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Socioeconomic status, lung function and admission to hospital for COPD: results from the Copenhagen City Heart Study

E. Prescott*, P. Lange+, J. Vestbo*, and the Copenhagen City Heart Study Group

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ABSTRACT: This study analysed the effect of education and income on development of chronic obstructive pulmonary disease (COPD) assessing lung function and hospital admission.

The study population consisted of 14,223 subjects, aged 20–90 yrs, randomly sampled from the population of Copenhagen in 1976. Association between socioeconomic factors and forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) at study entry was analysed by linear regression. The relation between socioeconomic factors and risk of admission to hospital for COPD from study entry until 1993 was assessed by register linkage.

Education and income were independently associated with FEV1 and FVC. The age- and height-adjusted difference in FEV1 (mean±SEM) between the highest and lowest level of education and income was 259±31 mL in females and 400±39 mL in males. After additional adjustment for quantity and duration of smoking and inhalation, the difference was 220±31 mL and 363±39 mL in females and males, respectively. Results for FVC were of the same magnitude. Using a socioeconomic index which combined information on education and household income the association with lung function did not differ by age. A total of 219 females and 265 males were admitted to hospital for COPD during follow-up. Education and income were significantly associated with admission to hospital. After detailed adjustment for smoking the relative risks (95% confidence intervals) for medium and high *versus* low socioeconomic index in females were 0.74 (0.55–1.02) and 0.27 (0.10–0.73), respectively. Corresponding relative risks in males were 0.47 (0.36–0.63) and 0.35 (0.17–0.70).

The results indicate that socioeconomic factors operating from early in life affect the adult risk of developing chronic obstructive pulmonary disease independently of smoking in both females and males.

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*The Copenhagen Center for Prospective Population Studies at the Institute of Preventive Medicine, University of Copenhagen, Denmark. +Copenhagen City Heart Study, Dept 7117, Rigshospitalet, University of Copenhagen, and Medical Dept I, Bispebjerg Hospital, Copenhagen, Denmark.

Correspondence: E. Prescott, The Copenhagen Center for Prospective Population Studies, Institute of Preventive Medicine, Kommunehospitalet, DK-1399 Copenhagen K, Denmark, Fax: 45 33913244

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Socioeconomic status, whether measured by education, income or occupation, has long been known to be associated with mortality from different diseases [1–3] and this inequality seems to be increasing [4, 5]. Some of this association is undoubtedly caused by smoking and some by occupational exposure to airborne pollutants, yet these two factors alone do not fully explain the relation, and further exploration is called for [6].

Only a few studies have addressed the association between socioeconomic status and respiratory morbidity in females [6–9], which is of interest because females are generally less likely to be exposed to occupational pollutants. Another important point is whether or not the relation between socioeconomic factors and lung function varies with age. Shedding light on this could help specify the nature of these socioeconomic factors. Thus, the aim of this study was to examine the association between socioeconomic status and respiratory disease by sex and age using a large population-based study. In addition, by including admission to hospital for chronic obstructive pulmonary disease (COPD) as an endpoint the clinical relevance of the association was examined.

Materials and methods

The study is based on data from the Copenhagen City Heart Study (CCHS), a cardiovascular study initiated in 1976 and described in detail previously [10]. Briefly, the population consisted of randomly selected, age stratified males and females, aged ≥20 yrs, living in a defined area of Copenhagen. From 1976 to 1978, 14,223 subjects were examined (response rate 74%). Examination included a self-administered questionnaire with questions regarding level of education, household income, tobacco consumption, pulmonary symptoms, *etc.*, and measurement of lung function by spirometry.

Recording of the forced expiratory volume in one second (FEV1) and forced vital capacity (FVC) were made on an electronic spirometer (Monaghan N 403, Litleton, CO, USA), which was calibrated daily. The largest of two measurements differing by <5% from each other was used. Predicted values were based on regression of FEV1 on age and height among healthy never-smokers for each sex separately [11].

Because smoking is strongly associated with lung function and socioeconomic status, tobacco exposure was studied in as much detail as possible. Current smokers were asked about the type of tobacco, daily tobacco consumption (calculated for cheroot and cigar smokers by equating one cheroot to 3 and one cigar to 5 g tobacco), years of smoking and whether they inhaled. Exsmokers were asked how long they had smoked.

Educational level was classified into three groups: 1) ≤7 yrs (completion of primary school); 2) 8–11 yrs; and 3) >11 yrs. Household income was also classified into three levels: 1) <4,000; 2) 4,000–10,000; and 3) >10,000 Danish kroner·month^{-1}. In some analyses information on education and income was combined in a socioeconomic index which had three levels: 1) low, comprising subjects with short education and low income; 2) high, comprising subjects with long education and medium or high income; and 3) intermediary, comprising the remaining subjects.

All subjects were followed using the National Hospital Discharge Register. The analyses are based on the first diagnosis registered, which is the main cause of medical action during hospital admission. COPD related hospital admissions were focused on International Classification of Diseases (ICD)-8 codes 490-92. To study whether differences in hospital admission rates were caused by generally different thresholds for hospital admission between educational groups, similar analyses were made of hospital admissions for pneumonia (ICD-8 codes 471 and 480-86). Follow-up was terminated on December 31, 1992.

Statistical analysis

The effect of education and income on FEV1 and FVC was analysed by multiple linear regression for each sex separately. The model was as follows: estimated FEV1 (or FVC) = $\beta_0 + \beta_1$ (age-50) + β_2 ((age-50)^2)+ β_3 (height-mean)+ $\beta_{4\text{-}11}$ (combined level of education and income), where β_0 denotes FEV1 (or FVC) for a subject of age 50 yrs and mean height (174 cm for males and 161 cm for females) belonging to the lowest level of education and income. Adjustment for smoking was best performed by simultaneously including smoking status in five categories, inhalation, and duration of smoking in 10-yr intervals, all treated as categorical variables. Models were examined for interaction between level of education, income, smoking, and age.

For analysis of hospital admission for COPD the Cox proportional hazards model was used [12] with age as the underlying timescale and delayed entry accordingly. This assumes that referral to hospital has not changed over the study period. This was examined by repeating analyses with calendar time as the timescale, but results were not affected. Regression coefficients were estimated by the maximum partial likelihood method as suggested by Cox. The model was best-fitted with smoking in categories as described for linear regression on FEV1. The assumption of proportional hazards was checked by comparing risk estimates for each covariate in separate age-intervals. Deaths from COPD not preceded by hospitalization for COPD were censored. Analyses were carried out using Stata software (Stata, College Station, TX, USA) [13].

Results

Analyses are based on 7,712 females and 6,511 males. Both females and males with a higher level of education were younger, illustrating the rising level of education in recent decades, and thus the association between education and the variables, shown in table 1, are likely to be confounded by age.

FEV1 and FVC increased with increasing level of education and household income in both females and males. The differences were attenuated by adjustment for smoking but remained highly significant. In a separate analyses of never-smokers using the combined socioeconomic index, the difference in FEV1 (mean±SEM) between low, intermediary, and high level of socioeconomic index were 49.2±25.8 mL and 184.4±55.3 mL, respectively, in females, and 247.7±87.8 mL and 260.1±112.4 mL in males (table 2).

The relation between age and the association between the socioeconomic index and FEV1, adjusted for age, height, and smoking, is shown in figure 1. Similar results were found for FVC. There was no interaction between the socioeconomic index and age in 10 yr age intervals, indicating that the association between socioeconomic index and FEV1 did not depend upon age.

During follow-up, 219 females and 265 males were admitted to hospital for COPD. After adjustment for smoking, education, household income and socioeconomic index were all predictors of hospital admission. The risk in

Table 1. – Characteristics of the Copenhagen City Heart Study by educational level at the first examination in 1976–1978*

	Females				Males			
	<8 yrs	8–11 yrs	>11 yrs	p-value$^+$	<8 yrs	8–10 yrs	>11 yrs	p-value$^+$
n	3753	3202	743		3097	2499	901	
Age yrs	54.9±10.3	51.2±11.7	45.1±14.0	<0.001	55.4±11.1	55.4±11.1	47.3±14.5	<0.001
Smoking habits								
Never-smokers	26.6	27.8	30.4	0.04	7.9	10.8	18.7	<0.001
Exsmokers	12.7	15.6	18.8	<0.001	19.6	19.8	19.0	0.86
Heavy smokers**	45.7	16.9	50.7	0.20	65.6	66.8	61.7	0.09
Years of smoking**	27.6±10.2	25.8±10.7	23.1±12.5	<0.001	36.7±12.2	32.5±12.5	29.6±14.1	<0.001
Inhalation**	71.4	68.5	68.5	0.06	79.5	75.9	73.1	<0.001
FEV1 % pred	83.1±18.7	87.0±17.0	89.2±15.7	<0.001	79.5±19.8	84.7±17.9	88.9±17.2	<0.001
FEV1/FVC %	79.2±10.1	80.7±9.2	81.5±8.8	<0.001	76.7±12.3	79.4±10.8	79.9±9.5	<0.001
High income	10.5	22.1	34.5	<0.001	9.3	25.9	48.2	<0.001

Data are presented as means±SD or percentages. FEV1: forced expiratory volume in one second; FVC: forced vital capacity. *: 14 females and 14 males excluded because of missing data on education; **: only current smokers included; $^+$: test for trend.

Table 2. – Association between educational level, household income and lung function: results from multiple linear regression

	Females					Males				
		FEV1		FVC			FEV1		FVC	
	n	Unadjusted*	Adjusted**	Unadjusted*	Adjusted**	n	Unadjusted*	Adjusted**	Unadjusted*	Adjusted**
Education <8 yrs										
Low income	1556	0	0	0	0	941	0	0	0	0
Medium income	1556	85.7±17.1	83.8±16.9	86.5±13.4	82.9±18.3	1837	162.0±27.6	169.8±27.4	140.0±29.7	150.8±29.8
High income	367	124.7±26.7	128.3±26.3	132.4±28.7	131.8±28.6	286	179.4±44.8	183.9±44.4	112.9±48.2	124.1±48.3
Education 8–11 yrs										
Low income	648	52.0±21.2	39.7±21.0	47.2±22.9	38.1±22.8	367	74.6±40.5	66.6±40.1	23.7±43.5	21.5±43.7
Medium income	1711	145.2±16.9	132.7±16.7	122.7±18.2	111.9±18.1	1456	259±28.9	248.6±28.6	189.8±31.1	185.8±31.2
High income	675	187.0±21.6	165.6±21.3	153.9±23.3	136.0±23.2	641	357.8±34.9	349.3±34.6	288.3±37.5	292.1±37.6
Education >11 yrs										
Low income	170	150.2±38.6	130.3±38.1	138.3±41.5	123.9±41.5	121	204.7±65.8	187.8±65.7	151.8±70.8	139.2±71.5
Medium income	304	155.1±29.3	135.0±28.9	147.5±31.5	124.9±31.4	341	413.2±42.5	384.0±42.2	392.3±45.8	381.0±45.9
High income	251	259.3±31.4	220.7±31.1	250.8±33.8	221.2±33.8	432	399.9±39.0	362.5±39.0	361.7±42.3	342.1±42.4

Values are estimated difference in forced expiratory volume in one second (FEV1) (mL) or forced vital capacity (FVC) (mL) between indicated level and lowest level of education and household income. Data presented as means±SEM. *: adjusted for age and height; **: adjusted for age, height and smoking. Model: estimated FEV1 (FVC)=β_0+β_1 (age-50)+β_2 (age-50)^2+β_3 (height-mean)+$\beta_{4–11}$ (socioeconomic index) + $\beta_{12–15}$ (smoking status (5 categories)) + β_{16} (inhalation) + $\beta_{17–22}$ (duration of smoking (7 categories)).

the lowest socioeconomic group was approximately three-fold higher than in the highest group, and was similar in females and males (table 3). A separate analyses on never-smokers was not possible because of too few hospital admissions. The relation between socioeconomic index and admission to hospital were further examined to determine whether it depended upon age by truncating or beginning, respectively, observations at age 65 yrs, and it was found that the association was strongest in the younger subjects.

To determine the extent to which the association between socioeconomic index and admission to hospital is caused by subjects with lower socioeconomic index having a generally lower threshold for admission to hospital, hospital admission for pneumonia was also examined. After adjustment for smoking, the relative risk (RR) for intermediary and high socioeconomic index in females was 0.88 (0.67–1.16) and 0.91 (0.51–1.62), respectively, and 0.83 (0.62–1.10) and 1.00 (0.59–1.69) in males.

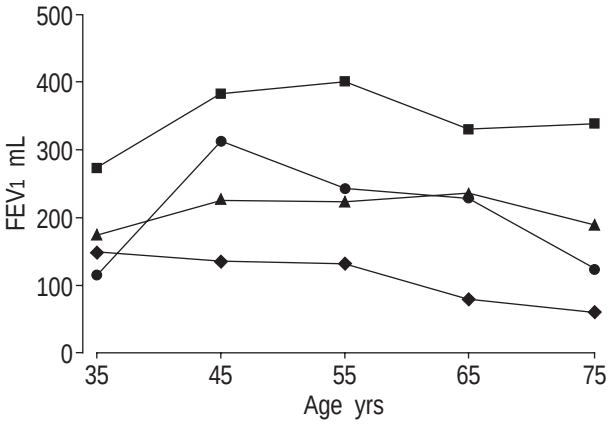

Fig. 1. – Estimated difference in forced expiratory volume in one second (FEV1; in mL) between level of socioeconomic index indicated and lowest level by age and sex. Model: estimated FEV1 = β_0 + β_1 (age-50) + β_2 (age-50)^2 + β_3 (height-mean) + $\beta_{4–7}$ (smoking status (5 categories)) + β_8 (inhalation) + $\beta_{9–14}$ (duration of smoking (7 categories)) + $\beta_{15–16}$ (socioeconomic index if age 30–39 yrs) + $\beta_{17–18}$ (socioeconomic index if age 40–49 yrs) + ... + $\beta_{23–24}$ (socioeconomic index if age 70–79 yrs). ◆ : females, medium; ● : females, high; ▲ : males, medium; ■ : males, high.

Discussion

It was shown that income and education are associated with lung function independently of smoking in both females and males. The effect was quantified in terms of lost millilitres of FEV1 and FVC and was found not to be trivial. These socioeconomic factors were also associated with subsequent admission to hospital for COPD, with the lowest socioeconomic level having a three-fold risk compared to the highest.

Methodology

The three indices for socioeconomic status generally used are education, income, and occupation. Level of education is widely used and accepted as a valid measure of socioeconomic status [14]; it is easily recordable, applies to every adult individual, and is relatively easy to compare between studies and countries. In females it is a better indicator of socioeconomic status than occupation, because large groups of females with no formal employment are difficult to classify. In addition, education will usually precede poor health, whereas indices such as low income may also result from poor health. Another concern is that people of higher age generally have lower average levels of education due to the gradually rising level of education in the last few decades, but for comparison within age groups, this is not a problem.

Lung function

Association between socioeconomic status and lung function was analysed on cross-sectional data measured two decades ago. Longitudinal data would give a more

Table 3. – Relative risks (RR) of admission to hospital for chronic obstructive pulmonary disease with 95% confidence intervals (CI) by education, household income and socioeconomic index. All models were adjusted for age

	Females				Males			
	Unadjusted		Adjusted*		Unadjusted		Adjusted*	
	RR	95% CI	RR	95% CI	RR	95% CI	RR	95% CI
Education								
<8 yrs	1		1		1		1	
8–11 yrs	0.65	0.49–0.86	0.70	0.52–0.93	0.55	0.42–0.72	0.59	0.44–0.78
>11 yrs	0.27	0.11–0.65	0.28	0.12–0.69	0.44	0.27–0.72	0.55	0.34–0.90
Household income								
Low	1		1		1		1	
Medium	0.87	0.64–1.19	0.80	0.59–1.09	0.50	0.38–0.65	0.50	0.38–0.66
High	0.63	0.40–1.01	0.59	0.37–0.95	0.30	0.20–0.45	0.32	0.21–0.49
Socioeconomic index								
Low	1		1		1		1	
Medium	0.78	0.57–1.06	0.74	0.55–1.02	0.45	0.35–0.60	0.47	0.36–0.63
High	0.27	0.09–0.74	0.27	0.10–0.73	0.28	0.14–0.55	0.35	0.17–0.70

*: model λ_i (age)=λ_0 (age) × exp ($\beta_{1\text{-}2}$ (education/household income/socioeconomic index) + $\beta_{3\text{-}6}$ (smoking status (5 categories)) + β_7 (inhalation) + $\beta_{8\text{-}13}$ (duration of smoking (7 categories))).

precise prediction, but with the aim of comparing effects of socioeconomic status the use of cross-sectional data is a valid approach. Based on the same cross-sectional data it has previously been reported that there is a strong association between smoking and reduction in FEV1, the size of which was similar to that found in other studies [15].

Education and household income were independently associated with FEV1 and FVC, and the association was only slightly attenuated by adjustment for smoking. The difference between highest and lowest level of socioeconomic index was equivalent to the reduction in FEV1 brought about by ~10 yrs of ageing in never-smokers [15]. Several studies, most from the 1970s, have found a socioeconomic gradient in various indices of obstructive lung disease, mainly for respiratory symptoms [6–9, 16–19]. Few studies, however, have attempted to quantify the effect of socioeconomic status on lung function. One study from 1971 on 410 male nonsmokers found that the difference in FEV1 between the highest and lowest social class (out of five) was 0.4 L [18]. In the Cracow study [7], occupational exposure was associated with an increased decline in FEV1 of 6.9 and 6.0 $mL \cdot yr^{-1}$ in males and females, respectively, but education as a dichotomized variable was not. In the French "Pollution Atmospherique Affections Respiratoires Chroniques" (PAARC) study, education and social class, both dichotomized, were associated with a difference in adjusted mean FEV1 of 94 and 63 mL, respectively in males, and 59 and 48 mL in females [8]. Both studies adjusted for smoking. Considering the differences in measures used, these results are consistent with the present findings.

The fact that a strong socioeconomic gradient was present in both sexes from a relatively young age indicates that it was only partly caused by occupational exposure. This is corroborated by a Norwegian study in which education remained a significant risk factor for obstructive lung disease after adjustment for occupational exposure [6]. The socioeconomic gradient was smaller in elderly females. This could be because they had less occupational exposure, but could also reflect that the covariates used are not good indicators of socioeconomic status in the older female birth cohorts, in whom education was less common.

Admission to hospital

Since COPD is a long-standing, crippling disease with a relatively low mortality rate, hospital admission is an appropriate measure of impact of this disease and could even be regarded as a form of morbidity *per se*, reflecting disease of some severity. In studies using this register-based information on hospitalization in studying COPD morbidity it has previously been found that the register had high validity in so far as both FEV1 and respiratory symptoms were strong predictors of hospitalization [15, 20, 21].

The association with admission to hospital was consistent when using education and income separately. In the combined socioeconomic index, males and females belonging to the lowest group had an approximately three times higher risk of hospital admission than subjects belonging to the highest. Unlike some studies [6, 8] the association between socioeconomic status and chronic obstructive lung disease was similar in males and females, perhaps because the majority of the females in this study belong to the work-force and are not as dependent on their husbands social class. In concordance with other studies showing that size of mortality differences associated with educational level decrease with increasing age [22], the socioeconomic gradient was stronger in subjects <65 yrs of age.

In order to try to determine the extent to which the socioeconomic gradient in risk of hospital admission for COPD reflected other factors related to socioeconomic status, *i.e.*, unspecific susceptibility or differences in use of general practitioner's, they were compared with admission for pneumonia. Despite a documented association between reduced lung function and pneumonia [23], the association between socioeconomic status and hospital admission for pneumonia was not as strong as for COPD. It is possible that RRs of admission for COPD are affected by diagnostic bias with subjects with low socioeconomic status being more likely to be classified as COPD. On the other

hand, the effect of socioeconomic status on respiratory disease may also have been underestimated, since relatively crude measures of socioeconomic status were employed [24, 25].

Adjustment for smoking was based on smoking habits recorded up to 17 yrs earlier. If subjects with higher socioeconomic status were more likely to quit smoking during follow-up, this may have influenced results. However, considering the pathogenesis of COPD, which develops after many years of smoking, differences in quitting rates are not likely to have affected the results.

Denmark and the other Nordic countries are generally regarded as homogenous welfare states and have been found to have a very low "social inequality index" [22, 26]. It has been shown, that the larger the income differentials, the larger the differences in mortality between socioeconomic groups [27]. Concordantly, socioeconomic differences in mortality in the Nordic countries are considerably smaller than in countries such as the UK, France, and the USA [28]. Despite this, this study has shown that socioeconomic status in Denmark is strongly and consistently associated with lung function and subsequent admission to hospital. The fact that the association is present in males and females at all ages indicates that the socioeconomic risk factors are likely to be multifactorial and may include intrauterine exposure [29–31], childhood infections [31, 32], housing conditions [33–36], occupational exposure, and other lifestyle factors. Further studies that explore the socioeconomic differences in respiratory disease with the aim of identifying potentially modifiable risk factors are necessary.

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