
| 3 | 3.95 | 82 | 3.01 | 80 | 2.02 | 57 | 24.80 | 80 | |
| 4 | 4.70 | 91 | 3.88 | 92 | 3.47 | 87 | 27.00 | 86 | |
| 5*‡ | 3.04 | 65 | 2.30 | 59 | 2.03 | 59 | 23.30 | 67 | 3 |
| 6† | 5.44 | 102 | 4.48 | 105 | 3.64 | 101 | 33.09 | 97 | 9 |
| 7*† | 4.12 | 79 | 3.28 | 79 | 1.89 | 48 | 30.33 | 75 | 4 |
| 8*† | 4.99 | 88 | 3.83 | 83 | 2.08 | 57 | 28.29 | 67 | −8 |
| 9† | 5.40 | 116 | 4.40 | 115 | 2.85 | 85 | 35.89 | 125 | −5 |
| 10† | 5.35 | 105 | 4.25 | 112 | 3.64 | 110 | 33.09 | 101 | 2 |
| 11 | 6.34 | 102 | 4.85 | 95 | 4.86 | 105 | 42.27 | 101 | −3 |
| 12† | 5.45 | 100 | 4.36 | 97 | 3.12 | 83 | 29.56 | 82 | 1 |
| 13 | 5.25 | 97 | 4.17 | 100 | 3.24 | 78 | 31.60 | 101 | 3 |
| 14* | 4.55 | 107 | 3.49 | 98 | 2.74 | 92 | 27.14 | 78 | 10 |
| 15* | 5.90 | 104 | 5.18 | 113 | 2.13 | 53 | 29.90 | 77 | −2 |
| 16 | 4.74 | 90 | 3.63 | 85 | 2.09 | 59 | 28.91 | 88 | −5 |
| 17 | 6.04 | 104 | 5.01 | 106 | 5.34 | 133 | 40.90 | 119 | 6 |
| 18* | 3.87 | 79 | 3.59 | 91 | 2.37 | 64 | 26.19 | 69 | −5 |
| 19*‡ | 4.33 | 77 | 3.80 | 88 | 3.23 | 77 | 32.20 | 75 | 0 |
| 20 | 4.69 | 101 | 4.02 | 107 | 2.28 | 69 | 29.87 | 87 | 10 |
| 21 | 5.55 | 113 | 4.63 | 117 | 3.97 | 104 | 31.05 | 100 | 4 |
| 22 | 5.5 | 98 | 4.34 | 102 | 3.50 | 80 | 23.90 | 83 | 0 |
| 23 | 5.28 | 93 | 3.97 | 85 | 3.26 | 85 | 39.43 | 113 | 6 |
| 24 | 4.96 | 99 | 3.93 | 97 | 1.93 | 57 | 35.77 | 116 | 0 |
| 25‡ | 5.91 | 116 | 4.11 | 109 | 3.68 | 83 | 31.84 | 108 | 4 |
| Mean | 4.99 | 98 | 4.01 | 96 | 3.06 | 81 | 30.80 | 91 | 2 |
| SD | 0.82 | 14 | 0.66 | 14 | 0.91 | 22 | 5.04 | 18 | 5 |

*Abnormal PFT (FVC, $FEV_1$, or DLCO).
†Abnormal $M\dot{V}O_2$.
‡Corticosteroid treatment.

≥ 85% of predicted maximum (#6,10) or an RER ≥ 1.12 (#15). ECGs at rest and during exercise were normal in all tested. Peak $\dot{V}O_2$ was normal in 10 firefighters (59%), and anaerobic threshold was normal in all 17 firefighters. At peak exercise, normal ventilatory reserve was found in 14 firefighters (82%), and normal VT/VC was found in 13 firefighters (76%). At anaerobic threshold, $\dot{V}E/\dot{V}CO_2$ was normal in all 17 firefighters, and $\dot{V}E/\dot{V}O_2$ was normal in 14 firefighters (82%). Gas exchange was normal or minimally reduced as indicated by normal VD/VT at rest in 15 firefighters (88%), by normal VD/VT at peak exercise in all 17 firefighters, and by normal $O_2$ saturation at rest and peak exercise in all 17 firefighters tested.

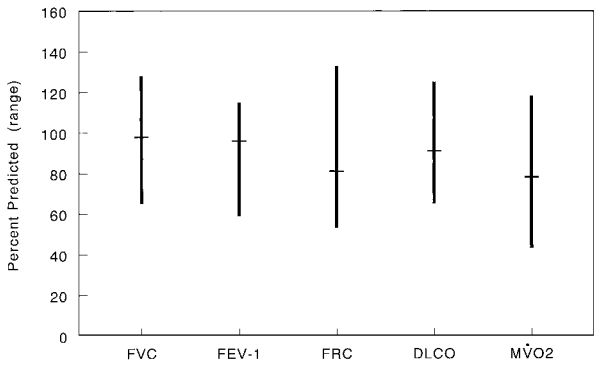


FIGURE 2. The ranges (high, low, and mean) for PFTs (n = 25) and $M\dot{V}O_2$ (n = 17) are shown for FDNY firefighter with biopsy-proven sarcoidosis. Both FVC and $FEV_1$ were normal in 20 firefighters (80%). Only one firefighter had an FVC and/or $FEV_1$ ≤ 65% predicted. FRC was normal in 14 firefighters (56%), but many were overweight; DLCO was normal in 17 firefighters (68%), and $M\dot{V}O_2$ was normal in 10 firefighters (59%). The EMS HCW had normal pulmonary functions (not shown).

These findings suggest that low $M\dot{V}O_2$ was due to gas exchange abnormalities in, at most, five firefighters, but none were significant enough to cause exercise desaturation. Figure 3 shows pulmonary functions (at rest and during exercise) according to whether the firefighters had normal or abnormal $M\dot{V}O_2$. No significant correlations were found between $M\dot{V}O_2$ and radiographic stage ($r = 0.2$; $p = 0.43$), or FVC ($r = -0.13$; $p = 0.63$), $FEV_1$ ($r = -0.01$; $p = 0.99$), DLCO ($r = 0.11$; $p = 0.68$), exercise VD/VT ($r = -0.38$; $p = 0.13$), exercise $O_2$ saturation ($r = -0.07$; $p = 0.78$), $\dot{V}E/\dot{V}CO_2$

**Table 3—*Sarcoidosis in FDNY Firefighters: Exercise Studies**

| Subject | $M\dot{V}O_2$, mL/kg/min | | | | Anaerobic Threshold, mL/kg/min | | | $O_2$ Pulse Absolute, mL/beat | HR Reserve Absolute, beats/min |
|---|---|---|---|---|---|---|---|---|---|
| | Absolute | % | Work, W | RER | Absolute | % $M\dot{V}O_2$ | % Predicted $M\dot{V}O_2$ | | |
| 1* | | | | | | | | | |
| 2† | 16.9 | 43 | 150 | 1.54 | 16.8 | 99 | 43 | 8 | 13 |
| 3 | | | | | | | | | |
| 4 | | | | | | | | | |
| 5*‡ | | | | | | | | | |
| 6† | 22.4 | 66 | 225 | 1.40 | 20.7 | 92 | 61 | 13 | 19 |
| 7*† | 25.2 | 60 | 175 | 1.14 | 18.8 | 75 | 45 | 12 | 13 |
| 8*† | 21.3 | 56 | 200 | 1.21 | 17.6 | 83 | 47 | 10 | 1 |
| 9† | 27.3 | 67 | 225 | 1.35 | 24.9 | 91 | 61 | 11 | 0 |
| 10† | 28.1 | 69 | 225 | 1.15 | 27.2 | 97 | 67 | 14 | 16 |
| 11 | | | | | | | | | |
| 12† | 27.9 | 69 | 225 | 1.20 | 24.4 | 87 | 60 | 12 | 7 |
| 13 | 28.0 | 80 | 250 | 1.27 | 17.8 | 85 | 63 | 15 | 23 |
| 14* | | | | | | | | | |
| 15* | 26.3 | 90 | 275 | 1.00 | 24.4 | 93 | 83 | 18 | 10 |
| 16 | 22.0 | 73 | 200 | 1.18 | 17.1 | 77 | 57 | 14 | 11 |
| 17 | 26.2 | 75 | 225 | 1.31 | 25.0 | 95 | 70 | 13 | 4 |
| 18* | 29.1 | 85 | 166 | 1.30 | 19.5 | 67 | 64 | 13 | 12 |
| 19*‡ | 44.1 | 107 | 200 | 1.17 | 24.1 | 54 | 58 | 14 | 5 |
| 20 | | | | | | | | | |
| 21 | 39.1 | 107 | 215 | 1.24 | 22.8 | 58 | 62 | 18 | 7 |
| 22 | 39.0 | 94 | 235 | 1.12 | 21.0 | 61 | 58 | 15 | 0 |
| 23 | 33.7 | 107 | 245 | 1.19 | 18.5 | 55 | 59 | 20 | 11 |
| 24 | 31.1 | 118 | 257 | 1.26 | 17.2 | 55 | 65 | 23 | 14 |
| 25‡ | | | | | | | | | |
| Mean | 28.7 | 78 | 217 | 1.24 | 21.0 | 78 | 60 | 14 | 10 |
| SD | 7.1 | 19 | 33 | 0.12 | 3.4 | 16 | 10 | 4 | 6 |

*Abnormal PFT (FVC, $FEV_1$, or DLCO).
†Abnormal $M\dot{V}O_2$.
‡Corticosteroid treatment.

($r = -0.33$; $p = 0.2$), and $\dot{V}E/\dot{V}O2$ ($r = -0.31$; $p = 0.2$). Figure 4 shows pulmonary functions (at rest and during exercise) according to whether the firefighters had normal or abnormal DLCO. No significant correlations were found between DLCO and radiographic stage ($r = -0.07$; $p = 0.72$), or exercise VD/VT ($r = -0.09$; $p = 0.72$), exercise $O_2$ saturation ($r = 0.03$; $p = 0.89$), $\dot{V}E/\dot{V}CO_2$ ($r = 0.38$; $p = 0.13$), and $VE/VO_2$ ($r = 0.34$; $p = 0.19$). In contrast to prior studies,[23,24,28,29] we could not demonstrate a significant correlation between DLCO and exercise performance, because DLCO averaged $91 \pm 18\%$ predicted and none had a DLCO $< 65\%$ predicted (Table 2).

After completing the diagnostic evaluation, 22 firefighters immediately returned to full firefighter duties. Given the absence of symptoms, no demonstrable airway hyperreactivity, and the paucity of pulmonary function findings at rest and during exercise, we lacked a medical justification for an alternative duty status decision. Three firefighters were treated with oral steroids by their personal physicians for dyspnea and abnormal pulmonary function (#5), dyspnea with stage 3 chest radiograph (#19), and arthralgias with normal pulmonary function (#25). During treatment, these three firefighters were restricted to office duties. After 8 to 12 months, all three firefighters were off medication, asymptomatic, and returned to full firefighter duties without restrictions. Posttreatment chest radiographs were unchanged, but gallium scans (pre- vs posttreatment) in both firefighters showed complete resolution. In the two firefighters who were treated for pulmonary complaints, pulmonary functions (flow rates, lung volumes, and diffusion) improved after treatment and remained relatively stable after 3 years of follow-up. On July 1, 1998, all 25 firefighters and the 1 EMS HCW were asymptomatic, had stable sarcoidosis by chest radiograph, and remained employed by FDNY at full duty.

## Discussion

Sarcoidosis is a multisystem, noncaseating, granulomatous disease affecting young to middle-age

**Table 4—*Sarcoidosis in FDNY Firefighters: Gas Exchange During Exercise***

| Subject | RR, breaths/min | VT/VC Maximum Exercise | $\dot{V}E/\dot{V}CO_2$ Anaerobic Threshold | $\dot{V}E/\dot{V}O_2$ Anaerobic Threshold | VD/VT Rest | VD/VT Maximum Exercise | $\dot{V}E$ Reserve, % MVV | $O_2$ Saturation Rest | $O_2$ Saturation Maximum Exercise |
|---|---|---|---|---|---|---|---|---|---|
| 1† | | | | | | | | 95 | 99 |
| 2‡ | 28 | 0.49 | 31.9 | 49.7 | 0.37 | 0.24 | 54 | 99 | 99 |
| 3 | | | | | | | | | |
| 4 | | | | | | | | 97 | — |
| 5†§ | | | | | | | | 95 | — |
| 6‡ | 36 | 0.36 | 25.2 | 29.4 | 0.58 | 0.25 | 55 | 97 | 94 |
| 7†‡ | 30 | 0.56 | 27.5 | 27.2 | 0.25 | 0.17 | 44 | 99 | 99 |
| 8†‡ | 24 | 0.37 | 23.3 | 27.4 | 0.27 | 0.11 | 58 | 96 | 93 |
| 9‡ | 20 | 0.75 | 29.1 | 39.3 | 0.19 | 0.06 | 35 | 99 | 98 |
| 10‡ | 20 | 0.53 | 22.6 | 24.2 | 0.54 | 0.10 | 66 | 98 | 96 |
| 11 | | | | | | | | | |
| 12‡ | 24 | 0.44 | 21.2 | 22.8 | 0.29 | 0.13 | 58 | 96 | 96 |
| 13 | 32 | 0.50 | 30.3 | 38.6 | 0.38 | 0.14 | 66 | 96 | 96 |
| 14† | | | | | | | | 95 | 95 |
| 15† | 28 | 0.46 | 25.8 | 24.6 | 0.29 | 0.16 | 56 | 98 | 96 |
| 16 | 24 | 0.56 | 24.7 | 25.5 | 0.33 | 0.15 | 50 | 96 | 96 |
| 17 | 40 | 0.39 | 24.8 | 30.1 | 0.24 | 0.07 | 47 | 95 | 97 |
| 18† | 31 | 0.61 | 24.0 | 27.0 | 0.25 | 0.12 | 50 | 97 | 98 |
| 19†§ | 36 | 0.67 | 24.0 | 26.0 | 0.27 | 0.07 | 25 | 95 | 96 |
| 20 | | | | | | | | 98 | — |
| 21 | 30 | 0.63 | 23.0 | 22.0 | 0.32 | 0.09 | 30 | 98 | 98 |
| 22 | 28 | 0.53 | 24.8 | 22.2 | 0.28 | 0.12 | 17 | 98 | 98 |
| 23 | 36 | 0.59 | 26.0 | 23.0 | 0.26 | 0.12 | 16 | 97 | 95 |
| 24 | 43 | 0.58 | 25.0 | 22.0 | 0.28 | 0.15 | 17 | 98 | 96 |
| 25§ | | | | | | | | | |
| Mean | 30 | 0.53 | 25.5 | 28.3 | 0.32 | 0.13 | 44 | 97 | 97 |
| SD | 7 | 0.11 | 2.8 | 7.5 | 0.11 | 0.05 | 17 | 1 | 2 |

*RR = respiratory rate; MVV = maximum voluntary ventilation.
†Abnormal PFT (FVC, $FEV_1$, or DLCO).
‡Abnormal $M\dot{V}O_2$.
§Corticosteroid treatment.

adults. Because sarcoidosis is usually asymptomatic, its incidence and prevalence are markedly influenced by case ascertainment methods.[1,3] Our study used all methods of case ascertainment, including the evaluation of symptomatic individuals and chest radiographic screening of the asymptomatic work-

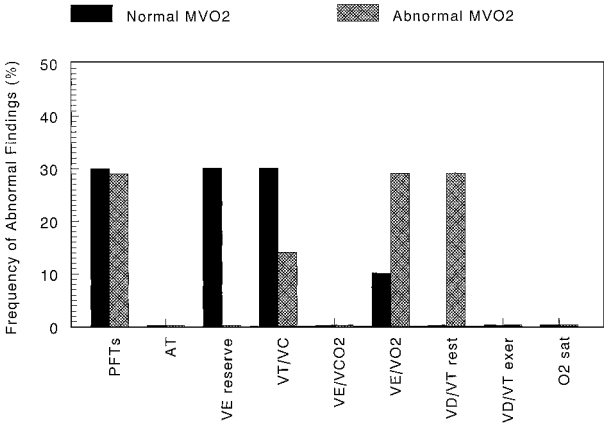


FIGURE 3. The 17 firefighters with sarcoidosis who underwent exercise testing were divided based on whether $M\dot{V}O_2$ was normal. No significant differences were found in resting pulmonary function (FVC, $FEV_1$, or DLCO), or in any exercise parameter (ventilatory, gas exchange, or cardiovascular).

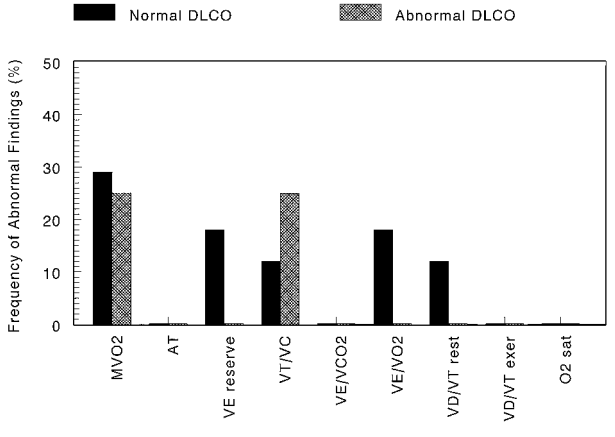


FIGURE 4. The 17 firefighters with sarcoidosis who underwent exercise testing were divided based on whether DLCO was normal. No significant differences were found in any exercise parameter (ventilatory, gas exchange, or cardiovascular).

force. We included only biopsy-proven cases and were able to compare all cases with preemployment chest radiographs. In our study, the average annual incidence proportion of sarcoidosis in FDNY firefighters was 12.9/100,000. On July 1, 1998, the point prevalence of sarcoidosis in FDNY firefighters was 222/100,000.

This is in sharp contrast to our control group of EMS HCWs, for whom the annual incidence proportion was zero and the point prevalence on July 1, 1998 was 35/100,000. Interestingly, no new cases were found in EMS HCWs despite the following: (1) greater nonwhite representation (42%) than FDNY firefighter (6%); and (2) previous reports indicating that HCWs may be disproportionately affected by sarcoidosis.[2,4,16] One difference between the firefighter and EMS HCW groups was time course. We only followed EMS controls for 4 years because the groups had merged in 1995. Although case ascertainment methods were identical, it is possible that prior to merger, unstated employment differences (hiring, illness reporting, follow-up, disability, and retirement) may have existed that could have influenced the point prevalence at the start or the subsequent incidence proportion. We believe this unlikely because of the following: (1) at the start of the study, no significant difference between the groups was found for the proportion of active employees with previously diagnosed sarcoidosis; (2) EMS job task descriptions do not prevent most individuals with sarcoidosis from performing their duties; and (3) the incidence proportion for EMS HCWs was zero.

Comparing FDNY firefighters to published historical controls is difficult. Most prior studies did not evaluate incidence, but instead reported only the point prevalence as determined from large-scale chest radiograph screening. Because such screenings are rare in the United States, most were European studies.[1,3,5–8] In the 1960s, the point prevalence for sarcoidosis ranged from 3.4/100,000 in Czechoslovakia[6] to 55/100,000 in Sweden.[7] A large percentage of FDNY firefighters claim Irish descent (39% in 1998). In Ireland, the reported point prevalence for sarcoidosis was 33.3/100,000.[8] Even if 100% of FDNY firefighters were of Irish descent, the point prevalence for sarcoidosis in FDNY firefighters would be seven times greater than expected.

It is also notable that point prevalence for sarcoidosis is high in FDNY firefighters, despite the underrepresentation of groups typically affected by sarcoidosis. In the United States, one of the few reported large-scale chest radiograph surveys was conducted in NYC from 1956 to 1962.[10] The point prevalence for sarcoidosis ranged from 17/100,000 in districts where the population was mostly white (> 80%) to 64/100,000 in districts where the population was mostly nonwhite (> 40%). Based on this data, the point prevalence for sarcoidosis in white FDNY firefighters is 13 times greater than expected.

Recently, the United States Navy and the National Institute for Occupational Safety and Health reported the incidence of sarcoidosis in United States Navy enlisted men from 1971 to 1993.[11] Mandatory chest radiographs were required for all recruits; for incumbents with symptoms; or at change of assignment, release, or discharge. Most of the diagnoses were biopsy proven. The average annual incidence proportion for sarcoidosis declined substantially (from 73.3 to 13.2/100,000) among African-American enlisted men (age group, 21 to 30 years old); and from 46.5 to 27.8/100,000 (age group, 31 to 40 years old). For white enlisted men, the incidence proportions were far lower, were not significantly different among age groups, remained relatively stable throughout the study, and were similar to findings reported in a prior United States Navy study from 1958 to 1971.[12] Compared to the average annual incidence proportion of 2.5/100,000 for white men in the United States Navy (from 1985 to 1993), the average annual incidence proportion in white male FDNY firefighters was five-and-a-half times greater.

The largest civilian United States study was from a Detroit, Michigan health maintenance organization (HMO). Annual incidence proportions (from 1990 to 1994) were 10/100,000 in white male subjects and nearly 20/100,000 in white male subjects 20 to 49 years old.[9] Using the latter proportion, this is eight times higher than the United States Navy study, and one-and-a-half times higher than our FDNY study. In contrast to our study, the HMO study used retrospective data and did not require biopsy confirmation (absent in 37% of white males). Our study required biopsy confirmation in all cases, thereby excluding common diseases that may masquerade as sarcoidosis (examples, tuberculosis, histoplasmosis, and lymphoma). The most important difference between studies was the inclusion by the HMO of "incidence" cases that may have been prevalence cases. Cases were considered new if there was no mention of prior disease in the medical history. Baseline chest radiographs are not required during enrollment into HMOs, and, even if available, their research protocol did not include a comparison with prior chest radiographs to differentiate incidence from prevalence. This affects not only asymptomatic cases but also symptomatic cases, as the latter may not be new cases but rather acute flare-ups in patients with unknown prior disease that would have been evident if prior chest radiographs were available. Only the United States Navy study and our FDNY study are true incidence studies.

As an occupational study, several additional issues

deserve comment. First, with the possible exception of two firefighters, we believe this group developed sarcoidosis only after employment as FDNY firefighters. Prior to 1995, sarcoidosis disallowed employment as an FDNY firefighter; complete medical evaluations (including history, examination, and chest radiograph) were obtained in all candidates, and records indicate adherence to this criterion. Second, this study attempted to exclude possible effects of prior or secondary employment. We reviewed records and interviewed each of the 25 firefighters. The occupational history for this group was unremarkable. None had been a firefighter prior to FDNY employment, and none were employed in occupations reported to be a high risk for sarcoidosis or sarcoidosis-like disease, such as beryllium workers,[17] health-care workers,[2,4,16] or United States Navy enlisted men.[11,12] One firefighter had prior military service, but he had been in the United States Army. Third, we are confident that the "healthy worker" effect, underreporting due to employment conditions, and/or longitudinal dropout did not significantly affect our findings. The "healthy worker" effect would reduce rather than increase our findings, and its impact was minimized because our case ascertainment methods included chest radiographs in asymptomatic firefighters. FDNY employment conditions, nonpunitive medical leave policies, and liberal benefits strongly favor the reporting of medical complaints. Because of generous disability benefits and the perception that disease is imminent, nearly all FDNY firefighters have a complete medical assessment prior to retirement or resignation. As part of this process, all abnormal findings were presented to FDNY Bureau of Health Services. Thus, we believe this study represents as complete a workforce survey as possible.

The increased incidence of sarcoidosis in FDNY firefighters is not unexpected. Environmental factors (infections, allergens, and toxins) have long been suspected in the development of sarcoidosis.[13–17] Few occupations are at higher risk for toxic exposures than firefighters. Although self-contained breathing apparatus and relatively impermeable uniforms are worn by all FDNY firefighters, it is common to remove mask and gloves during various aspects of fire fighting. Because FDNY fire activity is one of the highest in the world, with $>2{,}200$ structural fires per month, individual firefighter response records are not kept and it is impossible to determine common exposures to agents that may induce or augment antigen-driven cell-mediated immunity.[15] The best we can determine is that none served in the same unit and that they were all nearly evenly divided between engine and ladder units (Table 1). Alternatively, it is possible that sarcoidosis in firefighters represents hypersensitivity pneumonitis. This is unlikely, as there was no evidence of acute illness, no obvious common exposure, biopsy findings were not typical, and in many cases there were extraparenchymal manifestations (arthralgias and hepatitis) or extraparenchymal biopsy findings of noncaseating granulomas ($n = 14$; including two Kveim biopsies and one liver biopsy) not found in hypersensitivity pneumonitis (Table 1).

FDNY is not the only fire department to report an increased incidence of sarcoidosis. In 1993, Kern et al[18] reported a cluster of three cases of biopsy-proven sarcoidosis in white male firefighters from Providence, Rhode Island. Pulmonary functions were not reported. Serum neopterin was elevated, indicating γ-interferon-induced T-cell activation,[30,31] in one of three index cases, 20% of the index cohort, 22% of firefighter control subjects, but only 4% of police officer control subjects.[18] If T-cell activation is increased in firefighters, the cause is unknown, but it could be related to toxic exposures (general or specific) during fire fighting.

Although we found the incidence of sarcoidosis to be increased in firefighters, functional impact was minimal. Only two firefighters (#5,19) had cardiopulmonary symptoms (dyspnea or chest pain) that were severe enough to limit work activities (Table 1). One firefighter (#5) had moderate reductions in pulmonary function (Table 2). Exercise testing was not available to us at that time. The other firefighter (#19) had minimal reductions in pulmonary function (Table 2) and excellent exercise performance (Table 4). We had expected considerably more symptomatic functional work impairment in this group, since fire fighting is known to be a high workload activity[32–34] and sarcoidosis affects organs and physiologic processes responsible for oxygen exchange, delivery, and utilization. The $\dot{V}O_2$ required for fire fighting is estimated at 39 mL/kg/min.[32–33] Interestingly, only 3 of 17 firefighters (18%) had an $M\dot{V}O_2 \geq 39$ mL/kg/min, and yet most were asymptomatic or had symptoms that did not interfere with work performance. In nonfire-related work performance studies, an $M\dot{V}O_2 \geq 25$ mL/kg/min is sufficient for all but the most physically demanding activities.[35] Of the 17 firefighters tested, an $M\dot{V}O_2 \geq 25$ mL/kg/min was found in 13 firefighters (76%). We believe that the lack of functional impairment observed in this study was because few had evidence of moderate or severe pulmonary involvement (only two firefighters had pulmonary function $\leq 65\%$ predicted), none displayed airway hyperreactivity (Table 2), and none showed gas exchange abnormalities significant enough to cause exercise desaturation (Table 4). Thus, the lack of moderate to severe pulmonary dysfunction, coupled with possible self-selection for

less strenuous job assignments, accounted for the general absence of work-related performance problems.

In conclusion, the incidence and point prevalence of sarcoidosis is increased in FDNY firefighters when compared to EMS HCWs and historical controls. No obvious common work location or assignment was present. Radiographic, pulmonary function, and exercise capacity measurements demonstrate that for the majority, functional impairment was minimal. Future studies are planned to determine if a common infectious, allergic, or toxic antigen exists; the degree of T-cell activation; and the stability of sarcoidosis in this cohort of firefighters.

ACKNOWLEDGMENT: We thank Dr. S. Rakoff, Professor of Radiology, Albert Einstein College of Medicine, Montefiore Medical Center for interpretation of chest radiographs. We thank Dr. Katherine Freeman, Director of Biostatistics, Montefiore Medical Center, for review of epidemiology and statistical methods. We appreciate the dedication of Kevin Malley in teaching our pulmonary fellows exercise testing and the real difference between submaximal and maximal performance. Finally, we thank the subjects of this study for their trust, cooperation, and patience.

## References

1 Tierstein AS, Lesser M. Worldwide distribution and epidemiology of sarcoidosis. In: Fanburg BL, ed. Sarcoidosis and other granulomatous diseases of the lung. New York, NY: Marcel Dekker, 1983; 101–134
2 Parkes SA, Baker SB, Bourdillon RE, et al. Epidemiology of sarcoidosis in the Isle of Man: 1. A case controlled study. Thorax 1987; 42:420–426
3 Hosoda Y, Yamaguchi M, Hiraga Y. Global epidemiology of sarcoidosis: what story do prevalence and incidence tell us? Clin Chest Med 1997; 18:681–694
4 Bresnitz EA, Stolley PD, Isreal HL, et al. Possible risk factors for sarcoidosis: a case control study. Ann NY Acad Sci 1986; 465:632–642
5 Bauer HJ, Lofgren S. International study of pulmonary sarcoidosis in mass chest radiography. Acta Med Scand 1964; 176(suppl425):103–105
6 Levinsky L, Altmann V. Prevalence of pulmonary sarcoidosis in Czechoslovakia: proceedings of the Third International Conference on Sarcoidosis. Acta Med Scand 1964; (Suppl425); 176:171–173
7 Bauer HJ, Wijkstrom S. The prevalence of pulmonary sarcoidosis in Swedish mass radiography surveys. Sundbybeerg, Sweden: Center of Mass Chest Radiography of the Royal Swedish Medical Boards, 1963; 112–114
8 Logan J. Prevalence of sarcoidosis in Ireland: proceedings of the Third International Conference on Sarcoidosis. Acta Med Scand 1964; (Suppl425); 176:126
9 Rybicki BA, Major M, Popovich J, et al. Racial differences in sarcoidosis incidence: a 5 year study in a health maintenance organization. Am J Epidemiol 1997; 145:234–241
10 Robins AB, Abeles H, Chaves AD. Prevalence and demographic characteristics of sarcoidosis. Bureau of Tuberculosis, New York, NY: Department of Health, NY, 1962; 149–151
11 National Institute for Occupational Safety, Centers for Disease Control: sarcoidosis among US Navy enlisted men; 1965–1993. MMWR 1997; 46:539–543
12 Sartwell PE, Edwards LB. Epidemiology of sarcoidosis in the U.S. Navy. Am J Epidemiol 1974; 99:250–257
13 Gronhagen-Riska C, Saikku P, Riska H, et al. Antibodies to TWAR – a novel type of chlamydia – in sarcoidosis. In: Grassi C, Rizzato G, Pozzi E, eds. Sarcoidosis and other granulomatous disorders. Amsterdam, Holland: Elsevier Science Publishers, 1988; 297–300
14 Almenoff PL, Johnson A, Lesser M, et al. Growth of acid fast L forms from the blood of patients with sarcoidosis. Thorax 1996; 51:530–533
15 Nagai S, and Izumi T. Pulmonary sarcoidosis: population differences and pathophysiology. South Med J 1995; 88:1001–1010
16 Edmonstone WM. Sarcoidosis in nurses: is there an association? Thorax 1988; 43:342–343
17 Richeldi L, Kreiss K, Mroz MM, et al. Interaction of genetic and exposure factors in the prevalence of berylliosis. Am J Ind Med 1997; 32:337–340
18 Kern DG, Neill MA, Wrenn DS, et al. Investigation of a unique time-space cluster of sarcoidosis in firefighters. Am Rev Respir Dis 1993; 148:974–980
19 Siltzbach LS. Sarcoidosis: clinical features and management. Med Clin N Am 1967; 51:483
20 Bates DV. Normal pulmonary function. In: Bates DV, ed. Respiratory function in disease. 3rd ed. Philadelphia, PA: WB Saunders, 1989; 106–151
21 American Thoracic Society. Standardization of spirometry: 1987 update. Am Rev Respir Dis 1987; 136:1285–1289
22 American Thoracic Society. Single breath carbon monoxide diffusion capacity (transfer factor): recommendations for standard technique. Am Rev Respir Dis 1987; 136:1299–1307
23 Matthews JI, Hooper RG. Exercise testing in pulmonary sarcoidosis. Chest 1983; 83:75–81
24 Miller A, Brown LK, Sloane MF, et al. Cardiorespiratory responses to incremental exercise in sarcoidosis patients with normal spirometry. Chest 1995; 107:323–329
25 Shapiro GG, Bierman CW. Inhalation bronchoprovocation in children. In: Spector SL, ed. Provocative challenge procedures. Mount Kisco, NY: Futura Publishing, 1989; 405–410
26 Jones NL, McHardy GJR, Naimark A, et al. Physiological dead space and alveolar-arterial gas pressure differences during exercise Clin Sci 1966; 31:19–29
27 Wasserman K, Hansen JE, Sue DY, et al. Principles of exercise testing and interpretation. 2nd ed. Philadelphia, PA: Lea & Febiger, 1994; 53–81
28 Athos L, Mohler JG, Sharma OP. Exercise testing in the physiologic assessment of sarcoidosis. Ann NY Acad Sci 1986; 465:491–499
29 Sietsama KE, Kraft M, Ginzton L, et al. Abnormal oxygen uptake responses to exercise in patients with mild pulmonary sarcoidosis. Chest 1992; 102:838–845
30 Lacroniqu J, Auzeby A, Valeyre D, et al. Urinary neopterin in pulmonary sarcoidosis. Am Rev Respir Dis 1989; 139:1474–1478
31 Harris J, Bartelson BB, Barker E, et al. Serum neopterin in chronic beryllium disease. Am J Ind Med 1997; 32:21–26
32 Barnard RJ, Duncan HW. Heart rate and ECG responses in firefighters. J Occup Med. 1975; 17:247–250
33 O'Connell ER, Thomas PC, Cady LD, et al. Energy costs of simulated stair climbing as a job-related task in fire fighting. J Occup Med 1986; 28:282–284
34 Mannning JE, Griggs TR. Heart rates in firefighters using light and heavy breathing equipment: similar near-maximal exertion in response to multiple work load conditions. J Occup Med 1983; 25:215–218
35 American Thoracic Society. Evaluation of impairment/disability secondary to respiratory disorders. Am Rev Respir Dis 1986; 133:1205–1209

# The Incidence, Prevalence, and Severity of Sarcoidosis in New York City Firefighters

David J. Prezant, Atheya Dhala, Andrew Goldstein, Denise Janus, Felipe Ortiz, Thomas K. Aldrich and Kelly J. Kelly

*Chest* 1999;116;1183-1193
DOI 10.1378/chest.116.5.1183