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Pulmonary Physiological Measurements in Smokers and Nonsmokers

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The lung function of 163 middle-aged military officers was studied in relation to smoking habits. The 113 habitual cigarette smokers were found to have significantly lower average ventilatory capacities and increased residual volumes as compared with 50 nonsmokers. Although most subjects in both groups were within normal range, there were significantly more smokers who demonstrated abnormal results to tests of maximum voluntary ventilation, timed vital capacity, and residual volume. Habitual smokers also admitted to chronic cough and shortness of breath with greater frequency than did nonsmokers, although the differences were not statistically significant. The authors conclude that these differences cannot be explained on any factor other than that one group smoked and the other group did not.

aware of an increasing interest in the pulmonary physiological effect of long-term use of tobacco among healthy individuals,⁶⁻¹¹ and studies have invariably showed decreased physiological measurements in smokers. We have recently had the opportunity to evaluate ventilatory function and lung volume in a group of middle-aged military officers in connection with their annual physical examinations. The results of these tests are assessed in relation to the patients' smoking habits.

Material and Methods

Subjects were senior Air Force officers, aged 38 to 57, approximately 55% of whom were flying personnel (pilots, navigators, and so on). Subjects were hospitalized on the evening prior to testing. A complete medical history and physical examination was accomplished by an internist, and significant cardiac or pulmonary disease was excluded on the basis of history and physical findings, chest x-ray, electrocardiogram, and double Masters exercise test. In order to eliminate any acute effects of smoking, we asked the subjects to refrain from smoking, beginning at bedtime on the day prior to testing. Excellent cooperation was obtained. On reporting to the pulmonary function laboratory at 11:00 AM, each subject answered a brief questionnaire relative to past and present respiratory disease, symptoms, and smoking habits. For the purposes of analysis of results, those individuals who habitually smoked cigarettes at the time of examination were classified as smokers, and those who had never smoked or who had smoked only very occasionally in the past were classified as non-

THE RELATIONSHIP between cigarette smoking and chronic bronchopulmonary disease has been the subject of much discussion, speculation, and investigation in recent years. The frequent association between cigarette smoking and the syndromes of chronic cough, bronchitis, and pulmonary emphysema has been noted and reported.¹⁻⁷ We are

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smokers. Pipe, cigar, and ex-cigarette smokers were excluded. This left 163 subjects, 113 smokers and 50 nonsmokers. Smoking histories varied from a minimum of 15 to more than 25 years. A comparison of various physical factors in these two groups shows them to be comparable in other respects (Table 1). Cigarette smokers were further divided into two groups: those who professed to smoking one package of cigarettes daily or fewer (moderate) and those who consumed more than one package per day (heavy).

The following parameters were evaluated and compared:

1. Maximum voluntary ventilation (MVV) was determined with the use of a 13-liter respirometer. The "normal" or predicted value was calculated according to the formula of Baldwin et al.,¹³ and results expressed as a percentage of the predicted MVV.

2. The one-second and three-second vital capacities (FEV₁, and FEV₃) were determined with a vitalometer, and results expressed as a percentage of the total vital capacity.

3. Lung volumes were determined by the closed circuit helium dilution method, with the use of a gas analyzer-respirometer, and the ratio of residual volume to total lung capacity (RV/TLC x 100) was calculated.

Results

The questionnaire form was extremely brief and included questions relative to history or present symptoms of (1) asthma or wheezing, (2) pneumonia, (3) chronic cough, and (4) shortness of breath. The questions were worded simply, "Do you have or have you ever had . . .," and no attempt was made, in the laboratory or subsequently, to further elaborate on the "yes" or "no" answers. It was emphasized that this was purely for statistical purposes and would not become a part of the medical record, since many of these men are prone to minimize symptoms. The results of the history and symptom questionnaire are tabulated in Table 2.

No consistent or significant difference was noted between smokers and nonsmokers with respect to asthma, wheezing, or pneumonia. Symptoms of cough and shortness of breath are professed more frequently by smokers than by nonsmokers although the differences in frequency are just short

Table 1.—Comparison of Physical Factors in Subjects Studied

	50 Nonsmokers		113 Smokers	
	Mean	Standard Deviation	Mean	Standard Deviation
Age (years)	44.38	± 4.22	44.72	± 4.12
Height (inches)	70.55	± 2.16	70.50	± 2.40
Weight (pounds)	174.3	±18.6	176.7	±18.4

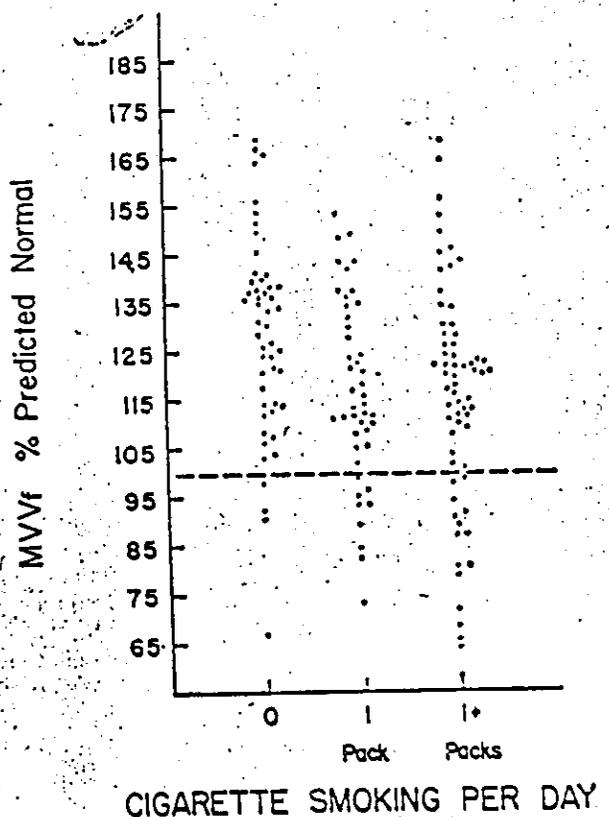
Table 2.—Tabulation of "Yes" Answers to Specific Questions of History or Symptoms

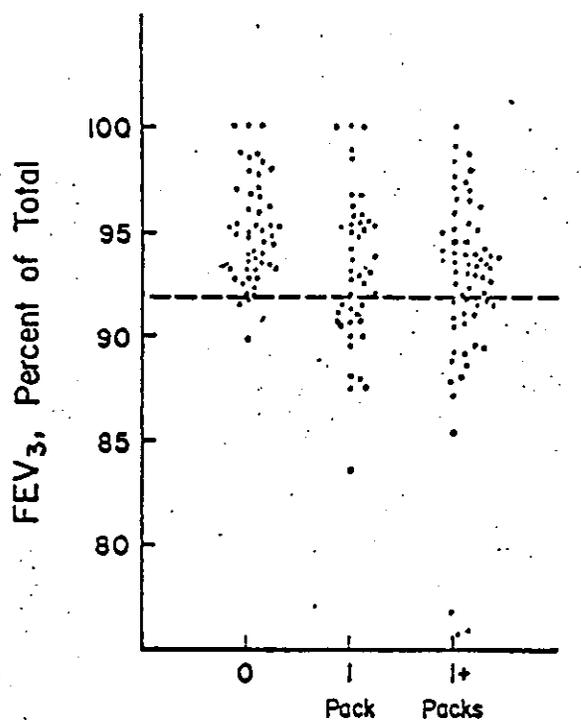
	50 Non-smokers		113 Smokers		1 Pack (65)		More Than One Pack/Day (67)	
	No.	%	No.	%	No.	%	No.	%
Asthma or wheezing.....	2	4.0	3	2.7	1	2.2	2	3.0
Pneumonia	7	14.0	15	13.3	4	8.7	11	16.4
Chronic cough	1	2.0	12	10.6	3	6.5	9	13.4
Shortness of breath.....	0	0.0	11	9.7	4	8.7	7	10.5

of statistical significance. By the results of the chi-square test, the frequency difference between nonsmokers and smokers, with respect to chronic cough, has a significance probability between 0.05 and 0.08; that with respect to shortness of breath, about 0.025. It is also noted that these symptoms increase in frequency with increasing cigarette consumption. Although no definite conclusions can be drawn from these data, a relationship between these symptoms and cigarette smoking is suggested. The infrequent history of asthma or wheezing and the equality of distribution of this history is of interest in that it indicates that the differences otherwise demonstrated between smokers and nonsmokers cannot be attributed to bronchial asthma.

The data obtained on pulmonary function testing

Fig 1.—Maximum voluntary ventilation related to smoking habit.





CIGARETTE SMOKING PER DAY

Fig 2.—FEV₃ (percent of total vital capacity) related to smoking habits.

are tabulated in Table 3. With the exception of total lung capacity, there were significant differences between smokers and nonsmokers in all functions measured. The most striking differences between the two groups are demonstrated in the results of the FEV₃ test and the residual volume-

Table 3.—Comparison of Pulmonary Function Studies in Smokers and Nonsmokers

	50 Nonsmokers		113 Smokers		P
	Mean	Standard Deviation	Mean	Standard Deviation	
Vital capacity (liters)	5.16	± 0.701	4.82	± 0.682	0.004
Vital capacity (% predicted).....	126.7	±15.37	118.2	±14.55	0.001
1-Sec timed ve (FEV ₁) (% of total).....	80.2	± 4.84	76.1	± 7.5	<0.001
3-Sec timed ve (FEV ₃) (% of total).....	95.3	± 1.24	91.7	± 3.34	<0.001
MVV† (liters/min).....	161.3	±26.0	141.0	±28.8	<0.001
MVV† (% predicted)	128.5	±20.25	115.8	±21.80	<0.001
Total lung capacity (liters)	7.37	± 0.986	7.42	± 0.898	0.75
Residual volume (liters)	2.19	± 0.502	2.60	± 0.560	<0.001
RV/TLC Ratio x 100	29.9	± 4.82	25.3	± 5.86	<0.001

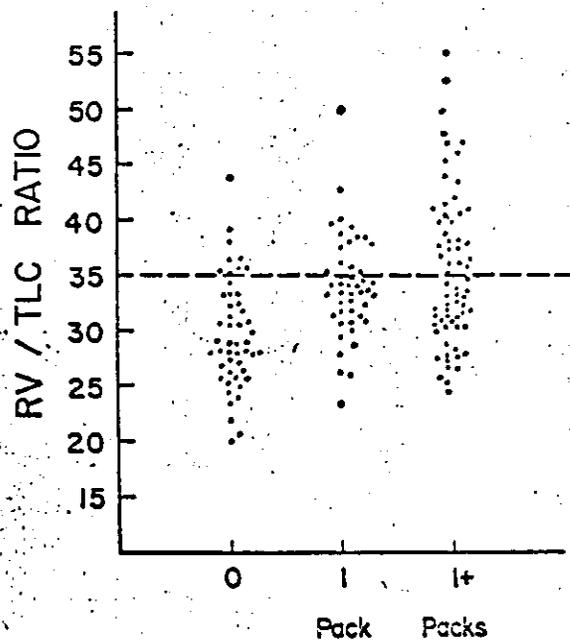
* FEV—Forced expiratory volume.
† MVV—Maximum ventilatory volume.

total lung capacity ratio (RV/TLC). An attempt was made to correlate the quantity of cigarette consumption with mean differences in maximum voluntary ventilation (Fig 1), timed vitalometry (Fig 2), and residual volume/total lung capacity ratio (Fig 3). The dotted horizontal line in the scattergrams separates the "normal" from the "abnormal" values. In all respects, the smokers display abnormal values significantly more frequently than do nonsmokers ($P < 0.01$), although there is no statistically significant difference demonstrated with increasing consumption of cigarettes. It is noted, however, that the lowest MVV and timed vital capacity values and the highest RV/TLC ratios were encountered in the heavy smokers.

Comment

The little-understood disease entities of chronic bronchitis and emphysema are responsible for more man days of disability and probably also, directly or indirectly, for more deaths than is cancer of the lung. In spite of this, the possible role of irritation from tobacco smoke as an etiological factor in chronic bronchitis and obstructive emphysema has received relatively scant attention in the professional literature and infinitely less publicity directed to the laity compared to the tobacco-lung cancer problem. In recent years, however, an increasingly convincing body of evidence is accumulating to implicate chronic use of tobacco, particu-

Fig 3.—Residual volume-total lung capacity ratio related to smoking habits.



CIGARETTE SMOKING PER DAY

larly inhalation of cigarette smoke, as a major factor in the etiology of chronic respiratory insufficiency. This evidence in general comes from three sources: (1) studies of the smoking habits of individuals with chronic respiratory symptoms,^{1,7} (2) histopathological studies of the bronchial mucosa,^{10,11} and (3) physiological measurements of healthy individuals.

Attempts to demonstrate the acute pulmonary functional effects which result from smoking have met with variable results. Bickerman and Barach¹⁰ were unable to demonstrate any significant change in lung function (vital capacity and maximum breathing capacity) in normal subjects after they had smoked one or more cigarettes. Similarly, others have been unable to demonstrate a significant change in the mechanics of breathing in normal subjects after smoking, although emphysematous subjects demonstrated increased airway resistance and work of breathing under similar circumstances.^{20,21} Motley and Kuzman²² could demonstrate no consistent or significant change in blood gases in normal or moderately emphysematous individuals after smoking. They did find a significant decrease in pulmonary compliance in most subjects, with an increase in the elastic work of breathing. Using the sensitive technique of body plethysmography, McIlroy and Nadel²³ demonstrated a significant decrease in airway conductance, which persisted for about one hour after the patient's inhalation of cigarette smoke. Although these conflicting results are difficult to interpret, it is probable that inconsistencies are related to sensitivity of techniques used in various studies. The conclusion of McIlroy and Nadel that "inhaling cigarette smoke produces a small but significant increase in airway resistance" seems reasonable.

Until recent years, very few physiological studies have been made of normal individuals in an attempt to quantitate physiological changes brought on by long-term smoking. Turley and Harrison²⁴ compared the vital capacity and ventilation indexes of 33 heavy smokers and 42 nonsmokers and concluded that tobacco had no deleterious effect on ventilatory efficiency. It should be noted that their subjects were medical students who undoubtedly had relatively short smoking histories. Fletcher¹ and Higgins⁹ studied the ventilatory capacities of several occupational groups in the British Isles in relation to smoking habits. Their studies on relatively large groups of healthy individuals demonstrated significantly decreased mean ventilation capacities and increased frequency of bronchitic symptoms in smokers. Whitfield et al.⁸ in a study of 58 otherwise healthy male subjects, noted a slight decrease in vital capacities and a significant increase in the residual volumes and in the residual volume/total lung capacity ratios in smokers as compared to nonsmokers. Flick and Paton⁶ found significant reduction in the maximum expiratory

flow rates of smokers as compared to nonsmokers in a Veterans' Hospital patient population. Subsequently, other reports^{16,17} have consistently demonstrated evidence of airway obstruction, increase in residual volume, and decrease in diffusion capacity in smokers.

It is worth noting that the group reported here is a relatively homogenous population. As professional military officers, they were selected as young men partly on their ability to pass a rigid physical examination. In subsequent years, they have been subjected to re-examination frequently and, in most cases, annually. Because of the nature of their profession, they are expected to "keep in shape," and habitually lead a vigorous life. The entire adult life of each individual studied has been lived in a similar environment, that of the US Air Force. Since Air Bases are almost universally located at some distance from population and industrial centers, air pollution from factory and automobile exhausts would not be expected to be a significant factor. These features are in marked contrast to other studies of "normal" populations, which include primarily city dwellers,^{7,9,10} sedentary groups,^{10,11} factory workers,¹² or hospital populations.^{2,13} The only detectable background difference is that one group smoked and the other did not. The inescapable conclusion is that this fact accounts for the differences in lung function between these two groups. It is evident, therefore, that smoking can result in airway obstruction and air trapping or hyperinflation. These physiological changes in otherwise healthy cigarette smokers differ only in degree from those seen in the patients with emphysema.

One might speculate on the effect on the lungs of repeated changes in atmospheric pressure incident to flying, since this could conceivably produce alveolar wall damage and, thereby, hyperinflation. In the study group there was a greater proportion of professional fliers among the nonsmokers (62%) than among the smokers (54%). Hence, if flying, per se, adversely affected lung function, it would tend to reduce any differences between smokers and nonsmokers as analyzed in this paper.

Conclusions

Lung volume and ventilatory studies of 163 middle-aged military officers were analyzed in relation to smoking habits. Habitual cigarette smokers were found to have decreased average vital capacities, maximum voluntary ventilation and timed vitalometry values, and increases in residual volume levels compared with those who had never smoked. There appears to be some correlation between the degree of physiological and symptomatic abnormality and the quantity of cigarettes consumed, although differences in this respect were not statistically sig-

nificant. The incidence of admitted cough and shortness of breath was found to be slightly greater among smokers than nonsmokers. The difference was slightly below the level of statistical signifi-

cance. These findings confirm previous reports of similar studies on somewhat less uniform populations.

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CORRECTION

Disabling Automobile Accidents.—In the lead paragraph of the original contribution titled "Facial Disfigurement in Automobile Accidents: A National Tragedy," published Aug 3 (185:354-357), it states incorrectly that 140,000 injuries resulted from automobile accidents alone in 1960. John Marquis Converse, MD, author of the communication, writes that "the correct figure is 1,400,000 accidents, and this apparently includes *only the truly disabling accidents* reported by the National Safety Council. According to the publication *Health, Education and Welfare Indicators* (July, 1963), the total number of persons injured in motor vehicle accidents was 5,000,000. Such injuries in 1961 totaled 4,400,000 and in 1962 totaled 5,100,000. So it can be seen that this is a problem of some magnitude, much greater than the figure in the article would indicate."