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Explaining the social patterning of lung function in adulthood at different ages: the roles of childhood precursors, health behaviours and environmental factors

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ABSTRACT

Background Lung function successfully predicts subsequent health. Although lung function is known to decline over age, little is known about changes in association with socioeconomic status (SES) throughout life, and whether explanatory factors for association vary with age or patterns for non smokers.

Methods Analyses were based on data on 24 500 participants aged ≥18 years from the 1995, 1998 and 2003 Scottish Health Surveys who were invited to provide 1 s forced expiratory volume (FEV_1) and forced vital capacity (FVC) lung measurements. Sex-stratified multiple linear regression assessed lung function–SES (occupational social class) associations and attenuation by covariates in three age groups (2003 data (n=7928)).

Results The FEV_1–SES patterns were clear ($p<0.001$) and constant over time. Relative to the least disadvantaged, FEV_1 in the most disadvantaged was lower by 0.28 L in men and 0.20 L in women under 40 years compared with differences of 0.51 L in men and 0.25 L in women over 64 years ($p_{interaction}<0.001$ men, $p_{interaction}=0.004$ women). The greatest attenuation of these results was seen by height, parental social class and smoking, especially among the under 65s. Second-hand smoke exposure and urban/rural residence had some impact among older groups. Adjusting for physical activity and weight had little effect generally. Similar patterns were seen for FVC and among never smokers.

Conclusions We found cross-sectional evidence that SES disparity in lung function increases with age, especially for men. Our findings indicate that early-life factors may predict inequity during younger adulthood, with environmental factors becoming more important at older ages.

INTRODUCTION

Lung function is an effective biomarker of respiratory disease and a major long-term predictor of illness and mortality from a range of diseases including non-respiratory conditions.[1 2] Historically, studies have demonstrated poorer lung function and more rapid decline among those in lower socioeconomic status (SES).[3–5] Although lung function is well known to decline with increasing age[6]—regardless of SES[7]—little is known about changes in SES patterns over the life course.

Among the main lung function measures are forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC) and the ratio of the two. It is important to understand why lung function is socially patterned in order to identify potential interventions for reducing decline; existing literature points to a number of candidate drivers. Early-life SES is associated with adult SES and has been linked with poorer respiratory function.[3 8 9] Attained height, which is positively associated with larger lung capacity,[10 11] is strongly socially patterned in childhood[12] and independently linked with adult SES, with smaller stature among lower status groups.[13] Cigarette smoking is known to assault existing lung function in a cumulative manner[14] and since it is more prevalent among lower status groups,[15] it may account for social gradients in FEV_1. Although FEV_1–mortality associations are known to exist for lifelong never -smokers,[1] it is unclear whether social patterning of FEV_1 exists in non-smokers. The roles of other behavioural determinants of FEV_1—weight and physical activity—are also potentially important in its social patterning. Additionally, environmental—and less modifiable (by individuals)—aspects associated with both respiratory health and social circumstances—such as second-hand smoke exposure[16] and urban/rural residence as a proxy for air quality[17 18]—are likely to play their part in driving the FEV_1–SES associations. However, it is not known whether different explanatory factors dominate at different life stages, or if the impacts of these are similar in non-smokers.

The primary aim of this study was to determine the extent to which the socioeconomic patterning of lung function varies with age, with the greatest emphasis on FEV_1. We hypothesised a priori that the social patterning of FEV_1 would be stronger at older ages. The secondary aim was to examine variations by age in the extent to which the social patterning of FEV_1 is explained by measures of childhood precursors (height and child SES), modifiable risk factors (smoking, physical activity and weight) and environmental determinants (second-hand smoke exposure and urban/rural area of residence). Finally, we examined patterns in never-smokers.

METHODS

Data for this study were combined from three sweeps of the Scottish Health Survey (SHeS) 1 year cross-sectional nationally representative samples of the population living in private households in Scotland, conducted in 1995–1996, 1998–1999, 2003–2004, with 67–81% response levels. The methodology has been described elsewhere,[19] but briefly, residential addresses from around one-third

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of the postcode sector areas (average population approximately 5000) of Scotland were sampled from all health boards. Participants were interviewed at home and subsequently visited by a nurse. The analysis presented here was based on adults aged 18 years and over.

Lung function measurements were made by a nurse using Vitalograph spirometers compatible across surveys.[20 21] The 1995 and 1998 surveys used the 'Escort' model, changed in 2003 to the direct replacement 'Micro spirometer' following the discontinuation of 'Escort', complying with the American Thoracic Society (ATS) standards.[20] Quality-assurance rules based on ATS criteria were employed.[21–23] Since our interest was in the relative contribution of explanatory factors to SES patterning, we used absolute lung function measurements rather than reference values. The index of SES used was social class of the chief income earner of the household based on the Registrar General's standard classification of occupation grouped into six classes.[24]

Smoking was measured in pack-years for current and ex-regular smokers, a cumulative total reflecting the amount and duration of cigarette consumption, with each pack-year equating to an average of 20 cigarettes smoked daily for 1 year.[25] Height and weight were measured by interviewers using standard protocols.

Respondents were asked about a range of physical activities carried out in the week prior to the interview, in terms of time spent being active, intensity and frequency. Respondents were classified as meeting (or not) current national physical activity recommendations—participation in moderate or vigorous activity on at least 5 days a week. Participants were asked to describe any long-standing illnesses, with respiratory diseases identified as those corresponding to the ICD-10 J00-J99 codes.[26] Parental social class was ascertained from information on the participants' fathers' and mothers' occupation, when participants were around 14 years of age, classified into five groups of the NS-SEC scheme.[27] Participants were asked (yes/no) if they were regularly exposed to other people's tobacco smoke.[28] Area of residence was categorised according to the Scottish Executive eightfold urban/rural classification.[29] Parental NS-SEC, smoke exposure and urban/rural data were only available from the 2003 survey, so analyses which included covariates are based on this year only.

Table 1 Characteristics of men and women, 18 years and older, averaged across the 1995, 1998 and 2003 Scottish Health Surveys (N=24 500)

Characteristic	Men		Women	
Social class % (n)				
I Professional	6.1	656	5.1	706
II Manager	24.3	2611	24.0	3297
IIInm Skilled non-manual	9.9	1060	16.8	2310
IIIm Skilled manual	35.2	3787	26.9	3702
IV Semiskilled	15.4	1651	16.1	2210
V Unskilled	5.8	620	7.2	991
Unknown	3.4	370	3.9	529
Age mean (SE)	45.9	15.6	46.1	16.0
Height (cm) mean (SE)	174.4	7.1	160.8	6.4
Weight (kg) mean (SE)	81.7	14.2	69.3	14.1
Cigarette pack-years mean (SE)	12.9	21.2	8.6	15.6
Cigarette smoking % (n)				
Never smoker	35.6	3828	41.6	5716
Used to smoke occasionally	5.1	545	5.7	781
Used to smoke regularly	24.1	2590	19.1	2629
Current smoker	33.1	3561	33.4	4590
Unknown	2.2	231	0.2	29
Meeting physical activity recommendations* % (n)	36.7	2685	28.0	2637
Parental social class† % (n)				
Managerial and professional	24.1	843	24.8	1100
Intermediate	7.0	245	7.6	335
Small employers/own account	9.8	344	9.9	438
Lower supervisory/technical	16.4	574	15.0	664
Semiroutine	33.3	1165	34.1	1512
Unknown	9.4	328	8.6	380
Exposed to second-hand smoke† % (n)	61.8	2133	55.7	2443
Area of residence† % (n)				
Large urban area (125 000+)	31.0	1085	32.7	1448
Other urban area (10 000–125 000)	27.8	972	28.2	1250
Accessible small town (3000–10 000)	11.6	405	11.6	515
Remote small town (3000–10 000)	2.8	97	2.6	115
Very remote small town (3000–10 000)	2.0	71	1.8	80
Accessible rural (<3000)	16.0	559	14.6	648
Remote rural (<3000)	2.7	95	2.9	127
Very remote rural (<3000)	6.1	215	5.6	246
FEV_1 (L) mean (SE)	3.7	1.0	2.7	0.7
FVC (L) mean (SE)	4.7	1.2	3.3	0.8
FEV_1/FVC ratio mean (SE)	0.79	0.11	0.81	0.10

*Data available for 1998 and 2003 only (N=16 770).
†Data available for 2003 only (N=7928).
FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity.

Statistical methods

A total of 24 500 participants (10 755 men and 13 745 women) aged over 18 years across the three surveys were offered a nurse visit, with data incompletely observed for FEV_1 (26%; including 0.8% rejected due to poor quality), FVC (29%; including 4% rejected due to poor quality), social class (4%), height (8%), weight (12%), cigarette pack-years (13%), cigarette smoking status (1%), physical activity (<1%), parental social class (9%) and exposure to second-hand smoke (1%). To account for missing data, we multiply imputed values in five data sets using the chained equations procedure[30] under the missing at random assumption based on all variables in table 1 and respiratory disease status.

Age-adjusted linear regression was used to determine the FEV_1–SES associations. Since there is a suggestion of sex differentials,[3] supported by a sex–social class interaction ($p<0.001$), we sex-stratified throughout. We assessed differential FEV_1–social class associations for those under 40 years, those 40–64 years old and those 65 years and over by testing for an age–social class interaction and undertook the main analyses split by age. We compared the difference in FEV_1 of individual classes relative to professional and managerial occupations, and by the slope index of inequality (SII), which uses information across the entire range of social groups, and may be interpreted as a comparison of the most disadvantaged and most advantaged individuals.[31] We assessed the degree of attenuation occurring on inclusion in models of: height and parental social class; cigarette smoking; physical activity and weight and second-hand smoke exposure and urban/rural area of residence. The magnitude of attenuation in the covariate-adjusted models was determined by the percentage change from baseline survey year-adjusted and age-adjusted results. The attenuation assessment was based on data from the 2003 survey only, as determined by covariate data availability (n=7928). Analyses were repeated for the FVC and FEV_1/FVC ratio. We also investigated patterns in those that had never smoked (n=10 451), using two age groups—above and below age 45—in the interests of power. The hierarchical data structure of individuals living in the health board region (seven groups) was accounted for using a sandwich estimator for within-cluster correlation.[32] The appropriateness of combining data from three separate surveys was assessed by fitting social class–survey interaction terms. In order to assess the robustness of our findings, we performed a series of sensitivity analyses: since individuals did not all have equal chances of selection in the survey, and to check for any bias arising from non-response, we reran analyses applying inverse probability weighting so that the weighted sample matched the population estimates for age/sex and geographical area;[33] we reran analyses excluding those with respiratory disease (n=15 361); we reran analyses confined to individuals with complete data on all covariates.

RESULTS

The mean age was just over 46 years and the mean FEV_1 was 3.7 L in men and 2.7 L in women (table 1). The FEV_1–SES patterns did not converge or diverge over time (p=0.224 men, p=0.543 women), validating the combination of data across surveys.

Relative to professionals (mean FEV_1=4.01 L), men in the other classes generally had significantly lower lung function (differences ranging from 0.09 L to 0.43 L; table 2). Results were similar but less marked for women (mean FEV_1=2.88 L in professionals; differences from 0.03 to 0.26 L). From the SII values comparing the most disadvantaged with the least disadvantaged across the socioeconomic range, the FEV_1 levels were lower by 0.41 L in men (age-adjusted and survey year-adjusted coefficients −0.41; 95% CI −0.54 to −0.29) and 0.26 L in women (−0.26 95% CI −0.31 to −0.22; table 2). Differentials in FEV_1 by SES widened with increasing age ($p_{interaction} < 0.001$ men, $p_{interaction} = 0.004$ women). More pronounced FEV_1–SES associations were seen in the older adults than in the youngest adults: with FEV differences between the least and most socioeconomically disadvantaged of 0.50 L in men and 0.31 L in women for the middle-aged adults and 0.51 L in men and 0.25 L in women for the oldest age group; differences for the younger age groups were 0.28 and 0.20 L, respectively.

Table 3 presents the linear regression results for the FEV_1–SES associations in terms of SII, with adjustment for survey

Table 2 Linear regression and slope index of inequality coefficients* for FEV_1 (L) by social class in men and women by age group in the 1995, 1998 and 2003 Scottish Health Surveys (N=24 500)

	Males				Females			
Social class	**n**	**Coefficient**	**95%**	**CI**	**n**	**Coefficient**	**95%**	**CI**
All ages								
Professional	682	0.00			737	0.00		
Intermediate	2713	−0.09	−0.19	0.01	3427	−0.03	−0.11	0.05
Skilled (non-manual)	1104	−0.15	−0.29	−0.01	2404	−0.12	−0.21	−0.03
Skilled (manual)	3908	−0.28	−0.41	−0.15	3849	−0.16	−0.24	−0.08
Partly skilled	1706	−0.33	−0.45	−0.22	2295	−0.20	−0.28	−0.12
Unskilled	641	−0.43	−0.56	−0.29	1031	−0.26	−0.36	−0.17
SII	10 755	−0.41	−0.54	−0.29	13 745	−0.26	−0.31	−0.22
18–39								
Professional	315	0.00			345	0.00		
Intermediate	1056	−0.02	−0.31	0.27	1310	−0.03	−0.19	0.14
Skilled (non-manual)	525	−0.08	−0.23	0.07	1123	−0.11	−0.26	0.05
Skilled (manual)	1413	−0.14	−0.40	0.12	1469	−0.11	−0.32	0.10
Partly skilled	667	−0.20	−0.38	−0.01	922	−0.16	−0.32	−0.01
Unskilled	215	−0.30	−0.52	−0.07	285	−0.22	−0.41	−0.03
SII	4190	−0.28	−0.52	−0.05	5454	−0.20	−0.28	−0.13
40–64								
Professional	312	0.00			342	0.00		
Intermediate	1328	−0.14	−0.34	0.05	1709	−0.03	−0.18	0.11
Skilled (non-manual)	468	−0.20	−0.38	−0.02	965	−0.09	−0.21	0.03
Skilled (manual)	1909	−0.38	−0.59	−0.16	1777	−0.19	−0.30	−0.08
Partly skilled	808	−0.42	−0.60	−0.24	1009	−0.22	−0.32	−0.13
Unskilled	330	−0.52	−0.71	−0.34	524	−0.29	−0.43	−0.14
SII	5155	−0.50	−0.65	−0.35	6326	−0.31	−0.38	−0.24
65 and over								
Professional	55	0.00			50	0.00		
Intermediate	330	−0.22	−0.73	0.28	409	−0.03	−0.24	0.17
Skilled (non-manual)	112	−0.20	−0.91	0.51	316	−0.16	−0.37	0.05
Skilled (manual)	586	−0.44	−0.85	−0.04	603	−0.19	−0.38	0.01
Partly skilled	232	−0.52	−1.07	0.04	365	−0.20	−0.48	0.08
Unskilled	96	−0.56	−1.10	−0.03	222	−0.25	−0.51	0.00
SII	1410	−0.51	−0.80	−0.22	1965	−0.25	−0.41	−0.09

*Adjusted by survey year and age, including a quadratic term for age; estimates represent the difference in FEV_1 (in L) for each social class group relative to the professional group.
FEV_1, forced expiratory volume in 1 s; SII, slope index of inequality.

Table 3 Slope index of inequality coefficients for FEV_1 (L) by social class adjusting for covariates in men and women by age group in the 2003 Scottish Health Survey (N=7928)

Age	Model	Males				Females			
		SII coefficient	95% CI		Per cent Explained	SII coefficient	95% CI		Per cent Explained
		n=1046				n=1340			
18–39	Survey year, age*	−0.29	−0.61	0.03	–	−0.21	−0.50	0.08	–
	Height†, parental social class	−0.15	−0.52	0.23	49	−0.12	−0.45	0.22	45
	Smoking	−0.27	−0.59	0.05	8	−0.17	−0.45	0.12	21
	Physical activity, weight	−0.29	−0.60	0.02	1	−0.22	−0.51	0.07	−4
	Second-hand smoke, urban/rural area	−0.29	−0.58	−0.01	0	−0.23	−0.52	0.05	−11
	All‡	−0.16	−0.49	0.16	43	−0.11	−0.44	0.22	46
		n=1616				n=2015			
40–64	Survey year, age*	−0.45	−0.67	−0.23	–	−0.30	−0.49	−0.12	–
	Height†, parental social class	−0.18	−0.50	0.14	59	−0.14	−0.47	0.19	54
	Smoking	−0.38	−0.61	−0.14	15	−0.24	−0.40	−0.08	21
	Physical activity, weight	−0.44	−0.67	−0.22	1	−0.29	−0.47	−0.11	4
	Second-hand smoke, urban/rural area	−0.36	−0.62	−0.11	18	−0.27	−0.43	−0.10	12
	All‡	−0.11	−0.45	0.23	76	−0.07	−0.42	0.27	75
		n=837				n=1074			
65 and over	Survey year, age*	−0.46	−0.89	−0.04	–	−0.21	−0.56	0.14	–
	Height†, parental social class	−0.42	−0.98	0.13	8	−0.22	−0.57	0.13	−5
	Smoking	−0.41	−0.83	0.01	12	−0.19	−0.52	0.15	11
	Physical activity, weight	−0.44	−0.86	−0.01	6	−0.19	−0.53	0.15	11
	Second-hand smoke, urban/rural area	−0.35	−0.79	0.09	25	−0.18	−0.55	0.18	13
	All‡	−0.29	−0.86	0.29	37	−0.17	−0.53	0.18	18

*Includes quadratic term for age representing the difference in FEV_1 (in L) of the most disadvantaged and most advantaged individuals according to social class.
†Includes quadratic term for height.
‡All covariates: survey year, age, height, parental social class, smoking, physical activity, weight, second-hand smoke and urban/rural area.
FEV_1, forced expiratory volume in 1 s; SII, slope index of inequality.

year, age and other covariates stratified by age group in the 2003 survey. For the youngest adults, height and parental social class together explained much of the social patterning of FEV_1 with 49% attenuation in men and 45% in women; smoking was also an important factor, itself explaining 8% and 21%, respectively, of the association. Adjusting for second-hand smoke and urban/rural area of residence explained none of the FEV_1–SES associations in either men or women; physical activity and weight had little impact. Inclusion of all covariates explained 43% and 46%, respectively, of the FEV_1–SES associations for men and women. For the middle-aged adults, height and parental social class together also explained the majority of the social patterning of FEV_1 with 59% attenuation in men and 54% in women; smoking was again an important factor, explaining 15% and 21%, respectively, of the association. Adjusting for second-hand smoke and urban/rural area of residence explained somewhat more of the FEV_1–SES associations in the middle-aged adults than in the youngest adults (18% in men and 12% in women); again, there was little impact by physical activity and weight. Inclusion of all covariates explained 76% and 75%, respectively, of the FEV_1–SES associations for men and women. In both men and women, height and parental social class and smoking explained less of the FEV_1–SES associations (up to 8%) in the 65 and over age group compared with the younger groups. As for the middle-aged adults, adjustment for second-hand smoke exposure and urban/rural residence had a somewhat greater impact on estimates in the oldest group (25% for men and 13% for women) than in the youngest group. Inclusion of all covariates explained far less of the FEV_1–SES associations in those 65 years and older (37% for men and 18% for women) than in the younger groups.

Results for FVC were similar (see online supplementary table S1), whereas there was no evidence of a socioeconomic gradient for FEV_1/FVC (age-adjusted and survey year-adjusted coefficients −0.01; 95% CI −0.03 to 0.01 for men and −0.01; 95% CI −0.05 to 0.02 for women).

Never smokers

When confining analyses to never smokers, we found broadly similar patterns of stronger socioeconomic patterning of lung function in the oldest age group (table 4). Similarly, the explanatory role of height and parental social class was greater among the younger ages compared with the older ages, whereas second-hand smoke exposure and urban/rural area of residence were apparently more important for those 45 and over than for the under 45s, particularly among women (table 5). All sensitivity analyses yielded similar results to those presented (data available on request).

DISCUSSION

Lung function, as indexed by FEV_1 and FVC, was patterned by SES for both men and women in the SHeSs 1995–2003 and was stable over this time period; no socioeconomic gradient was found for the FEV_1/FVC ratio. However, in our cross-sectional data, we found evidence of widening social disparities over age, especially among men. The explanatory role of covariates appeared greater among the younger age groups, with the greatest emphasis on markers of childhood precursors and smoking. Environmental factors were apparently more important for the older age groups, particularly among men. Whereas adjustment for height and parental social class always resulted in non-significant socioeconomic gradients in lung function, associations were not explained by adult weight or physical activity in any age group. Crucially, our findings were similar in never smokers, and were robust when confined to those without respiratory disease.

Table 4 Linear regression and slope index of inequality coefficients* for FEV_1 (L) by social class in male and female never smokers by age group in the 1995, 1998 and 2003 Scottish Health Surveys (N=9613)

	Males				Females			
Social class	n	Coefficient	95% CI		n	Coefficient	95% CI	
All ages								
Professional	344	0.00			408	0.00		
Intermediate	1119	0.02	−0.12	0.16	1632	−0.01	−0.13	0.12
Skilled (non-manual)	453	−0.07	−0.28	0.14	1030	−0.09	−0.24	0.06
Skilled (manual)	1293	−0.12	−0.33	0.08	1565	−0.11	−0.22	0.00
Partly skilled	518	−0.23	−0.42	−0.04	788	−0.14	−0.26	−0.02
Unskilled	161	−0.35	−0.62	−0.08	302	−0.16	−0.34	0.02
SII	3888	−0.35	−0.53	−0.16	5725	−0.19	−0.29	−0.10
18–44								
Professional	225	0.00			270	0.00		
Intermediate	673	0.02	−0.14	0.18	863	−0.03	−0.20	0.13
Skilled (non-manual)	291	−0.07	−0.24	0.11	582	−0.07	−0.28	0.13
Skilled (manual)	720	−0.09	−0.27	0.09	767	−0.10	−0.29	0.09
Partly skilled	295	−0.19	−0.43	0.06	336	−0.11	−0.23	0.00
Unskilled	76	−0.27	−0.51	−0.02	96	−0.18	−0.44	0.09
SII	2280	−0.27	−0.49	−0.04	2914	−0.15	−0.27	−0.02
45 and over								
Professional	118	0.00			138	0.00		
Intermediate	446	−0.02	−0.42	0.38	769	0.02	−0.18	0.23
Skilled (non-manual)	162	−0.10	−0.69	0.50	448	−0.08	−0.30	0.13
Skilled (manual)	573	−0.22	−0.62	0.18	798	−0.13	−0.32	0.06
Partly skilled	224	−0.34	−0.68	0.00	452	−0.14	−0.35	0.07
Unskilled	85	−0.49	−0.87	−0.10	206	−0.13	−0.38	0.11
SII	1608	−0.48	−0.73	−0.24	2811	−0.23	−0.38	−0.07

*Adjusted by survey year and age, including a quadratic term for age; estimates represent the difference in FEV1 (in L) for each social class group relative to the professional group.
FEV_1, forced expiratory volume in 1 s; SII, slope index of inequality.

To our knowledge, this is the first study to identify widening social inequalities in lung function with increasing age. Our findings that SES patterning of FEV_1 and FVC remained (albeit non-significantly) following adjustment for childhood social class, smoking and height and various other confounders concur with earlier work.[34] Indications that environmental factors seem more important in explaining SES-lung function associations at older ages are in line with evidence that contemporary circumstances may be more important for broader measures of health at older ages.[35] Importantly, there is evidence that measures of lung development act as biomarkers for childhood exposures.[11] With data on parental social class and height, we were able to proxy early-life socioeconomic circumstances such as childhood diet, maternal smoking, low birthweight, prematurity and

Table 5 Slope index of inequality coefficients for FEV_1 (L) by social class adjusting for covariates in male and female never smokers by age group in the 2003 Scottish Health Survey (N=3426)

		Males			Per cent	Females			Per cent
Age	Model	SII* coefficient	95%	CI	Explained	SII* coefficient	95%	CI	Explained
		n=669				n=837			
18–44	Survey year, age†	−0.37	−0.78	0.05	–	−0.17	−0.55	0.21	–
	Height‡, parental social class	−0.23	−1.02	0.56	38	−0.12	−0.56	0.32	30
	Physical activity, weight	−0.39	−0.79	0.02	−5	−0.17	−0.58	0.24	0
	Second-hand smoke, urban/rural area	−0.34	−0.76	0.07	7	−0.20	−0.62	0.21	−20
	All§	−0.21	−0.91	0.49	43	−0.14	−0.55	0.27	17
		n=723				n=1197			
45 and over	Survey year, age†	−0.47	−0.88	−0.07	–	−0.27	−0.56	0.02	–
	Height‡, parental social class	−0.52	−1.14	0.09	−11	−0.25	−0.53	0.04	8
	Physical activity, weight	−0.48	−0.89	−0.07	−2	−0.26	−0.55	0.03	3
	Second-hand smoke, urban/rural area	−0.40	−0.87	0.06	15	−0.23	−0.53	0.08	15
	All§	−0.46	−1.08	0.16	2	−0.21	−0.49	0.08	23

*SII: slope index of inequality representing the difference in FEV_1 (in L) of the most disadvantaged and most advantaged individuals according to social class.
†Includes quadratic term for age.
‡Includes quadratic term for height.
§All covariates: survey year, age, height, parental social class, smoking, physical activity, weight, second-hand smoke and urban/rural area.
FEV_1, forced expiratory volume in 1 s.

childhood infections. Our additional inclusion here of second-hand smoke exposure and urban/rural residence,which may capture traffic-related air pollution,[18] goes further than previous studies examining explanations for social class differences in pulmonary function.[34] Further, compared with previous studies, we use a more refined measure of smoking, capturing cumulative exposure. Similar findings in never smokers alone indicate the importance of the broader socioeconomic effects over and above smoking and other individual behavioural factors per se.[36]

Methodological issues to consider include the fact that our analyses are based on cross-sectional survey data prohibiting our ability to assess lung function reductions over age within individuals. Our finding of greater inequalities in middle-aged and older adults compared with younger adults could be due to a genuine change over age, possibly explained by the long latency of causes of respiratory disease. An alternative explanation would be a cohort effect. It could be that for older cohorts, compromised lung function is being impacted by chronic obstructive pulmonary disease, while for those born mainly after the introduction of the Clean Air Act in Scotland (in 1956), and subsequent closure of mines in the 1980s, the air quality was better for people across the social spectrum. However, we tested this and found no differential effect by decade of birth (data available on request). Although the effects of childhood poverty in today's society may no longer be mediated by air pollution, there may be other important pathways, such as early-life parental smoking and obesogenic factors. Reverse causality may also be an issue: for instance, in relation to physical activity and weight, there may be individuals who do not exercise (and are overweight) because they have poor lung function. The measure of childhood social class is based on the parental occupation when the respondent was aged 14 years and therefore may not necessarily be picking up circumstances related to low birthweight and prematurity. However, our inclusion of height as a proxy for childhood precursors will have gone some way towards capturing circumstance at that earliest life stage. In an attempt to distinguish the effects of height from modifiable and environmental determinants, we did not universally adjust for height (or weight). There is some evidence that FEV_1 and FVC are stronger predictors of mortality than height, and that height has no independent predictive power after lung function is taken into account.[37] Obesity is a further relevant factor to lung function.[18] Since weight and height have been included simultaneously in fully adjusted models, body mass has implicitly been captured. That we found similar results when confining our investigation to never smokers alleviates concerns of residual confounding by smoking. Other covariates that may be of interest, but were not available here, include dietary measures such as plasma vitamin C levels—since low antioxidant and fresh produce intake levels have been linked with lower respiratory function and SES[34 38] and birthweight as an indicator of intrauterine growth exposure.[39]

The legitimacy of implementing multiple imputation is based on the validity of the missing at random assumption that the chance of FEV_1 and FVC being measured satisfactorily does not depend on the level of the lung function itself. However, the higher proportions of respiratory illness (10% vs 7.7%), smokers (37.2% vs 32.4%), individuals in manual classes (59.7% vs 53.3%) and older people (mean age 46.6 vs 45.8 years) among those who did not have a satisfactory lung function measurement, compared with those who did, indicate that the missingness of lung function does depend on its true value. If present, such misclassification would lead to an underestimation of the association. Nevertheless, with the addition of information on the presence of respiratory disease as well as smoking, social class and age along with the other variables used in the multiple imputation, this will have gone some way to addressing arising bias by correcting the imputed lung function measurements.

We did not find stronger socioeconomic patterns in the 65 and over age group, which suggests that survival bias might be having an effect; the suggestion that childhood precursors were even less important and that second-hand smoke and urban/rural area were relatively more important in this age group lends further weight to the importance of current circumstances at older ages. Measures of lung function reflect an individual's place in a trajectory over age that starts with growth up to a peak in their 20s, followed by a decline, the pace of which depends on the hazards accompanying the process of ageing. The determinants of growth are likely to be different from those of decline, consistent with our data. That height, childhood social class and smoking explained much of the SES patterning of lung function in the under 65-year-old groups, and second-hand smoke exposure and urban/rural residence accounted for some of the patterning in the 40 years and over age groups but less so in the young adults, indicates that early life and current factors may be determining some of the inequity at younger ages,[34] whereas environmental effects could act cumulatively, becoming stronger in magnitude with increased exposure at older ages.[40] Generally, social patterning was stronger and covariate attenuation greater in men than women, perhaps reflecting occupational hazard exposure among men.

Our study included almost 10 000 never smokers, among whom associations were consistent with the whole sample. This is of particular interest as it reveals a true distinction of associations due to individuals smoking and those not, reinforcing the importance of the childhood developmental and other effects. Future work could concentrate on the importance of looking at the determinants of the trajectory of lung function over the life course, particularly in never smokers.

These findings have implications for policy aimed at reducing inequalities in respiratory health, suggesting the need to focus on nutrition and a health-promoting environment from infancy through childhood as well as on smoking prevention and cessation in adulthood. If lung function disparities arising from birth-related inequalities occur earlier in life than the onset of chronic diseases, the value of lung function as an easily measurable early public health indicator of health inequalities could be considered.

What is already known on this subject

- Poorer lung function is associated with disadvantaged social circumstances in childhood and adulthood.
- Height and cigarette smoking partially account for the lung function–socioeconomic status (SES) association, but it has not been fully explained.
- The changing social patterning of lung function as people age, and the effects of childhood precursors and environmental factors are underexamined.

What this study adds

- There was evidence of widening social inequalities in lung function over age which held for never-smokers.
- Childhood precursors and smoking were found to be the most important determinants of lung function–socioeconomic status (SES) association, especially at younger ages, whereas contemporaneous environmental factors had only a small impact and this was mainly for older ages.
- Adjustment by weight and physical activity was not found to impact on the lung function–SES association.

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