Decline of the lung function related to the type of tobacco smoked and inhalation

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Abstract

Data from a five year follow up study on 4372 smokers and 3753 non-smokers were analysed to investigate the influence of the type of tobacco smoked and whether the subjects said they inhaled or not on the decline in forced expiratory volume in one second (FEV₁). The study sample comprised 1492 smokers of plain cigarettes and 1936 smokers of filter cigarettes, 1711 smokers of cheroots or cigars, and 233 male pipe smokers. Over the five years, smokers, especially those who said that they inhaled, had a higher rate of decline of FEV₁ than non-smokers, in whom the average decline in FEV₁ was 25 ml/year for women and 30 ml/year for men. There was no significant difference in the decline in FEV₁ between filter cigarette smokers and plain cigarette smokers. The decline in FEV₁ in cigar or cheroot smokers was the highest for all the smoking groups, and associated with a very high tobacco consumption in this group. Among pipe smokers who inhaled, the decline in FEV₁ was slightly higher than in the cigarette smokers, whereas non-inhaling pipe smokers had a decline in FEV₁ that was similar to that of non-smokers. In general, the smokers who said that they did not inhale had a smaller decline in FEV₁ than those who said that they did. The effect of inhalation varied in magnitude in different smoking groups, being most pronounced in pipe smokers.

Ventilatory function declines with age in adults. Tobacco smoking is a major cause of an accelerated decline in ventilatory function and the major cause of chronic obstructive pulmonary disease. This has been extensively studied in relation to cigarette smoking, but few studies have been able to analyse differences in the effects of smoking different kinds of tobacco on chronic obstructive lung disease.¹⁻³ The main reason for this is that even in large epidemiological studies there are often too few subjects smoking tobacco in forms other than cigarettes to allow a useful analysis. In several studies chronic obstructive lung disease has been related to the type of cigarette smoked by comparing high tar or medium tar with lower tar cigarettes or filter with plain cigarettes. In most of these studies phlegm production has correlated positively with tar yield and the absence of filters.³⁻⁷ The relation of tar yield

and lack of filter to ventilatory function, however, has been inconsistent. In a reanalysis⁸ of cross sectional data from the Whitehall study⁹ Lee showed that smokers of lower tar cigarettes had a slightly higher forced expiratory volume in the first second (FEV₁) than smokers of high tar cigarettes. But in three other studies,¹⁰⁻¹² two of them longitudinal, there was no significant association between tar content or use of filters and FEV₁.

The aim of our study was to analyse the association between decline in FEV₁ during a five year follow up and smoking of cigars or cheroots, pipes, filter cigarettes, and non-filter cigarettes. As inhalation may affect the relation of smoking to the decline in FEV₁, inhaling versus not inhaling was a further variable in the analysis.

Methods

POPULATION

A prospective epidemiological study, the Copenhagen City heart study, was initiated in 1976. The participants were selected from among 90 000 people living in a defined area around Rigshospitalet, the University Hospital of Copenhagen. A sample of 19 698 subjects aged 20 years or more was selected at random after age stratification. The sample fraction was highest (50%) for persons aged 40-69 years. The subjects were invited by letter to an examination on a specific date during the period 1 March 1976 to 31 March 1978 and invited again five years later during the period 6 April 1981 to 7 September 1983. A total of 14 223 (74% of those invited) attended the first examination and 12 698 (70% of those invited) attended the second examination. Details of the selection procedure and a description of non-responders have been given elsewhere, together with the questionnaire and the complete examination programme.^{13 14} From the total sample of 11 135 subjects who attended both examinations the following subjects were excluded: (a) 344 persons with a history of bronchial asthma; (b) 1866 persons who at either examination said that they smoked more than one type of tobacco, or who changed the type of tobacco they smoked between the two examinations; (c) 626 subjects who stopped, started, or restarted smoking during the observation period; (d) four women who smoked a pipe; and (e) 170 subjects with incomplete data for the analysis. The final study sample comprised 4372 smokers and 3753 non-smokers.

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PULMONARY FUNCTION

FEV₁ was recorded on the same electronic spirometer (Monaghan N 403, Littleton, Colorado) at the two examinations; this was calibrated daily. At least two measurements had to be within 5% of each other. The largest volume was used in the analysis.

QUESTIONNAIRE ON SMOKING HABITS

On both occasions participants were asked to report the form and type of the tobacco they smoked and if they inhaled while smoking. They were not asked if they had smoked different kinds of tobacco before the first examination. Subjects were then divided into the following groups: NS: Non-smokers—subjects who did not smoke tobacco at either examination; CIGP: subjects smoking only plain (non-filter) cigarettes during the observation period; CIGF: subjects smoking only filter cigarettes during the observation period; CER: subjects smoking only cigars, cheroots, or cigarillos during the observation period; PIPE: men smoking only a pipe during the observation period.

The following equivalents for the tobacco content were used: one plain or filter cigarette = 1 g; one cigar = 5 g; one cheroot or cigarillo = 3 g; 1 g of pipe tobacco = 1 g. The mean value for daily tobacco consumption reported at the two examinations was used in the analyses.

SOCIAL STATUS AND ALCOHOL CONSUMPTION

As both socioeconomical status and alcohol consumption might be associated with lung function,¹⁵⁻¹⁷ these variables were included in the analysis. As an indicator of socioeconomical status we used the duration of school education as reported at the first examination.

STATISTICAL METHODS

For each subject the difference in FEV₁ between the first and the second examination was divided by the precise length of the observation period to obtain an estimate of the annual decline in FEV₁ (Δ FEV₁ in millilitres). We performed a separate multiple linear regression analysis of Δ FEV₁ for men and women. The analysis covered both non-smokers and smokers and focused on the contribution of a given type of tobacco to Δ FEV₁. The dependent variable was Δ FEV₁ and the independent variables of interest were the different smoking groups, generated by combining the use or non-use of inhalation (+ and -) with the type of tobacco smoked (CIGP, CIGF, CER, PIPE) (thus there were eight smoking groups for men and six for women). Membership of these groups was indicated by eight binary variables for men (x_{CIGP+} , x_{CIGP-} ; x_{CIGF+} , x_{CIGF-} ; x_{CER+} , x_{CER-} ; x_{PIPE+} , x_{PIPE-}) and six for women (x_{CIGF+} , x_{CIGF-} ; x_{CER+} , x_{CER-}), assigned the value 1 for those belonging to a particular group and 0 otherwise.

Additional independent variables included in the regression model (the confounders) were: age (x_a in years), height (x_h in cm), education (x_e in years), and daily alcohol consumption (x_{alc} in drinks/day). FEV₁ was not included as a confounder in the regression model in the first examination, as suggested by Vollmer.¹⁸

The regression model for men was:

$$\Delta FEV_1 = C_0 + C_1 \cdot x_{CIGP+} + C_2 \cdot x_{CIGP-} + C_3 \cdot x_{CIGF+} + \dots + C_9 \cdot x_{PIPE-} + C_9 \cdot x_a + C_{10} \cdot x_h + C_{11} \cdot x_e + C_{12} \cdot x_{alc}.$$

The regression model for women was similar, except for the lack of variables describing pipe smoking. The question whether the above model could be simplified by reducing the number of smoking groups—for example, by disregarding the distinction between inhalers and non-inhalers—was evaluated by analysis of variance. A significance level of 5% was used.

The fit of the regression models was tested by plotting the residuals against the predicted values of Δ FEV₁ and against each of the independent variables included. We investigated whether the fit of the data could be improved by expanding the models with first order interaction terms, but found no significant improvement.

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Results

At the first examination plain cigarette smokers had the lowest FEV₁ as a percentage of their predicted value, inhaled more frequently, and consumed slightly more alcohol than did subjects in the other groups (table 1).

The mean daily consumption of tobacco and the unadjusted mean annual decline in FEV₁ in the different smoking and inhalation groups is given in table 2. In all smoking groups the inhalers consumed more tobacco than the non-inhalers. The highest daily tobacco consumption was seen in the cigar and cheroot smokers. Δ FEV₁ was lowest in non-smokers and highest

Table 1 Characteristics of the subjects according to smoking group (inhalation given as a frequency, other variables as arithmetical means)

Smoking group: (n)	Women				Men				
	NS (2417)	CIGP (703)	CIGF (1462)	CER (404)	NS (1336)	CIGP (789)	CIGF (474)	CER (307)	PIPE (233)
Age (y)	53.6	50.4	48.1	59.1	52.3	51.1	46.8	56.9	53.7
Tobacco (g/day)	0	13.6	12.9	31.8	0	17.3	16.9	37.2	15.9
Alcohol (drinks/day)	0.3	0.5	0.4	0.4	1.3	2.3	1.9	1.7	1.3
Education (years)	8.5	8.1	8.5	8.2	8.9	8.4	8.7	8.6	8.8
Inhalation (%)		84	76	22		93	90	46	54
FEV ₁ %*	97.6	86.1	91.3	94.5	98.4	88.7	91.9	92.0	97.0

*As % of predicted values, obtained by estimating the regression of FEV₁ on age and height among symptomless never smokers from the Copenhagen City heart study. The estimates were: for women FEV₁(ml) = 410 - 27.6 × age (y) + 21.2 × height (cm); for men FEV₁(ml) = - 469 - 35.2 × age (y) + 32.0 × height (cm).
NS—non-smokers; CIGP—plain cigarette smokers; CIGF—filter cigarette smokers; CER—cigar or cheroot smokers; PIPE—pipe smokers.

Table 2 Average daily tobacco consumption and decline in FEV₁ (Δ FEV₁) according to the type of tobacco smoked and whether smoke was inhaled

Smoking group	Women			Men		
	n	Tobacco consumption (g, range)	Δ FEV ₁ (ml/y, SEM)	n	Tobacco consumption (g, range)	Δ FEV ₁ (ml/y, SEM)
NON-SMOKERS	2417	0	25 (2)	1336	0	30 (3)
SMOKERS						
Plain cigarettes						
Did not inhale	591	14 (1-43)	34 (13)	734	18 (1-79)	46 (3)
Inhaled	112	11 (1-40)	27 (7)	55	16 (1-55)	53 (13)
Filter cigarettes						
Did not inhale	1111	14 (1-48)	28 (5)	427	17 (1-50)	42 (5)
Inhaled	351	10 (1-40)	32 (3)	47	14 (1-45)	30 (17)
Cigar or cheroots						
Did not inhale	89	43 (3-110)	44 (8)	141	45 (3-110)	66 (6)
Inhaled	315	29 (3-110)	41 (4)	166	31 (3-110)	52 (8)
Pipe						
Did not inhale				126	16 (5-39)	56 (9)
Inhaled				107	15 (5-50)	32 (11)

in cigar and cheroot smokers in both sexes. Generally, the smokers who inhaled had a higher decline in FEV₁ than those who did not.

The results of the multiple linear regression analysis of decline in FEV₁ are given in table 3. All groups of smokers who reported that they inhaled experienced a significantly higher decline in FEV₁ than the non-smokers. The decline in FEV₁ among the non-inhalers was not significantly higher than among the non-smokers for any type of tobacco, though the decline in cigar and cheroot smokers almost reached the 5% significance level. When no distinction between the type of tobacco was made, female non-inhalers showed a significantly greater decline in FEV₁ than the non-smokers. Among male non-inhalers the decline in FEV₁ was about 9 ml a year greater than among non-smokers, but this difference was not significant.

The contribution of smoking to the decline in FEV₁ appeared to be higher among cigar and cheroot and pipe smokers who inhaled than among cigarette smokers who inhaled. This possibility was explored further in both sexes separately by additional regression analyses. The first analysis compared cigarette smokers who inhaled with cigar and cheroot smokers who inhaled; the second analysis compared cigarette smokers who inhaled with pipe smokers who inhaled. None of the differences in decline in FEV₁ reached significance, though

the difference between male cigar and cheroot smokers and cigarette smokers almost did ($p = 0.055$).

The difference between the decline in FEV₁ in plain cigarette smokers and filter cigarette smokers was not significant for either sex.

Except for male plain cigarette smokers, the decline in FEV₁ was greater among smokers who inhaled than among those who did not inhale. The difference between inhalers and non-inhalers was only significant for pipe smokers.

The multiple regression analysis showed that Δ FEV₁ increased significantly with age, height, and (in men) with alcohol consumption. In both sexes the length of education was not significantly related to decline in FEV₁.

Discussion

As in previous studies, we found that smokers have a steeper decline in FEV₁ than non-smokers, who on average had a decline of 25-30 ml a year.^{12,19} We have focused on the longitudinal changes in FEV₁ rather than the cross sectional findings, because the latter are more difficult to interpret in aetiological terms. Even so, our results should be interpreted with caution as we cannot exclude the possibility that the choice of the type of tobacco was affected by the smoker's ventilatory function.

Table 3 Regression analysis of decline in FEV₁ (ml/y) on age, height, alcohol consumption, and the different types of tobacco smoking for smokers and non-smokers of both sexes (decline in non-smokers used as baseline)

Independent variable	Women		Men	
	Regression coefficient (SEM)	p	Regression coefficient (SEM)	p
Intercept	-96.7		-141.0	
Age (y)	1.2 (0.1)	<0.001	0.8 (0.2)	<0.001
Height (cm)	0.4 (0.2)	0.05	0.7 (0.3)	<0.05
Alcohol drinks/day	0.4 (1.7)	NS	2.1 (0.9)	<0.05
Smoking groups:				
NON-SMOKERS	0		0	
SMOKERS				
Plain cigarettes				
Did not inhale	13.3 (3.8)	<0.001	14.3 (5.6)	<0.005
Inhaled	1.0 (7.8)	NS	18.3 (15.1)	NS
Filter cigarettes				
Did not inhale	11.1 (3.1)	<0.001	14.9 (6.1)	<0.05
Inhaled	7.1 (4.7)	NS	-3.0 (15.6)	NS
Cigars or cheroots				
Did not inhale	20.6 (9.0)	<0.05	33.6 (9.6)	<0.001
Inhaled	8.5 (4.9)	0.09	16.8 (9.0)	0.06
Pipe				
Did not inhale			27.9 (10.1)	<0.01
Inhaled			-2.1 (10.7)	NS

NS indicates $p > 0.1$.

COMPARISON OF PLAIN AND FILTER CIGARETTES
We found no significant difference in the decline in FEV₁ between plain cigarette smokers and filter cigarette smokers.

At the time of our study the average tar content in Danish cigarettes was 35 mg per cigarette for plain and 23 mg per cigarette for filter cigarettes. The comparison in our analysis is therefore likely to reflect differences between high tar and medium tar cigarettes. Most previous studies have been unable to show any significant benefit from smoking lower tar cigarettes rather than high and medium tar cigarettes in terms of lung function^{9,10,12} or mortality from chronic obstructive lung disease.²⁰ In a survey of 365 subjects followed for more than 10 years, the maximum saving in the decline in FEV₁ that was achieved by changing to lower tar cigarettes (a reduction of about 12 mg tar per cigarette) was estimated

to be less than 8 ml a year.¹² Our results also suggest that the tar content of cigarettes is relatively unimportant with respect to the development of ventilatory impairment.^{9,10}

CIGAR OR CHEROOT AND PIPE SMOKING

Cigar or cheroot and pipe smokers comprised 21.6% of our smokers. This is a much higher proportion than in most previous epidemiological surveys,^{2,3} but is typical for Denmark.²¹ In studies from other countries cigar and pipe smokers have been observed to have less impaired lung function¹⁻³ and lower mortality from chronic obstructive lung disease than cigarette smokers.²²

In the present study the decline in FEV₁ in cigar and cheroot smokers was higher than in any other smoking group. This is in keeping with the fact that they consumed two to three times more tobacco than the cigarette smokers.

Pipe smokers who did not inhale had a decline in lung function similar to that seen in non-smokers. It has been suggested that it might be possible to train cigarette smokers to avoid inhalation when switching to pipe smoking.²³ On the other hand, pipe smokers who said that they inhaled had slightly greater decline in FEV₁ than the cigarette smokers. Pipe smoking as such cannot therefore be regarded as harmless. These observations are in accordance with the finding of a very high mortality in Swedish pipe smokers, who inhale more frequently than pipe smokers in Britain.²⁴

INHALATION

The importance of inhalation for the development of chronic obstructive lung disease has been the subject of some controversy. Doll and Peto reported a positive association between mortality from chronic obstructive lung disease and inhalation of tobacco smoke,²² whereas Beck *et al.*, in a cross sectional study of cigarette smokers, were unable to relate inhalation to poorer lung function.¹¹

In the present study subjects who inhaled, except for male smokers of plain cigarettes, had a steeper decline in FEV₁ than those who did not inhale. The effect of inhalation varied between the smokers of different kinds of tobacco, and was significant only in pipe smokers. When considering all smoking groups separately, we found that the decline in FEV₁ was not significantly greater in non-inhalers than among the non-smokers. But when we pooled data from all smoking groups the decline in lung function in female non-inhalers was significantly higher than in female non-smokers. A similar, though non-significant, trend was observed in men. Our interpretation of these findings is that, although the decline of FEV₁ is less accelerated in non-inhalers than in inhalers, the non-inhalers still have a higher risk of developing ventilatory impairment than non-smokers.

OTHER VARIABLES RELATED TO DECLINE IN FEV₁
The decline of FEV₁ increased significantly with age and height, as reported in many

previous longitudinal studies.²⁵⁻²⁷

Alcohol contributed significantly to the decline in FEV₁ in men. In our previous study, in which only the data from subjects with relatively unchanged alcohol consumption throughout the observation period were analysed, a significant effect of alcohol on decline in FEV₁ was observed in both sexes.¹⁷

Although we recently reported a weak but significant association between ventilatory function and socioeconomic status,²⁸ we were unable in this analysis to show a significant association between the decline in lung function and formal education. A possible explanation for this may be the relatively short observation period in the present study, or it may be that in a sample of a general population factors associated with poor socioeconomic status influence ventilatory function mainly during childhood and adolescence.

Conclusions

In this study there was no significant difference in the decline in lung function between filter and plain cigarette smokers. Cigar and cheroot smokers had a slightly higher rate of decline of FEV₁ than cigarette smokers, presumably because of a very high tobacco consumption. The effect of pipe smoking on decline in lung function was strongly inhalation dependent, being negligible in non-inhalers but slightly higher than in cigarette smokers in those who inhaled. Subjects who said they inhaled experienced a significantly higher rate of decline in FEV₁ than non-smokers. The effect of inhalation differed in magnitude between smokers of different kinds of tobacco, being most pronounced in pipe smokers.

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