Howard (1970), Bates (1973), Sharp et al. (1973), Fletcher et al. (1976), Fletcher and Peto (1977), Bosse et al. (1981), Beck et al. (1982), and Clement and van de Woestijne (1982). Although these investigations did not characterize the course of airflow obstruction across the entire human lifespan, the results provide a conceptual model for considering its development (Figure 15). Ventilatory function, generally measured by the $FEV_1$, increases during childhood and reaches a maximum level during early adulthood (Cotes 1979; Knudson et al. 1983). From this peak; the $FEV_1$ gradually and progressively declines with age. In people who develop airflow obstruction, a similar gradual loss of function occurs, but at a more rapid rate (Fletcher et al. 1976; Speizer and Tager 1979). Continued excessive loss of $FEV_1$ eventually results in symptomatic airflow obstruction when ventilatory function reaches a level at which activities are limited and dyspnea occurs. Evaluation by a physician for symptoms may lead to a clinical diagnosis at this point in the natural history of the disease process. This model may not satisfactorily describe the development of airflow obstruction in all individuals (Burrows 1981), but the accumulating evidence, reviewed below, indicates that a sustained excessive loss of ventilatory function most often leads to the development of clinically important chronic airflow obstruction.

In the conceptual model (Figure 15), there are three different measures of the frequency of airflow obstruction in a particular population: the prevalence of reduced ventilatory function as measured by the $FEV_1$, the $FEV_1/FVC$ ratio, or other physiological parameters; the prevalence of physician-diagnosed airflow obstruction; and the frequency of excessive functional loss in a population followed over time. The first two measures can be determined from a single cross-sectional survey, whereas the third requires longitudinal observation. At present, scant data are available for the third category. The prevalence of physician-confirmed airflow obstruction is determined not only by the proportion of affected people in the population, but also by the patterns of medical care access and usage and the diagnostic practices of individual physicians. Furthermore, the clinical labels applied by physicians to people with airflow obstruction are variable and may include "chronic bronchitis," "emphysema," "COLD," and other terms. Thus, estimates of disease prevalence based on reported physician diagnoses may differ from those derived from physiological assessment.

## Prevalence of Airflow Obstruction

Numerous populations throughout the world have been surveyed to assess the prevalence of airflow obstruction (Stuart-Harris 1968a, 1968b; Higgins 1974). Most often, the investigative techniques have included a respiratory symptoms questionnaire and measurement of pulmonary function, generally with a spirometer or peak flow meter.

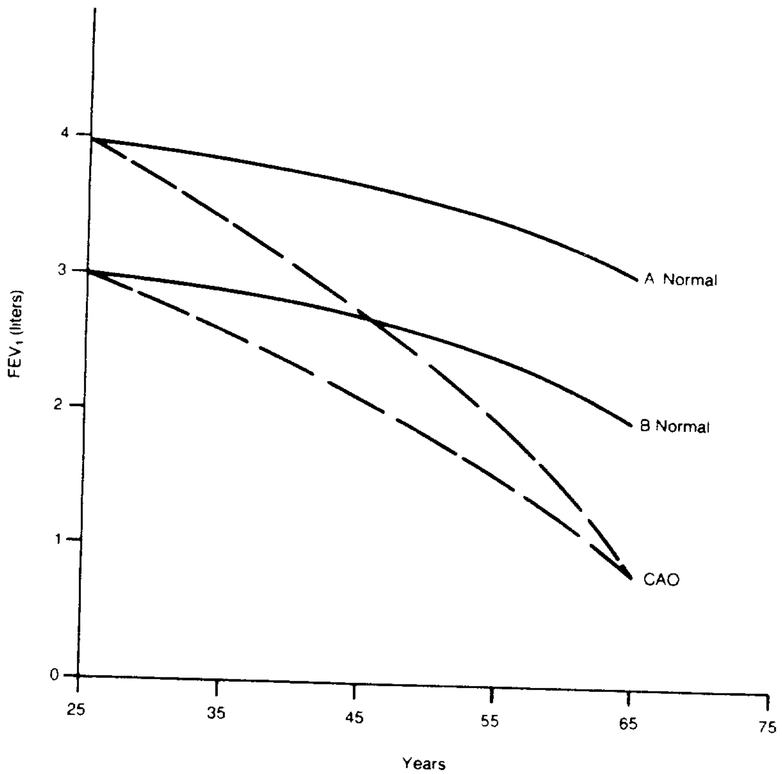

**FIGURE 15.—Decline of FEV$_1$ at normal rate (solid line) and at an accelerated rate (dashed line)**

NOTE: A: person who has attained a "normal" maximal FEV$_1$ during lung growth and development; B: person whose maximal FEV$_1$ has been reduced by childhood respiratory infection.
SOURCE: Samet et al. (1983).

The latter technique has the disadvantage of effort dependence. Early recognition of the potential problem of observer bias led to the development of standardized methods (Cochrane et al. 1951; Higgins 1974; Ferris 1978). Thus, most investigators throughout the world have used the British Medical Research Council questionnaire in the original form or with some modifications (Samet 1978). Standardization has been less uniform for lung function measurements, but minor variations in procedures would not introduce important differences in disease prevalence among the various populations examined.

Although many different populations have been surveyed since the 1950s, surprisingly few published reports provide data concerning the prevalence of airflow obstruction in the general population

(Tables 4 and 5). Comparisons among the available studies are limited by varying methodologies and inconsistent approaches in calculating rates. For example, only crude rates are available in some reports, and reference populations for age standardization also vary. The investigations summarized in Tables 4 and 5 were selected because they offer estimates of the prevalence of airflow obstruction in defined community-based samples. Those reports that describe mean levels of lung function parameters but not their distributions were excluded. Investigations of specific occupational groups were also excluded because prevalence estimates based on such populations may be biased by the overrepresentation of healthy persons (Monson 1980) and workplace exposures may have affected the frequency of disease.

For the United States, the available information spans the time period 1961 to 1979 and covers most geographic regions (Table 4). Regardless of the definition, it is apparent that airflow obstruction is common among adults in the United States. A higher proportion of men than women is affected, and the prevalence increases with age (Ferris and Anderson 1962; USPHS 1973; Lebowitz et al. 1975; Detels et al. 1979; Samet et al. 1982). Few minority populations have been studied. In New Mexico, Hispanic whites had a lower prevalence of physician-diagnosed current chronic bronchitis or emphysema than non-Hispanic whites (Samet et al. 1982). Although blacks have been included in several surveys (Bouhuys et al. 1979), prevalence estimates for this racial group have not been published. The available data (Table 4) do not permit a satisfactory assessment of changes in prevalence rates with time over the years 1961 to 1979.

The National Health and Nutrition Examination Surveys (NHANES 1) included spirometry in their evaluation of a representative sample of the U.S. population. The numerical values for these measures are reported by age, sex, and smoking status for the white population in the tables in the appendix to this chapter. The changes in mean values of these measures between age groups are also presented for white male and female smokers and nonsmokers in Figures 16 through 23. Differences between smokers and nonsmokers are evident for each of these spirometric measures. These differences are portrayed for successive age groups at one point in time, and therefore cannot be used to describe the changes with age or smoking status that one would expect in an individual or population followed sequentially. These data represent only those people in the study population who were willing and physically able to maximally exert themselves on the various spirometry tests. Others were disqualified by the examining physician because of existing medical conditions. The sampling nonresponse was higher among segments of the population expected to perform less well on the test, including people with existing airflow limitation. Therefore,

## TABLE 4.—Prevalence of indices of airflow obstruction in selected U.S. adult populations

| Author, year of study, location, reference | Number and type of population | Index | Prevalence (per 100) |
|---|---|---|---|
| Higgins and Kjelsberg, 1959–1960, Tecumseh, Michigan (*1967*) | 4,500 men and women, 20 years or older, community sample | Emphysema based on physician history and examination | Men 4.1[1]<br>Women 1.1[1] |
| Higgins, 1962–1979, Tecumseh, Michigan (*1983*) | 4,916, 4,443, and 4,930 men and women, 16 to 74 years old, in 1962–65, 1967–69, 1978–79 | Obstructive airways disease: $FEV_1$ less than 65% predicted, and $FEV_1/FVC$ ratio less than 80% | Men Women<br>1962–65 4.8[2] 2.5[2]<br>1967–69 3.7[2] 1.4[2]<br>1978–79 3.7[2] 2.2[2] |
| Ferris and Anderson, 1961, Berlin, New Hampshire (*1962*) | 1,167 men and women, community sample | Irreversible obstructive lung disease, including wheezing, dyspnea, or $FEV_1/FVC$ ratio less than 60% | Men 8.6[1]<br>Women 8.1[1] |
| Mueller et al., 1967, Glenwood Springs, Colorado (*1971*) | 609 men and women, community sample | Chronic airway obstruction: $FEV_1/FVC$ ratio less than 60% | Men 13.2[1]<br>Women 1.5[1] |
| U.S. Public Health Service, 1970, United States (*1973*) | 116,000 men and women, nationwide sample | Presence of the condition during the previous year | Chronic bronchitis<br>Men 3.1[1]<br>Women 3.4[1]<br>Emphysema<br>Men 1.0[1]<br>Women 0.3[1] |

## TABLE 4.—Continued

| Author, year of study, location, reference | Number and type of population | Index | Prevalence (per 100) |
|---|---|---|---|
| Lebowitz et al., 1972–1973, Tucson, Arizona (*1975*) | 3,805 men and women, adults and children, community sample | Physician-confirmed illness, current | Men over 44 years<br>Chronic bronchitis 10.2<br>Emphysema 13.3[1]<br>Women over 44 years<br>Chronic bronchitis 9.0[1]<br>Emphysema 4.3[1] |
| Knudson et al., 1972–1973, Tucson, Arizona (*1976*) | 3,805 men and women, adults and children, community sample | $FEV_1$ and $FEV_1/FVC$ ratio lower than 95th percentile for "normal" | Asymptomatic cigarette smokers<br>$FEV_1$ 7.8[1]<br>$FEV_1/FVC$ 8.1[1] |
| Detels et al., 1973–1974, Burbank and Lancaster, California (*1979*) | 3,465 and 4,509 men and women, in Burbank and Lancaster, respectively, community samples | $FEV_1$ less than 50% of predicted value | Lancaster<br>18–59 yrs 0.8[2]<br>60 yrs 6.5[2]<br>Burbank<br>18–59 yrs 1.0[2]<br>60 yrs 6.2[2] |
| Tager et al., 1973-1974, East Boston, Massachusetts (*1978*) | 1,770 men and women, community sample of index subjects and their relatives | $FEV_1$ less than 65% of predicted | Men 5.6[1]<br>Women 3.4[1] |
| Ferris et al., 1974–1977, six cities in the U.S. (*1979*) | 7,909 men and women, community sample | $FEV_1/FVC$ less than, equal to 60% | Men 5.0[1]<br>Women 1.9[1] |

## TABLE 4.—Continued

| Author, year of study, location, reference | Number and type of population | Index | Prevalence (per 100) | |
|---|---|---|---|---|
| Samet et al., 1978–1979, Albuquerque, New Mexico (*1982*) | 1,722 men and women, community sample | Physician-diagnosed current chronic bronchitis or emphysema | Non-Hispanic whites | |
| | | | Men | 3.6[2] |
| | | | Women | 3.4[2] |
| | | | Hispanic whites | |
| | | | Men | 0.8[2] |
| | | | Women | 1.8[2] |

[1] Crude rate.

[2] Age-adjusted rate.

[3] Age and sex-adjusted rate.

## TABLE 5.—Prevalence of indices of airflow obstruction in selected adult non-U.S. populations

| Author, year of study, location, reference | Number and type of population | Index | Prevalence (per 100) | |
|---|---|---|---|---|
| Anderson et al., 1963, Chilliwack, British Columbia (*1965*) | 558 men and women, community sample | Obstructive lung disease, including wheezing, dyspnea, or $FEV_1/FVC$ ratio less than 60% | Men<br>Women | 12.6[1]<br>8.7[1] |
| | | $FEV_1/FVC$ ratio less than 60% | Men<br>Women | 7.3[1]<br>3.5[1] |
| Mimica, 1969, Croatia, Yugoslavia (*1975*) | 4,214 men and women, samples of six communities | $FEV_1/FVC$ ratio less than 60% | Men<br>Women | 8.3[1]<br>1.9[1] |
| Sawicki, 1968, Krakow, Poland (*1977*) | 4,355 men and women, community sample | $FEV_1/FVC$ ratio less than 60% | Men<br>Women | 7.0[1]<br>5.0[1] |
| Huhti et al., 1968-1970, Hankasalmi, Finland (*1978*) | 1,162 men, community sample | $FEV_1/FVC$ ratio less than 60% | Men | 7.6[1] |
| Brown and Gajdusek, year not stated, Western Caroline Islands (*1978*) | 240 men and women, community sample | Chronic obstructive airway disease: clinical and spirometric criteria | Men and women | 7.9[1] |
| Anderson, year not stated, Lufa, Papua New Guinea (*1979*) | 770 men and women, 25 years or older, community sample | $FEV_1/FVC$ ratio less than 60% | Men<br>Women | 9.0[1]<br>3.6[1] |

[1] Crude rate.

the estimated means are probably overestimates of the true population values. Nevertheless, the figures clearly portray the magnitude of the effect that smoking exerts on expiratory flow rates in a national population sample.

Airflow obstruction is also prevalent outside the United States (Table 5). The disease can be identified in both technologically advanced and less developed populations. As in the United States, in other countries the prevalence of airflow obstruction is higher among men than among women.

## Determinants of Airflow Obstruction

### *Introduction*

Current understanding of the natural history of airflow obstruction suggests that risk factors operative during both childhood and adulthood may influence the development of disease. In the conceptual model proposed in Figure 15, childhood factors might increase the risk of airflow obstruction by lowering the maximum $FEV_1$ attained during lung growth and development, by predisposing to increased $FEV_1$ decline during adulthood, or by both mechanisms (Speizer and Tager 1979). During adulthood, in the model of Figure 15, risk factors for airflow obstruction must increase the rate at which lung function deteriorates.

Many endogenous and exogenous determinants of the development of airflow obstruction have been postulated (Tables 6 and 7). However, in spite of over 30 years of intensive investigation, the available data are definitive only for cigarette smoking and for $\alpha_1$-antitrypsin deficiency (Speizer and Tager 1979; USDHHS 1980).

### *Cigarette Smoking and Chronic Airflow Obstruction*

In nearly every population studied worldwide, cigarette smoking is the predominant determinant for the prevalence of airflow obstruction (Tables 8, 9, and 10). The uncommon exceptions primarily involve populations in whom severe chest infections or wood smoke exposure may have an etiological role (Woolcock et al. 1973; Anderson 1979a). The relationship between cigarette smoking and airflow obstruction has been variably described in the published reports. In some, the prevalence of airflow obstruction has been considered; in others, mean values of lung function parameters have been compared across categories of smoking use. In several more recent analyses, multiple regression or other multivariate techniques have been used for more careful characterization of dose-response relationships. Because the epidemiologic criteria for airflow obstruction are generally based on the $FEV_1$, this section focuses on studies that have included measurements of this parameter. The selected studies involve community samples (Tables 8 and 9) and

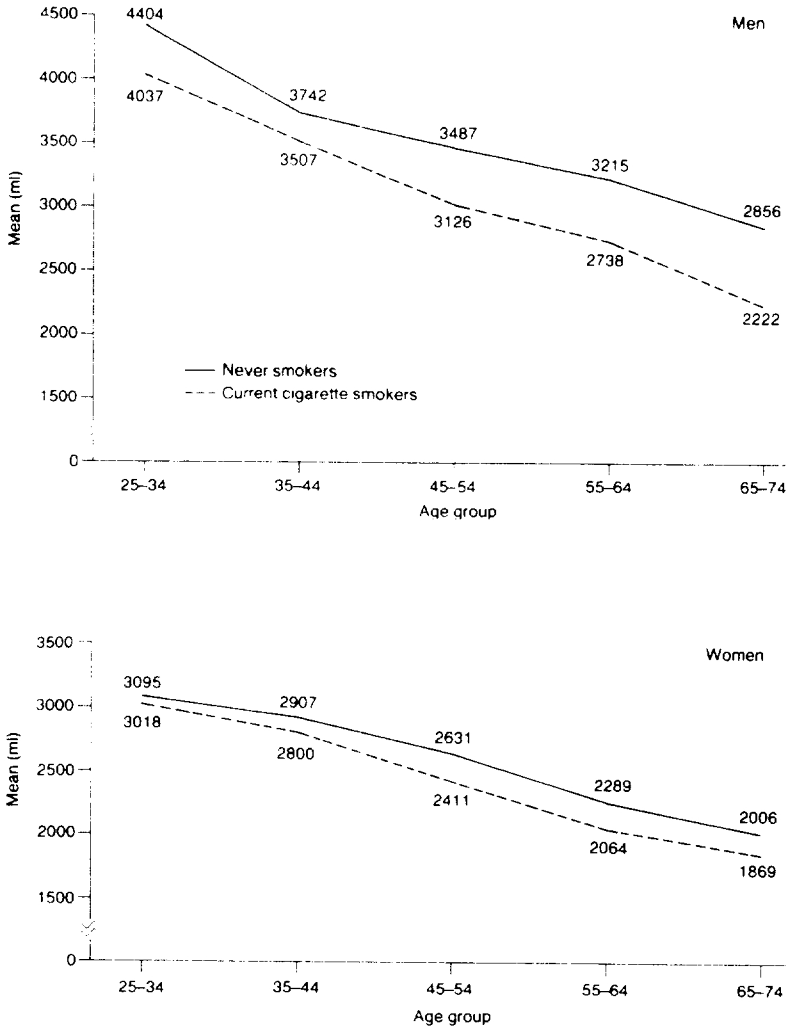

**FIGURE 16.—Mean FEV$_1$ for white persons by smoking status, sex, and age, United States, 1971–1975**

NOTE: Values adjusted by the direct method to reflect the age distribution of the U.S. population at the midpoint of the survey.

SOURCE: National Center for Health Statistics. Unpublished data from the first National Health Nutrition and Examination Survey (NHANES 1).

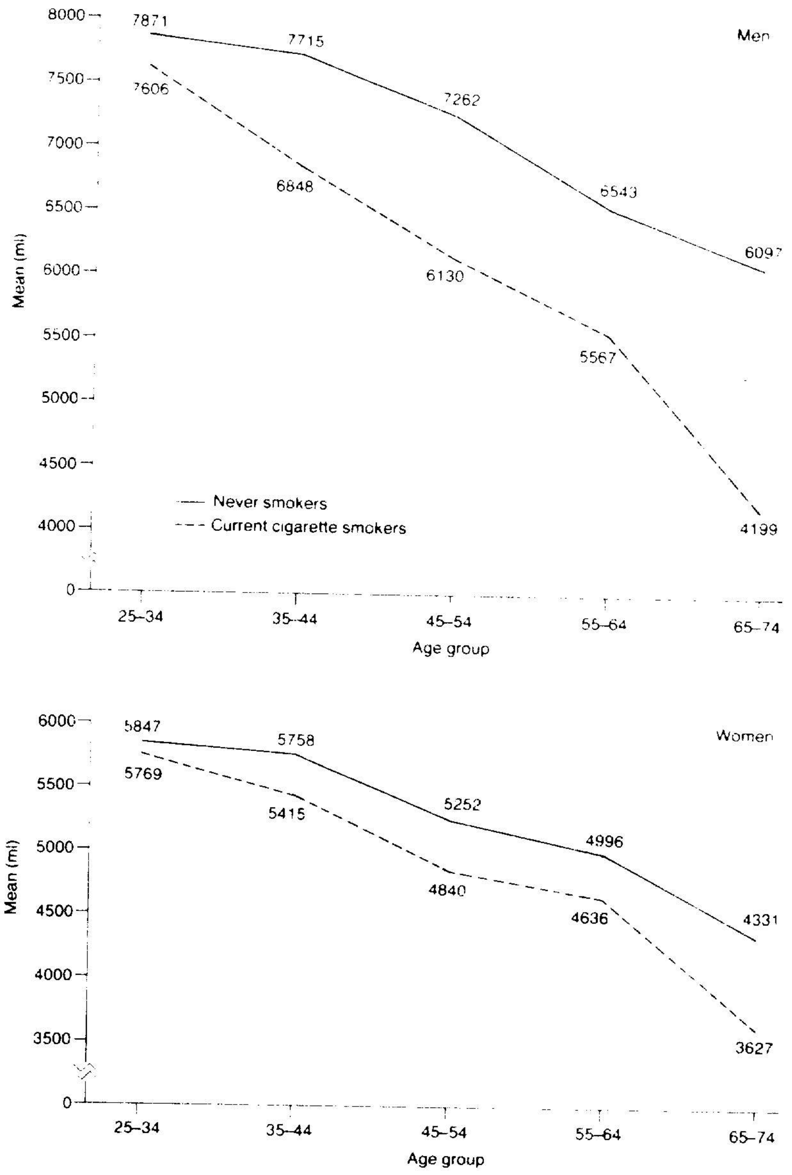

**FIGURE 17.—Mean flow at 25 percent of FVC for white persons by smoking status, sex, and age, United States, 1971–1975**

NOTE: Values adjusted by the direct method to reflect the age distribution of the U.S. population at the midpoint of the survey.

SOURCE: National Center for Health Statistics. Unpublished data from the first National Health Nutrition and Examination Survey (NHANES I).

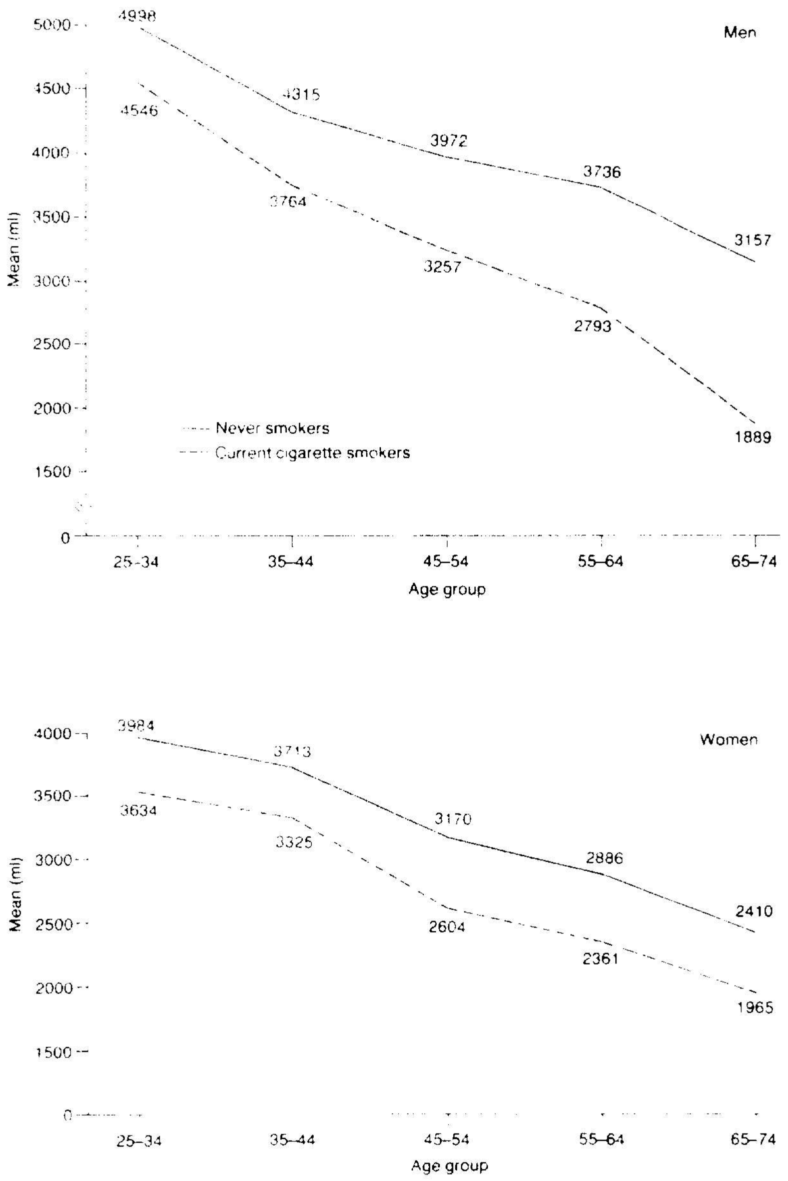

**FIGURE 18.—Mean flow at 50 percent of FVC for white persons by smoking status, sex, and age, United States, 1971–1975**

NOTE: Values adjusted by the direct method to reflect the age distribution of the U.S. population at the midpoint of the survey.

SOURCE: National Center for Health Statistics. Unpublished data from the first National Health Nutrition and Examination Survey (NHANES I).

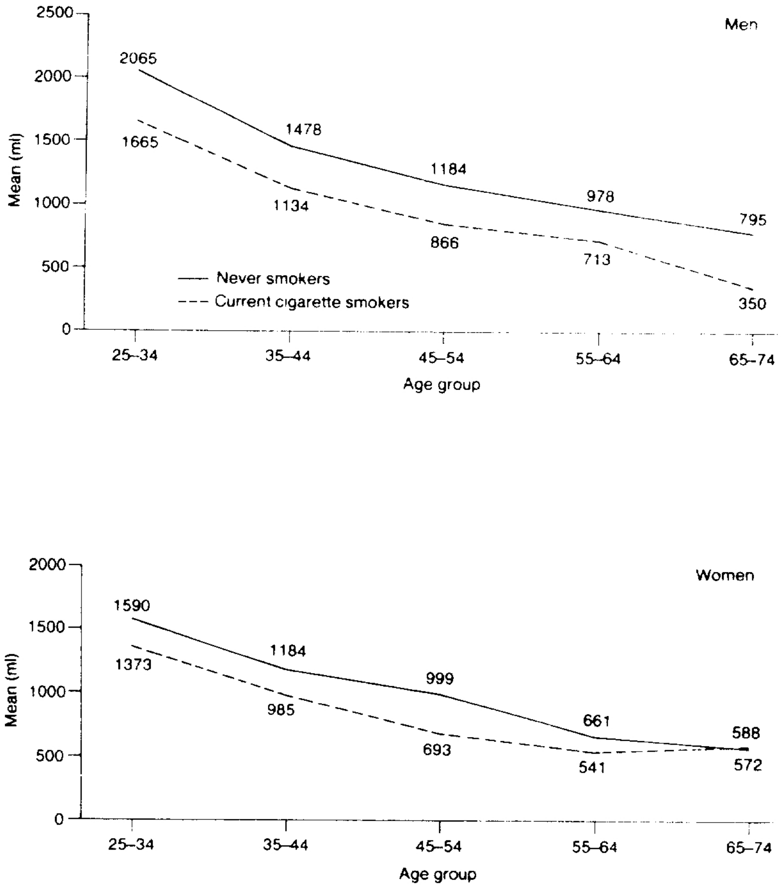

**FIGURE 19.—Mean flow at 75 percent of FVC for white persons by smoking status, sex, and age, United States, 1971–1975**

NOTE: Values adjusted by the direct method to reflect the age distribution of the U.S. population at the midpoint of the survey.

SOURCE: National Center for Health Statistics. Unpublished data from the first National Health Nutrition and Examination Survey (NHANES 1).

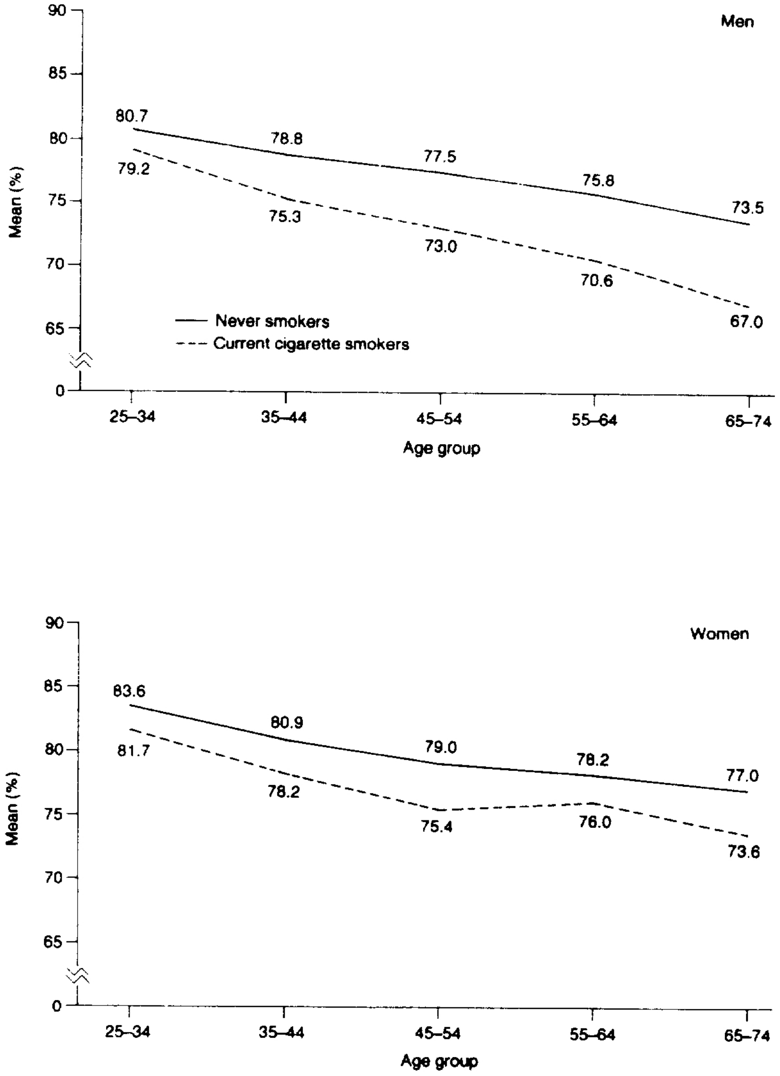

**FIGURE 20.—Mean FEV$_1$/FVC ratio for white persons by smoking status, sex, and age, United States, 1971–1975**

NOTE: Values adjusted by the direct method to reflect the age distribution of the U.S. population at the midpoint of the survey.

SOURCE: National Center for Health Statistics. Unpublished data from the first National Health Nutrition and Examination Survey (NHANES 1).

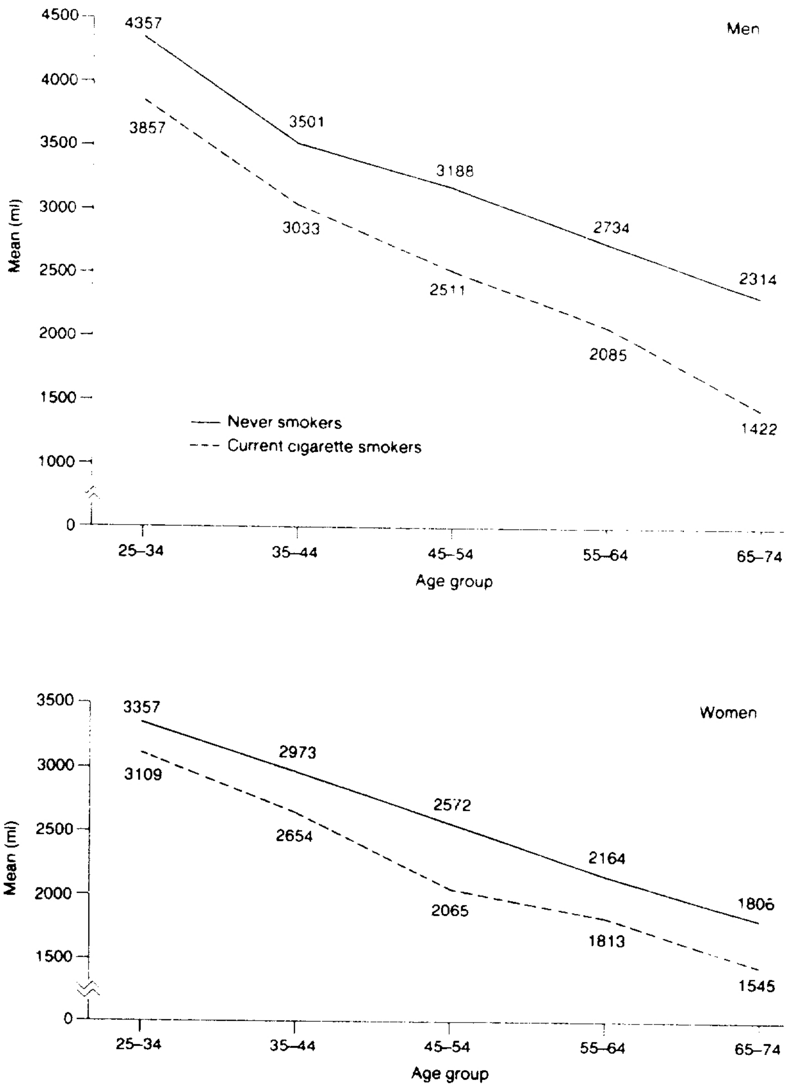

**FIGURE 21.—Mean MMEF for white persons by smoking status, sex, and age, United States, 1971–1975**

NOTE: Values adjusted by the direct method to reflect the age distribution of the U.S. population at the midpoint of the survey.

SOURCE: National Center for Health Statistics. Unpublished data from the first National Health Nutrition and Examination Survey (NHANES 1).

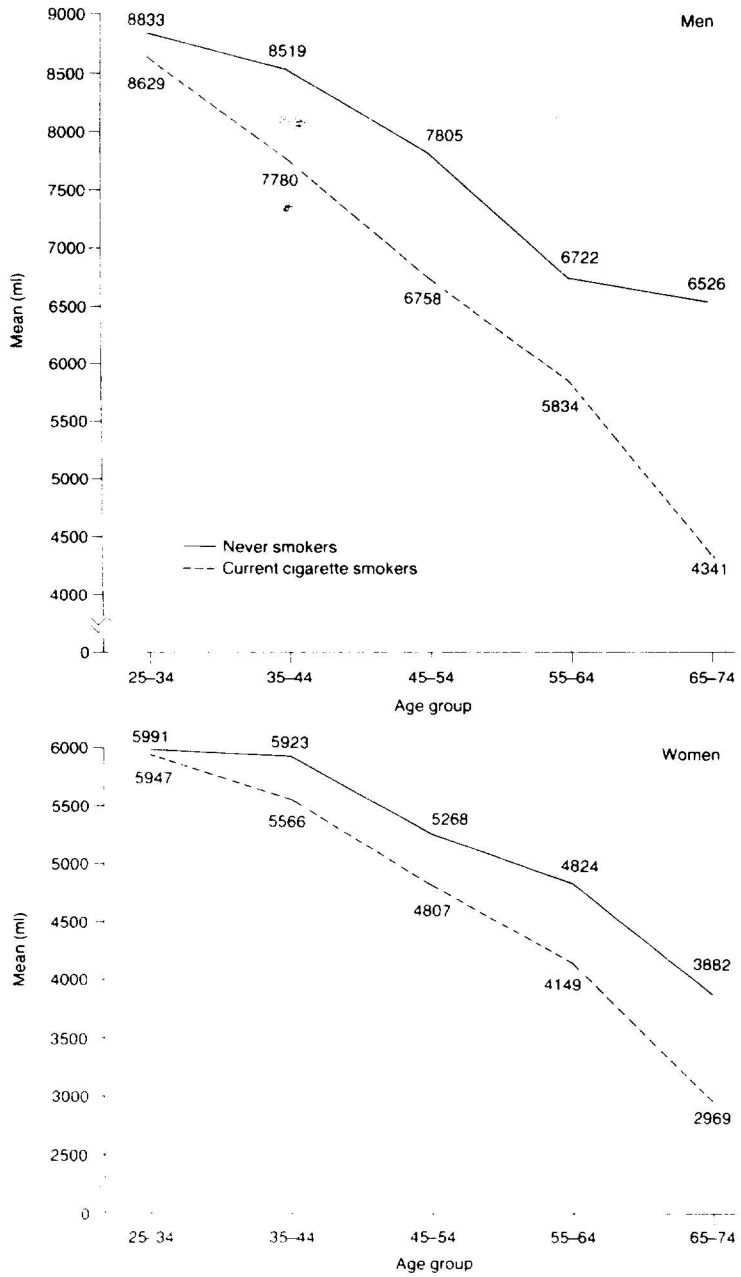

**FIGURE 22.—Mean MEFR for white persons by smoking status, sex, and age, United States, 1971-1975**

NOTE: Values adjusted by the direct method to reflect the age distribution of the U.S. population at the midpoint of the survey.

SOURCE: National Center for Health Statistics. Unpublished data from the first National Health Nutrition and Examination Survey (NHANES 1).

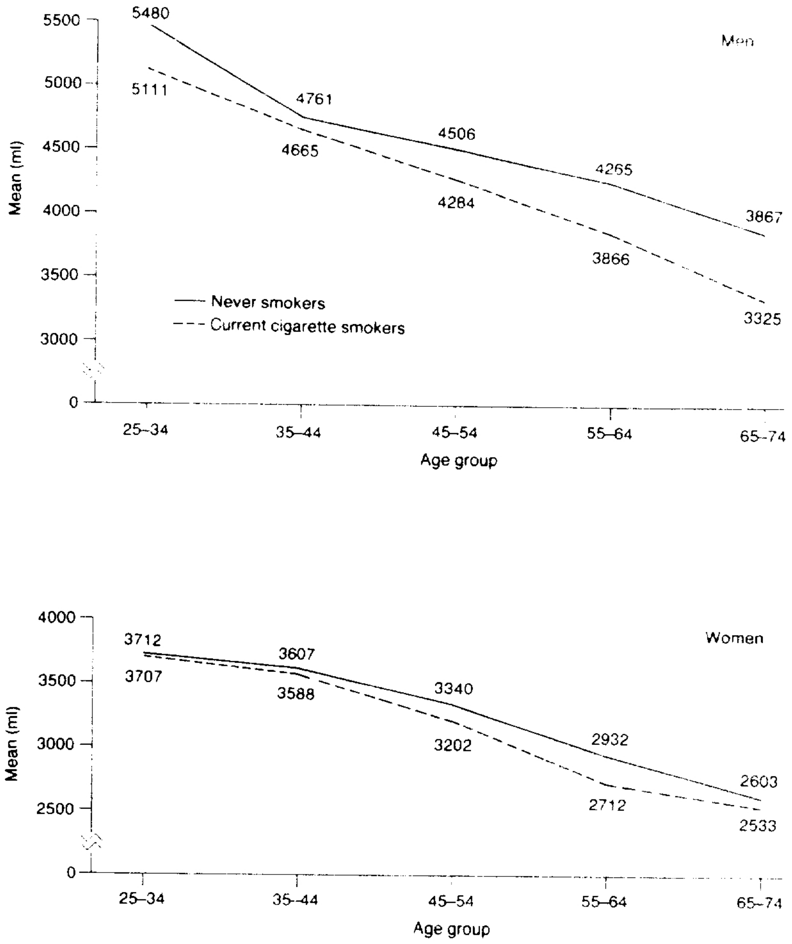

**FIGURE 23.—Mean forced vital capacity for white persons by smoking status, sex, and age, United States, 1971–1975**

NOTE: Values adjusted by the direct method to reflect the age distribution of the U.S. population at the midpoint of the survey.

SOURCE: National Center for Health Statistics. Unpublished data from the first National Health Nutrition and Examination Survey (NHANES 1).

TABLE 6.—Postulated risk factors for airflow obstruction during childhood

| |
|---|
| Active cigarette smoking |
| Air pollution, indoor and outdoor |
| Airways hyperreactivity |
| Atopy |
| Familial factors |
| Passive exposure to tobacco smoke |
| Respiratory illnesses |
| Socioeconomic status |

TABLE 7.—Morbidity

| ESTABLISHED RISK FACTORS FOR AIRFLOW OBSTRUCTION DURING ADULTHOOD |
|---|
| Active cigarette smoking |
| Alpha$_1$-antitrypsin deficiency |
| PUTATIVE RISK FACTORS FOR AIRFLOW OBSTRUCTION DURING ADULTHOOD |
| ABH secretor status |
| Air pollution |
| Airways hyperreactivity |
| Alcohol consumption |
| Atopy |
| Childhood respiratory illnesses |
| Familial factors |
| Occupation |
| Passive exposure to tobacco smoke |
| Respiratory illnesses |
| Socioeconomic status |

occupational groups (Table 10) with exposures that have little or no effect on lung function. The selected studies are all cross sectional in design and thus describe the relationship between cigarette smoking and lung function level at only a single point in time.

Investigations in the United States, spanning the time period 1958 to 1977, convincingly demonstrate that cigarette smoking is a strong determinant of FEV$_1$ level and the prevalence of airflow obstruction (Table 8). In every population for which prevalence data are available, airflow obstruction is more common among smokers than among nonsmokers (Mueller et al. 1971; Knudson et al. 1976; Detels et al. 1979; Rokaw et al. 1980). In fact, in a multivariate analysis of determinants of airflow obstruction in East Boston, lifetime cigarette consumption was the only statistically significant predictor (Tager et al. 1978). Data from populations outside the United States (Table 9) and from a variety of occupational groups (Table 10) confirm the importance of cigarette smoking. Effects of cigarette smoking on FEV$_1$ level have been readily demonstrated in employed populations

## TABLE 8.—Association between cigarette smoking and $FEV_1$ level in selected U.S. adult populations

| Author, year of study, location, reference | Number and type of population | Findings | | |
|---|---|---|---|---|
| Ashley et al., 1958, Framingham, Massachusetts, (*1975*) | 1,238 men and women, 37 to 69 years of age | By linear regression, significant decline of $FEV_1/FVC$ ratio with pack-years of cigarette consumption in men; similar decline demonstrated in women, but not significant for all age groups | | |
| Higgins and Kjelsberg 1959–1960, Tecumseh, Michigan (*1967*) | 5,140 men and women, 16 to 79 years of age | Age-adjusted mean $FEV_1$ (liters) | | |
| | | | Men | Women |
| | | Nonsmokers | 3.32 | 2.34 |
| | | Ex-smokers | 3.31 | 2.34 |
| | | Current smokers | 3.12 | 2.28 |
| Higgins et al., 1963, Marion County, West Virginia (1968a) | 926 white men, 20 to 69 years of age | Mean $FEV_1$ (liters) | | |
| | | Nonsmokers | 3.64 | |
| | | Ex-smokers | 3.25 | |
| | | Current smokers | | |
| | | 1-14/day | 3.67 | |
| | | 15–24/day | 3.51 | |
| | | ≥25/day | 3.30 | |
| Higgins et al., 1962–1965, Tecumseh, Michigan (*1977*) | 4,669 men and women, 20 to 74 years of age | Mean normalized $FEV_1$ score | | |
| | | | Men | Women |
| | | Nonsmokers | 10.2 | 10.1 |
| | | Ex-smokers | 9.9 | 10.0 |
| | | Current smokers | | |
| | | <20/day | 9.8 | 9.9 |
| | | ≥20/day | 9.5 | 9.6 |

TABLE 8.—Continued

| Author, year of study, location, reference | Number and type of population | Findings |
|---|---|---|
| Mueller et al., 1967, Glenwood, Colorado (*1971*) | 609 men and women, 20 to 69 years of age | Prevalence of $FEV_1/FVC < 60\%$<br>Men Women<br>Nonsmokers 3 1<br>Current smokers 19 2 |
| Ferris et al., 1967, Berlin, New Hampshire (*1973*) | 848 men and women, 30 to 80 years of age | By multiple regression, in men and women, $FEV_1$ drops by 0.01 liters for each cigarette smoked per day |
| Burrows et al., 1972–1973, Tucson, Arizona (*1977*) | 2,369 men and women, above 14 years of age | By multiple regression analysis, $FEV_1$ drops by 0.31 and 0.24 percent of predicted value per pack-year of smoking in men and women, respectively |
| Knudson et al., 1972–1973, Tucson, Arizona (*1976*) | 2,735 men and women, all ages | Prevalence (%) of abnormal $FEV_1$ and/or $FEV_1/FVC$<br>Asymptomatic nonsmokers 8.3<br>Asymptomatic smokers 13.3 |
| Tager and Speizer, 1973–1974, East Boston, Massachusetts (*1976*) | 633 men and women, 15+ years of age | By multiple regression, in men and women, significant reduction of an $FEV_1$ score with increasing lifetime consumption, and in smokers compared with nonsmokers |
| Tager et al., 1973–1974, East Boston, Massachusetts (*1978*) | 1,251 men and women, | By multiple logistic analysis, lifetime cigarette consumption only significant predictor of airflow obstruction, defined as $FEV_1$ less than 65% predicted |
| Beck et al., 1972–1974, Lebanon and Ansonia, Connecticut, Winnsboro, South Carolina (*1981*) | 4,690 men and women, 7+ years of age | By multiple regression analysis, significant dose–response relationships of adjusted residual $FEV_1$ with measures of cigarette smoking: duration, pack-years, and cigarettes per day |

## TABLE 8.—Continued

| Author, year of study, location, reference | Number and type of population | Findings | | |
|---|---|---|---|---|
| Ferris et al., 1974–1977, U.S. communities (*1979*) | 8,480 men and women, 25 to 74 years of age | Mean residual $FEV_1$ (liters) after correction for height and age | | |
| | | Lifetime packs | Men | Women |
| | | None | 0.25 | 0.06 |
| | | <3,000 | 0.21 | 0.04 |
| | | 3,000–8,999 | 0.01 | –0.05 |
| | | 9,000–17,999 | –0.19 | –0.20 |
| | | ≥18,000 | –0.45 | –0.28 |
| Detels et al., Rokaw et al., 1973–1975, Burbank, Lancaster, Long Beach, California (Detels et al., 1979, Rokaw et al., 1980) | Approximately 8,000 men and women, 18 years or older | Prevalence (%) of $FEV_1$ below 75% predicted, age and sex-adjusted | | |
| | | | Never smoked | Current smoker |
| | | 18–59 years old | | |
| | | Burbank | 6.6 | 12.5 |
| | | Lancaster | 3.4 | 6.6 |
| | | Long Beach | 5.3 | 10.0 |
| | | ≥60 years old | | |
| | | Burbank | 15.9 | 23.5 |
| | | Lancaster | 13.4 | 21.7 |

# TABLE 9.—Association between cigarette smoking and lung function in selected non-U.S. populations

| Author, year of study, location, reference | Number and type of population | Findings | | |
|---|---|---|---|---|
| Higgins, 1956, Vale of Glamorgan, Wales (*1957*) | 581 men and women, 25 to 74 years of age | In men, reduced peak flow rates and indirect maximum voluntary ventilation in smokers compared with nonsmokers; no effect of smoking in women | | |
| Higgins et al., 1957 Stavely, England (*1959*) | 776 men, aged 25 to 34 and 55 to 64 | Mean indirect maximal breath capacity (liters) | | |
| | | | 25 to 34 yrs | 55 to 64 yrs |
| | | Nonsmokers | 145 | 101 |
| | | Ex-smokers | 143 | 89 |
| | | Current smokers | | |
| | | Light | 140 | 87 |
| | | Heavy | 133 | 80 |
| Higgins et al., 1958, Rhondda Fach, Wales (*1961*) | 537 men, aged 35 to 64, and 173 women, aged 55 to 64 | Mean indirect maximal breathing capacity (liters), men | | |
| | | | Miners | Nonminers |
| | | Nonsmokers | 93.1 | 114.6 |
| | | Ex-smokers | 93.6 | 105.9 |
| | | Current smokers | | |
| | | Light | 89.0 | 104.1 |
| | | Heavy | 88.3 | 99.4 |
| | | No effect of smoking in women | | |

## TABLE 9.—Continued

| Author, year of study, location, reference | Number and type of population | Findings | | |
|---|---|---|---|---|
| College of General Practitioners, 1958, Britain (*1961*) | 787 men and 782 women, aged 40 to 64 | Age-adjusted mean PEFR[1] (liters/minute) | | |
| | | | Men | Women |
| | | Nonsmokers | 448 | 318 |
| | | Ex-smokers | 417 | 300 |
| | | Current smokers | | |
| | | 1–14/day | 412 | 314 |
| | | 15–24/day | 399 | 310 |
| | | ≥ 25/day | 398 | 265 |
| Sluis-Cremer and Sichel, 1962–1963, Carletonville, South Africa (*1968*) | 533 men, 35 years or older | Reduced $FEV_1$ and PEFR[1] with increased tobacco consumption | | |
| Huhti, 1961, Harjavalta, Finland (*1967*) | 420 men, 608 women, aged 40 to 64 | All women, nonsmokers; in men, reduced $FEV_1$ and PEFR[1] in smokers compared with nonsmokers | | |
| Wilhelmsen et al., 1963, Göteborg, Sweden (*1969*) | 339 men, aged 50 | Mean $FEV_1$ (liters) | | |
| | | Nonsmokers | 3.72 | |
| | | Ex-smokers | 3.71 | |
| | | Current smokers | | |
| | | 1–14 g/day | 3.58 | |
| | | ≥ 15 g/day | 3.36 | |
| Huhti et al., 1968–1970, Hankasalmi, Finland (*1978*) | 1,162 men, aged 25 to 69 | Reduced $FEV_1$ in smokers compared with nonsmokers; increased prevalence of $FEV_1$/FVC ratio less than 60% in smokers | | |

## TABLE 9.—Continued

| Author, year of study, location, reference | Number and type of population | Findings | | |
|---|---|---|---|---|
| Mimica, 1969, Croatia, Yugoslavia (*1975*) | 4,214 men and women, 35 to 54 years of age | | Mean $FEV_1$ (liters) | |
| | | | Men | Women |
| | | Nonsmokers | 3.58 | 2.62 |
| | | Ex-smokers | 3.57 | 2.70 |
| | | Current smokers | | |
| | | Light | 3.42 | 2.64 |
| | | Heavy | 3.42 | 2.60 |
| Neri et al., 1969–1973, Sudbury and Ottawa, Canada (*1975*) | 5,488 men and women, 14 years of age or older | Declining ratio of $FEV_1/FVC$ with number of cigarettes smoked daily | | |
| Manfreda et al., 1974, Portage la Prairie and Charleswood, Canada (*1978*) | 502 men and women, 25 to 55 years of age | Significant regression of $FEV_1/FVC$ ratio on number of cigarettes smoked daily | | |
| Anderson, year not stated, Karkar Island, Papua New Guinea (*1976*) | 548 men and women, 25 years of age or older | | Age and height-adjusted mean $FEV_1$ (liters) | |
| | | | Men | Women |
| | | Nonsmokers | 2.56 | 2.13 |
| | | Smokers | 2.40 | 2.01 |
| Anderson, year not stated, Lufa, Papua New Guinea (*1979*) | 733 men and women 25 years of age or older | | Age and height-adjusted mean $FEV_1$ (liters) | |
| | | | Men | Women |
| | | Nonsmoker | 2.58 | 2.36 |
| | | Ex-smoker | 2.62 | 2.27 |
| | | Occasional | 2.57 | 2.29 |
| | | Regular | 2.63 | 2.43 |

[1] Peak expiratory flow rate

## TABLE 10.—Association between cigarette smoking and lung function level in selected occupational groups

| Author, year of study, location, reference | Number and type of population | Findings | |
|---|---|---|---|
| Sharp et al., 1960–1961, Chicago, U.S. (*1965*) | 1,887 men, aged 43 to 58 years, employed at an electronics plant | Mean $FEV_1$ (liters) | |
| | | Nonsmokers | 3.15 |
| | | Smokers | |
| | | < one pack per day | 3.02 |
| | | ≥ one pack per day | 2.90 |
| Fletcher et al., 1961, London, England (*1976*) | 1,136 men aged 30 to 59, employed at bank or in maintenance of transportation equipment | Adjusted $FEV_1$ (liters) | |
| | | Nonsmokers | 3.28 |
| | | Ex-smokers | 3.16 |
| | | Current smokers | |
| | | 1–4 cigarettes/day | 2.81 |
| | | 5–14 cigarettes/day | 3.05 |
| | | 15–24 cigarettes/day | 2.99 |
| | | ≥ 25 cigarettes/day | 2.94 |
| Goldsmith et al., 1961, San Francisco, U.S. (*1962*) | 3,311 longshoremen | Mean $FEV_1$ percent of predicted value | |
| | | Never smokers | 100 |
| | | Ex-smokers | 97 |
| | | Current smokers | |
| | | 10 cigarettes/day | 93 |
| | | 11–39 cigarettes/day | 93 |
| | | ≥ 40 cigarettes/day | 94 |

## TABLE 10.—Continued

| Author, year of study, location, reference | Number and type of population | Findings |
|---|---|---|
| Balchum et al., 1961, Los Angeles, U.S. (*1962*) | 1,456 men employed in various industries | Prevalence (per 100) of $FEV_1/FVC$ ratio less than 70 percent<br>Nonsmokers 7.6<br>Smokers 18.8 |
| Coates et al., 1962, Detroit, U.S. (*1965*) | 1,584 male and female postal employees, aged 40 or older | Reduced $FEV_1$ and $FEV_1/FVC$ ratio in smokers of 25 or more cigarettes daily compared with nonsmokers |
| Densen et al., 1961–1963, New York City, U.S. (*1969*) | 12,500 males employed as postal or transit workers | Age- and height-adjusted $FEV_1$ (liters)<br>Postal workers: White, Nonwhite; Transit workers: White, Nonwhite<br>Nonsmokers 3.29 3.05 3.39 3.08<br>Cigarette smokers<br>$<25$ g per day 3.14 2.95 3.15 3.00<br>$\geq 25$ g per day 3.06 2.93 3.02 2.95 |
| Bandé et al., 1960–1975, Belgium (*1980*) | 7,123 male military personnel, a few over age 45 | By multiple regression, in cross-sectional analysis, significant effect of smoking on $FEV_1$ level after age 35 |
| Comstock et al., 1962–1963 and 1967, U.S. and Japan (*1973*) | Three cross-sectional studies of men working for telephone company; U.S.—1,302 and 1,194 subjects, aged 40 to 65, 6% in study; Japan—592 subjects, aged 40 to 60 | Mean $FEV_1$ level as percent predicted<br>U.S.: Study 1, Study 2; Japan<br>Cigarettes per day<br>None 106 103 99<br>1–14 104 101 100<br>15–24 98 92 98<br>$\geq 25$ 95 93 99 |