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16. Abstract

Chronic obstructive pulmonary disease continues to manifest an increasing prevalence in male Americans. A recent study of commercial airline pilots revealed a 12-percent prevalence of minor-to-moderate spirometric impairment. Because commensurate data were not available for general aviation pilots, in whom such impairment could also compromise flight safety, a parallel study was made.

The British Medical Research Council and smoking questionnaires, chest expansion, and spirometric measurements of FEV_1, FVC, $FEV_1\%$, MVV, and $FEF_{25-75\%}$ were assessed in 181 male general aviation pilots. All data showed a general relationship to increasing age and amount of smoking. Based on $FEV_1\%$ and $FEF_{25-75\%}$ combined, minor degrees of spirometric impairment were exceeded by 25.4 percent of the pilots and moderate degrees, by 12.7 percent. Negligible impairment was reflected in the remaining spirometric parameters. Subsequent testing of such spirometrically impaired pilots for altitude, fatigue, and orthostatic tolerances related to general aviation is planned.

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SPIROMETRIC ASSESSMENT OF POTENTIAL RESPIRATORY IMPAIRMENT IN GENERAL AVIATION AIRMEN

I. Introduction.

Chronic obstructive pulmonary disease (COPD) mainly encompasses emphysema, chronic bronchitis, and asthma. Recent statistics indicate an increasing prevalence of COPD in the American population.[2,13] The risk of incurring COPD is estimated at 5 to 10 times greater in men than in women.[4] In general, COPD is positively correlated with age, inhaled cigarette smoking, and contamination of the gaseous environment.[8]

Several variations of COPD of "sufficient degree to be symptomatic" and/or "to interfere with pulmonary function" are among the conditions for which medical certification of airmen is denied or deferred.[6] Quantitative spirometric standards for healthy, normal American males have been established by previous studies.[10,12] Quantitative spirometry in a recent study of 257 commercial airline pilots (40–59 yr of age) showed that minor-to-moderate spirometric impairment existed in 12 percent of this population and was highly correlated with age and cigarette smoking.[4] Unless clinically indicated, quantitative spirometric evaluation is not a mandatory part of the aeromedical examination. Minor-to-moderate spirometric impairment could adversely affect safe flight by the general aviation pilot breathing only ambient air at cabin altitudes approaching 12,500 ft.

Currently, published prevalence data on minor-to-moderate degrees of spirometric impairment in general aviation pilots do not appear to exist. Based on quantitative spirometry, the main objectives of this study are to ascertain if minor spirometric impairment is present or exceeded in the male general aviation population and, if present, at what age threshold such impairment appears in the nonsmokers (NS), smokers (S), and ex-smokers (ES) of this population. If spirometric impairment is present to substantial degrees, additional research can be initiated to test the effect of such degrees of impairment on critical aspects of safe flight. Any adverse effect revealed by such testing could be countered by an educational Advisory Circular and/or the formulation of a relevant screening aeromedical standard based on quantitative spirometric values.

II. Materials and Methods.

Selection of Subjects. Volunteer males, 30 yr of age or older, were recruited from personnel of the FAA Aeronautical Center and residents of communities surrounding Oklahoma City. Each volunteer was a general aviation pilot and possessed a current airman medical certificate at the time of spirometric assessment. Prior to spirometry, each subject was examined medically for any thoracic condition that would preclude testing of this type. A questionnaire on smoking history[14] and one by the British Medical Research Council (BMRC) on respiratory symptoms[11] were completed by all subjects. Age, height, weight, Framingham relative weight, and total number of pack years of inhaled cigarette smoking for all subjects in each smoking category are summarized in Table 1.

Spirometry Protocol. All spirometry was conducted in a temperature-controlled room with each subject seated in a comfortable padded chair. A Collins 13.5-liter spirometer was used to obtain timed paper recordings of the expiratory forced vital capacity (FVC) and maximum ventilatory volume (MVV) maneuvers. Both maneuvers were conducted in accordance with standardized clinical spirometry procedures.[1] For each of these two maneuvers, the best recording from three maximum efforts was selected for subsequent analysis.[12] From the FVC recording, the 1-sec forced expired volume (FEV_1), the FVC, and the forced midexpiratory flow ($FEF_{25-75}\%$) were measured directly. The $FEV_1/FVC \times 100$ ($FEV_1\%$) was calculated by

TABLE 1.—NS=nonsmoker=never smoked, or smoked for≤1 pack year and had quit for≥5 years. S=smoker=current smoker with a total smoking amount of≥5 pack years. ES=ex-smoker=total smoking amount of≥5 pack years and had currently quit for≥6 months. Pack year=an average of 20 cigarettes smoked per day per year. Age calculated to the nearest completed year. Ht=height in cm measured in stocking feet. Wt=weight in kg measured shirtless and shoeless and corrected for residual clothing weight.[9] FRW=Framingham relative weight=[actual weight in pounds/136 pounds+4 (Ht in inches−60)] x 100.[10]

		Smoking Categories		
		NS	S	ES
Age (yr)	m	45.5	44.5	48.1
	SE	1.1	1.2	1.1
Ht (cm)	m	175.5	177.5	174.5
	SE	0.8	0.8	0.8
Wt (kg)	m	83.1	84.1	82.0
	SE	1.5	1.7	1.9
FRW (%)	m	106.2	105.4	105.6
	SE	1.6	1.9	1.8
Amount Smoked (pack yr)	m	0.1	29.6	32.5
	SE	0.007	2.4	3.5
N		69	55	57

using the directly measured parameters. A 12-sec portion of the best 20-sec MVV recording was measured and proportionalized to represent the MVV per minute. All gas volumes were corrected to BTPS. As a correlate of FVC, circumferential chest expansion (maximum inspiration minus maximum expiration) was measured in centimeters horizontally at the nipple level with a steel tape according to a standard anthropometric procedure.[7]

III. Results.

BMRC Questionnaire. This questionnaire covers seven subjective respiratory symptom areas and has a total of 27 yes/no questions. Table 2 summarizes the percent of "yes" answers for all subjects in each age bracket and smoking category. In the "all ages" category, nonsmokers manifested the fewest subjective respiratory symptoms followed in ascending order by the ex-smokers and smokers. This general symptomatic separation of the three smoking categories was even more accentuated in each of the "cough," "phlegm," "breathlessness," "wheezing," and "weather" categories of the questionnaire. The smaller percentage of respiratory symptoms in the ex-smokers compared with the smokers may reflect a real benefit of quitting the habit. Within each smoking category, the relationship of increasing subjective symptoms with age was not as clear cut as might be expected. The unexpected lowest percentage of symptoms occurred in the nonsmokers who were 60 yr of age or older. This probably reflects unique health maintenance by these five older pilots, because most of their spirometry parameters exceeded 100 percent of their predicted normal values.

Spirometry. In this study, all FEV_1, FVC, and MVV values are expressed as percentages of the predicted normal values based on the Veterans Administration-Army study.[10] All $FEF_{25-75}\%$ values are expressed in the same manner but are based on the study of Morris *et al.*[12] For these four parameters, 80 percent is the generally accepted threshold value for minor spirometric impairment[3] and 70 percent, for moderate impairment.[3] All values greater than 80 percent indicate normality, and those between 70 and 80 percent indicate minor impairment. For $FEV_1\%$, the commensurate threshold values for minor and moderate spirometric impairment are 75 percent and 65 percent respectively.

The FEV_1, FVC, $FEV_1\%$, MVV, and $FEF_{25-75}\%$ data are summarized in Tables 3–7; age brackets and smoking categories are identical to those in Table 2. Subject numbers in each age bracket/smoking category are omitted from these five tables because the identical data are compiled in Table 2. For all five parameters, the data within each age bracket reveal a general pattern of greatest separation between the nonsmokers and the other two smoking categories. In the "all ages" category of each table, an expected stronger data separation between the smokers and ex-smokers was most probably diluted by the complete absence of data for the≥60-year-old smokers. Although sufficient

TABLE 2.—NS, S, and ES are defined in Table 1. %=percent of 27 questions (BMRC questionnaire) answer "yes." m=mean, SE=standard error, and N=number of subjects.

BMRC (% yes)		AGE 30-39	40-49	50-59	≥60	All
NS	m	5.2	8.7	7.4	3.0	6.8
	SE	1.4	2.5	2.7	1.8	1.2
	N	22	22	20	5	69
S	m	12.7	12.1	23.0	—	15.9
	SE	3.1	3.4	4.2	—	2.2
	N	19	18	18	—	55
ES	m	12.5	8.8	9.3	18.5	10.3
	SE	4.0	1.9	1.8	14.9	1.7
	N	8	24	20	5	57
All	m	9.3	9.7	12.9	10.7	10.7
	SE	1.6	1.5	1.9	7.5	1.0
	N	49	64	58	10	181

numbers of ≥60-year-old smoking pilots reside in proximity to the location of this study, all who were actively solicited for the study refused to participate.

For all five spirometric parameters, the data within each smoking category reveal a general pattern of decreasing values with age. Despite the absence of data in this study for the ≥60-year-old smokers, this group's age-related decrements in spirometric parameters would conservatively be expected to equal or exceed those manifested by the ≥60-year-old ex-smoker group (Tables 3–7).[15]

TABLE 3.—Summary of FEV_1 data. Δ=number of individuals with minor spirometric impairment, defined as a % of predicted normal value of <80%. □=number of individuals with moderate spirometric impairment, defined as a % of predicted normal value of <70%. All other symbols are defined in Table 1.

FEV_1 (% Pred.)		AGE 30-39	40-49	50-59	≥60	All
NS	m	107.3	111.4	115.6	109.8	111.2
	SE	2.9	2.4	3.2	5.4	1.6
	Δ	0	0	0	0	0
	□	0	0	0	0	0
S	m	105.2	100.9	100.0	—	102.0
	SE	4.3	3.0	2.7	—	2.0
	Δ	2	0	0	—	2
	□	1	0	0	—	1
ES	m	105.6	103.6	106.2	84.3	103.1
	SE	3.2	2.5	3.4	14.1	2.1
	Δ	0	0	1	1	2
	□	0	0	1	1	2
All	m	106.2	105.5	107.5	97.0	105.9
	SE	2.1	1.6	2.0	8.3	1.1
	Δ	2	0	1	1	4
	□	1	0	1	1	3

TABLE 4.—Summary of FVC data. All symbols are defined in Table 3.

FVC (% Pred.)		AGE 30-39	40-49	50-59	≥60	All
NS	m	104.8	106.6	109.9	101.9	106.7
	SE	2.8	2.5	3.0	4.9	1.5
	Δ	0	0	0	0	0
	□	0	0	0	0	0
S	m	104.6	98.2	98.1	—	100.4
	SE	3.5	2.9	2.3	—	1.7
	Δ	0	0	1	—	1
	□	0	0	0	—	0
ES	m	104.4	103.5	103.9	91.0	102.7
	SE	3.5	2.0	2.5	8.0	1.5
	Δ	0	1	0	1	2
	□	0	0	0	1	1
All	m	104.7	103.1	104.2	96.4	103.5
	SE	1.9	1.5	1.6	4.8	0.9
	Δ	0	1	1	1	3
	□	0	0	0	1	1

TABLE 5.—Summary of FEV_1% data. Δ=number of individuals with minor spirometric impairment, defined as a % of measured FVC of <75%. □=number of individuals with moderate spirometric impairment, defined as a % of measured FVC of <65%. All other symbols are defined in Table 2.

FEV_1% (%)		AGE 30-39	40-49	50-59	≥60	All
NS	m	83.3	83.1	81.3	80.6	82.4
	SE	0.7	0.7	1.2	1.1	0.5
	Δ	0	1	3	0	4
	□	0	0	0	0	0
S	m	81.7	81.3	78.3	—	80.4
	SE	2.0	1.0	1.5	—	0.9
	Δ	2	1	5	—	8
	□	1	0	0	—	1
ES	m	82.8	79.2	79.2	66.8	78.6
	SE	1.1	1.1	1.8	8.0	1.1
	Δ	0	6	4	3	13
	□	0	0	2	1	3
All	m	82.6	81.1	79.6	73.7	80.6
	SE	0.9	0.6	0.9	4.4	0.5
	Δ	2	8	12	3	25
	□	1	0	2	1	4

As reflected in Tables 3–7, most of the age bracket/smoking category mean values for this sample of the male general aviation population exceeded the commensurate normal values for the male United States population.[10 12] Although these data indicate a higher average-state-of-pulmonary-health in airmen, some individuals within this sample did manifest spirometric values that quantitatively indicated minor or moderate spirometric impairment. In Tables 3–7, the Δ symbol designates the number of individuals manifesting minor spirometric impairment and the □ symbol, the number manifesting moderate impairment. Minor spirometric impairment was indicated by the data values of 25

TABLE 6.—Summary of MVV data. All symbols are defined in Table 3.

MVV (% Pred.)		AGE 30-39	40-49	50-59	≥60	All
NS	m	119.6	123.9	131.4	129.3	125.1
	SE	5.8	3.7	4.8	16.4	2.8
	Δ	0	0	0	0	0
	□	0	0	0	0	0
S	m	121.1	119.8	113.8	—	118.3
	SE	6.0	5.7	4.0	—	3.0
	Δ	1	0	0	—	1
	□	1	0	0	—	1
ES	m	110.0	114.4	117.9	85.5	112.5
	SE	3.4	3.8	6.0	17.7	3.2
	Δ	0	1	0	2	3
	□	0	0	0	2	2
All	m	118.6	119.2	121.3	107.4	119.1
	SE	3.5	2.5	3.1	13.5	1.8
	Δ	1	1	0	2	4
	□	1	0	0	2	3

TABLE 7.—Summary of $FEF_{25-75}\%$ data. All symbols are defined in Table 3.

$FEF_{25-75}\%$ (% Pred.)		AGE 30-39	40-49	50-59	≥60	All
NS	m	107.5	111.0	122.4	112.0	113.3
	SE	4.9	4.7	7.4	7.8	3.1
	Δ	4	1	1	0	6
	□	0	0	0	0	0
S	m	98.7	99.9	90.9	—	96.5
	SE	6.6	6.5	5.5	—	3.6
	Δ	3	5	5	—	13
	□	1	2	5	—	8
ES	m	104.5	94.5	105.0	59.0	96.5
	SE	7.4	6.1	7.7	14.4	4.3
	Δ	0	8	4	4	16
	□	0	7	3	3	13
All	m	103.6	101.7	106.6	85.5	102.9
	SE	3.6	3.4	4.3	11.7	2.2
	Δ	7	14	10	4	35
	□	1	9	8	3	21

individuals (13.8%) for $FEV_1\%$ (Table 5) and by 35 individuals (19.3%) for $FEF_{25-75}\%$ (Table 7). At most, only 2.2 percent of the individuals manifested minor spirometric impairment in FEV_1, FVC, and MVV (Tables 3, 4, and 6). Although only 4 (2.2%) subjects manifested data values indicating moderate impairment for $FEV_1\%$, 21 (11.6%) did so for $FEF_{25-75}\%$. The greater prevalence of moderate impairment for this latter parameter is not surprising in view of the general knowledge that $FEF_{25-75}\%$ is a more sensitive detector of peripheral airway impairment, which is usually manifested earlier in COPD than spirometric impairment of the more proximal larger airways.[9]

Because analysis of the circumferential chest expansion data revealed no useful distinctions, further consideration of this parameter was deemed unnecessary.

IV. Discussion.

Although the general value of a BMRC-type of questionnaire is well recognized, its use as a quantitative reflection of COPD is somewhat limited.[15] The cigarette-smoking history is a bit more rewarding in its use, because it has been established that both the number of cigarettes smoked per day and the number of years of such inhaled smoking are directly related to the severity of COPD.[15] The pack-year unit continues to be useful in this regard.[15]

As reflected in Tables 3–7, substantial amounts of minor and moderate spirometric impairment were manifested in this sample of male general aviation pilots. Table 8 summarizes the percentages of prevalence of minor and moderate spirometric impairment for all five spirometric parameters combined. The %Δ symbol designates the percentage of individuals manifesting minor impairment in at least one spirometric parameter; the %□ designates the percentage of individuals manifesting moderate impairment in at least one parameter. In the "all ages" category of Table 8, (i) the smokers and ex-smokers clearly manifest much greater prevalences for minor and moderate impairment compared to the nonsmokers and (ii) the greater prevalences for the ex-smokers compared with the smokers is most probably due to the absence of data for the ≥60-year-old smokers, because the average number of pack-years of smoking for this latter group probably equals or exceeds the 85.4 pack-year average for the ≥60-year-old ex-smokers who had already ceased smoking for 12.4 yr. In all three smoking categories combined in Table 8, (i) a trend of increasing prevalence for minor and moderate spirometric impairment with age is manifested; (ii) the expected largest age-related prevalence of spirometric impairment manifested by the ≥60-year-old group are probably underestimates because of the absence of data for the ≥60-year-old smokers; and (iii) the first sharp increase in prevalence of moderate spirometric impairment occurs in the fourth age decade and is due mainly to the smokers and ex-smokers. The prevalence values appearing in Table 8 are due almost entirely to impairment of $FEV_1\%$ and $FEF_{25-75}\%$. This general finding is completely consonant with the accepted theory that the earliest manifestation of COPD is usually peripheral airway impairment.[9] These data suggest that a reasonable quantitative

TABLE 8.—Summary of % prevalence of minor and moderate spirometric impairment. %Δ= percentage of individuals having at least one spirometric value <75% for FEV_1% or <80% for the remaining four spirometric parameters. %□=percentage of individuals having at least one spirometric value <65% for FEV_1% or <70% for the remaining spirometric parameters. All other symbols are defined in Table 2.

Prevalence of Spirometric Impairment		AGE 30-39	40-49	50-59	≥60	All
NS	%Δ	22.7	9.1	20.0	0	15.9
	%□	0	0	5.0	0	1.4
	N	22	22	20	5	69
S	%Δ	26.3	27.8	38.9	—	30.9
	%□	10.5	11.1	27.8	—	16.4
	N	19	18	18	—	55
ES	%Δ	0	37.5	25.0	80.0	31.6
	%□	0	29.2	15.0	60.0	22.8
	N	8	24	20	5	57
All	%Δ	20.4	25.0	27.6	40.0	25.4
	%□	4.1	14.1	15.5	30.0	12.7
	N	49	64	58	10	181

screening for spirometric impairment in airmen can be achieved by using only the expired FVC maneuver from which both FEV_1% and FEF_{25-75}% are measured.

On the basis of objective quantitative data, substantial amounts of minor and moderate spirometric impairment were manifested in this sample of male general aviation pilots. However, for any such airman, the appearance of a measured value that is quantitatively equivalent to minor or moderate spirometric impairment implies only the possibility of an existing medical pulmonary condition that could adversely affect safe flight. Spirometry is merely a way of quantitating the various mechanical aspects of ventilatory impairment. Whether the quantitated minor-to-moderate spirometric impairment observed in this study constitutes an incursion on safe flight to any degree can be ascertained only by testing such spirometrically impaired pilots in critical aspects of flight safety such as altitude, fatigue, and orthostatic tolerances. Such studies have already been planned.

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