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Papers

Mortality in relation to smoking: 50 years' observations on male British doctors

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Abstract

Objective To compare the hazards of cigarette smoking in men who formed their habits at different periods, and the extent of the reduction in risk when cigarette smoking is stopped at different ages.

Design Prospective study that has continued from 1951 to 2001.

Setting United Kingdom.

Participants 34 439 male British doctors. Information about their smoking habits was obtained in 1951, and periodically thereafter; cause specific mortality was monitored for 50 years.

Main outcome measures Overall mortality by smoking habit, considering separately men born in different periods.

Results The excess mortality associated with smoking chiefly involved vascular, neoplastic, and respiratory diseases that can be caused by smoking. Men born in 1900-1930 who smoked only cigarettes and continued smoking died on average about 10 years younger than lifelong non-smokers. Cessation at age 60, 50, 40, or 30 years gained, respectively, about 3, 6, 9, or 10 years of life expectancy. The excess mortality associated with cigarette smoking was less for men born in the 19th century and was greatest for men born in the 1920s. The cigarette smoker versus non-smoker probabilities of dying in middle age (35-69) were 42% *v* 24% (a twofold death rate ratio) for those born in 1900-1909, but were 43% *v* 15% (a threefold death rate ratio) for those born in the 1920s. At older ages, the cigarette smoker versus non-smoker probabilities of surviving from age 70 to 90 were 10% *v* 12% at the death rates of the 1950s (that is, among men born around the 1870s) but were 7% *v* 33% (again a threefold death rate ratio) at the death rates of the 1990s (that is, among men born around the 1910s).

Conclusion A substantial progressive decrease in the mortality rates among non-smokers over the past half century (due to prevention and improved treatment of disease) has been wholly outweighed, among cigarette smokers, by a progressive increase in the smoker *v* non-smoker death rate ratio due to earlier and more intensive use of cigarettes. Among the men born around 1920, prolonged cigarette smoking from early adult life tripled age specific mortality rates, but cessation at age 50 halved the hazard, and cessation at age 30 avoided almost all of it.

Introduction

During the 19th century much tobacco was smoked in pipes or as cigars and little was smoked as cigarettes, but during the first few decades of the 20th century the consumption of manufactured cigarettes increased greatly.[1] This led eventually to a rapid increase in male lung cancer, particularly in the United Kingdom (where the disease became by the 1940s a major cause of death). Throughout the first half of the 20th century the hazards of smoking had remained largely unsuspected.[1] Around the middle of the century, however, several case-control studies of lung cancer were published in Western Europe[2–6] and North America,[7–10] leading to the conclusion in 1950 that smoking was "a cause, and an important cause" of the disease.[5]

1951 prospective study

This discovery stimulated much further research into the effects of smoking (not only on lung cancer but also on many other diseases), including a UK prospective study of smoking and death among British doctors that began in 1951 and has now continued for 50 years.[11–17] The decision that this study would be conducted among doctors was taken partly because it was thought that doctors might take the trouble to describe their own smoking habits accurately, but principally because their subsequent mortality would be relatively easy to follow, as they had to keep their names on the medical register if they were to continue to practise. Moreover, as most doctors would themselves have access to good medical care, the medical causes of any deaths among them should be reasonably accurately certified.

The 1951 study has now continued for much longer than originally anticipated, as the doctors did indeed prove easy to follow, and they provided further information about any changes in their smoking habits along the way (in 1957, 1966, 1971, 1978, and 1991). A final questionnaire was sent out in 2001.

By 1954 the early findings[11] had confirmed prospectively the excess of lung cancer among smokers that had been seen in the retrospective studies.[2–10] Findings on cause specific mortality in relation to smoking were published after four periods of follow up (after four years,[12] 10 years,[13] 20 years,[14 15] and 40 years[17]). The early results from this study,[12–14] together with those from several others that began soon after, showed that smoking was associated with mortality from many different diseases. Indeed, although smoking was a cause of the large majority of all UK lung cancer deaths, lung cancer accounted for less than half of the excess mortality among smokers.

As recently as the 1980s, however, the full eventual effects on overall mortality of smoking substantial numbers of cigarettes throughout adult life were still greatly underestimated, as no population that had done this had yet been followed to the end of its life span. The present report of the 50 year results chiefly emphasises the effects on overall mortality (subdivided by period of birth) of continuing to smoke cigarettes and of ceasing to do so at various ages.

Long term hazards

With the passage of time and the maturation among UK males of the smoking epidemic—that is, the arrival of a period in which even in old age those who still smoked had, in general, been smoking cigarettes regularly since youth—the 40 year results[17] showed that the risks from really persistent cigarette smoking were much larger than had previously been suspected[1] and suggested that about half of all persistent cigarette smokers would eventually be killed by their habit. The 50 year results consolidate these findings, following even the participants who were born after 1900 well into old age.

Britain was the first country in the world to experience a large increase in male lung cancer from cigarette smoking.[18–20] But, even in Britain, those born in the latter part of the 19th century had, at a given age, much lower lung cancer rates than the worst affected generation of men who were born in Britain in the first few decades of the next century. Hence, after presenting the findings for mortality during 1951-2001 in the study as a whole, this report considers separately the findings among those doctors born in the 19th century (1851-1899) and those born in the 20th century (1900-1930, considering separately 1900-1909, 1910-19, and 1920-29). Only among those born in the 20th century—many of whom were young when they started smoking substantial numbers of cigarettes—can we hope to assess the full hazards of continuing to smoke cigarettes throughout adult life, and, correspondingly, the full long term benefits of stopping at various ages.

Previous reports of this and other studies[13 14 17 21 22] have reviewed the associations of smoking with many specific causes of death and considered the reasons for them, leading to the conclusion that in this study the substantial differences between smokers and non-smokers in overall mortality are due chiefly to the causal effects of smoking. This report therefore uses only 11 major categories of cause of death, some of which are quite broad, and several of its main analyses are of all cause mortality.

Methods

Information about smoking habits was obtained in 1951, and periodically thereafter, from two thirds of all male British doctors, and their cause specific mortality has been monitored prospectively from 1951 to 2001, supplementing the information available from state records with data from personal inquiries.

Study population

The 1951 questionnaire was sent to all doctors resident in the United Kingdom whose addresses were known to the BMA. At that time no relevant ethics committees existed. Usable responses were received from two thirds, yielding information on the smoking habits of 34 439 male doctors (10118, 7477, 9459, and 7385 respectively born before 1900, in 1900-1909, in 1910-19, and in 1920-30). Their age specific smoking habits have been reported previously[14]; only 17% were lifelong non-smokers.

Efforts have been made to follow until 2001 all those not known to have died, with the exception of 17 who were struck off the medical register for unprofessional conduct, 467 who requested (mostly in the fifth decade of the study) no further questionnaires, and 2459 who were known to be alive but living abroad on 1 November 1971, when we withdrew them. Among the remaining 31 496 the follow up of mortality is, irrespective of any other migration, 99.2% complete (with only 248 untraced (usually since the 1970s)); 5902 are known to have been alive on 1 November 2001 and 25 346 are known to have died before then. Those withdrawn before the end of the study or untraced are included in the analyses of mortality until the time of withdrawal, or until contact was last made.

Questionnaires

The original questionnaire in 1951 asked only a few questions about the individual's current smoking habits or, for ex-smokers, about the types and amounts of tobacco last smoked. These were elaborated in further questionnaires in 1957, 1966, 1971, 1978, and 1991, to which the response rates (after reminders) varied between 98% initially and 94% finally. Accounts of the questions asked have been reported previously,[11–17] as have the trends in cigarette consumption.[14] Only the 1978 questionnaire,[16] which was limited to those born in the 20th century, sought information about a wide range of characteristics (height, weight, blood pressure, alcohol, etc, including medical history) and asked those who had stopped smoking whether they had done so because they had already developed some serious respiratory or vascular disease. The 2001 questionnaire sought only to check that we had identified correctly the individuals we believed we had traced.

To help assess the effects of persistent cigarette smoking, those categorised as "current cigarette smokers" in reply to a particular questionnaire had to have reported smoking cigarettes, and only cigarettes, in that and any previous reply. This excludes all who had previously replied that they were using any other type of tobacco, or no tobacco. Likewise, those classified as "former cigarette smokers" were either ex-smokers in 1951 whose last habit involved only cigarettes, or current cigarette smokers (defined as above) who had stopped. The terms "never smoker" or "non-smoker" mean lifelong non-smoker—that is, they exclude any respondent who had smoked on most days for a year. Those who, despite reminders, failed (perhaps because of illness) to complete a particular questionnaire could generally be traced for mortality and so continued to be analysed according to their previously reported smoking habits.

Causes of death

Causes were obtained for 98.9% of the deaths. The underlying cause on the death certificate was classified according to ICD-7 (international classification of diseases, seventh revision) until 1978, then ICD-9 (except that "lung cancer" always excluded pleural mesothelioma, and "pulmonary heart disease" included death from myocardial degeneration or heart failure with mention of chronic obstructive pulmonary disease). Until 1971 special inquiries of any mention of lung cancer were made, but (perhaps because these men were themselves doctors) this rarely changed the certified cause.[14]

Statistical methods

Standardised mortality rates

The main analyses of mortality in relation to smoking seek to determine whether, among men in the same five year age group (16 groups, from 20-24 years to 90-94 years, then ≥95 years) and the same time period (either 10 five year or 50 one year periods), the death rate is related to the previously reported smoking habits. Apart from some directly standardised analyses at ages 70-89, this generally involves, as before,[17] indirect standardisation (for age group and time period) to the "person years" distribution of the whole population being considered. From these indirectly standardised death rates, we calculated relative risks.

To assess the effects of smoking on mortality at ages 60 and above for the cohort of men born in the 19th century and the cohort born in the 20th century, the relative risks comparing various categories of smokers with never smokers are calculated

Table 1 Cause specific mortality by smoking habit, standardised indirectly for age and study year, for all 34 439 men born in 19th or 20th century (1851-1930) and observed 1951-2001

		Age standardised mortality rate per 1000 men/year									
			Cigarette smokers (no other smoking habit previously reported)							Standardised tests for trend (χ^2 on 1 df)*	
					Current (cigarettes/day)			Other smokers			
Cause of death	No of deaths 1951-2001	Lifelong non-smokers	Former	Current	1-14	15-24	≥25	Former	Current	N/X/C†	Amount†
Cancer of lung	1052	0.17	0.68	2.49	1.31	2.33	4.17	0.71	1.30	394	452
Cancers of mouth, pharynx, larynx, oesophagus	340	0.09	0.26	0.60	0.36	0.47	1.06	0.30	0.47	68	83
All other neoplasms	3893	3.34	3.72	4.69	4.21	4.67	5.38	3.66	4.22	32	36
Chronic obstructive pulmonary disease	640	0.11	0.64	1.56	1.04	1.41	2.61	0.45	0.64	212	258
Other respiratory disease	1701	1.27	1.70	2.39	1.76	2.65	3.11	1.69	1.67	44	70
Ischaemic heart disease	7628	6.19	7.61	10.01	9.10	10.07	11.11	7.24	7.39	138	133
Cerebrovascular disease	3307	2.75	3.18	4.32	3.76	4.35	5.23	3.24	3.28	48	65
Other vascular (including respiratory heart) disease	3052	2.28	2.83	4.15	3.37	4.40	5.33	2.99	3.08	77	94
Other medical conditions	2565	2.26	2.47	3.49	2.94	3.33	4.60	2.49	2.44	34	54
External causes	891	0.71	0.75	1.13	1.08	0.79	1.76	0.89	0.92	17	27
Cause unknown	277	0.17	0.28	0.52	0.39	0.57	0.59	0.25	0.31	16	24
All cause (No of deaths)	25 346	19.38 (2917)	24.15 (5354)	35.40 (4680)	29.34 (1450)	34.79 (1725)	45.34 (1505)	23.96 (5713)	25.70 (6682)	699	869

*Values of χ^2 on one degree of freedom for trend between three or four groups: values ≥15 correspond to P<0.0001.
†N/X/C compares three groups: lifelong non-smokers, former cigarette smokers, and current cigarette smokers. Amount compares four groups: never smoked regularly, and current cigarette smokers consuming 1-14, 15-24 or ≥25 cigarettes/day when last asked.

separately within each cohort. (Thus, the relative risk is 1 for non-smokers in both cohorts, irrespective of any changes over time in the death rates for non-smokers.)

Survival curves

The proportions expected to survive from one age to another are calculated by multiplying together the relevant five year age specific survival probabilities. These probabilities are calculated as exp(– 5R), where exp is the exponential function and R is the annual death rate (deaths/person years) in that age range. (This exponential approximation is of adequate accuracy for each age range up to and including 90-94 years.)

When survival curves of smokers and non-smokers (or of smokers, non-smokers, and ex-smokers) are to be compared to assess the effects of tobacco, they have to be standardised for calendar year. To do this, we calculated the death rate in each five year age group by dividing the weighted sum of the numbers of deaths in the relevant five year time periods by the similarly weighted sum of the numbers of person years. (The weights are proportional to the amount of statistical information contributed by that time period to the smoker versus never smoker comparison in that age group; hence, this ignores periods with no deaths or without any smokers in the relevant age group.)

Results

Mortality by smoking habit and cause of death

Table 1 shows mortality by smoking habit for 11 major categories of cause of death, and for all causes combined. In these and all other analyses, current cigarette smokers are restricted to those who in all their previous replies (including the first, in 1951) reported smoking only cigarettes. Likewise, former cigarette smokers are restricted to those who, before stopping, had reported in all their previous replies smoking only cigarettes (or who had stopped before 1951, having last smoked only cigarettes).

As previously,[17] lung cancer and chronic obstructive lung disease are closely related to continued cigarette smoking and to the daily number of cigarettes smoked. For each of the other nine categories of cause of death there are more moderate, but again highly significant (each $P < 0.0001$), positive relations with the continuation of cigarette smoking and with the daily number smoked.

Effects on overall mortality

How far, in this particular population, such relations between smoking and mortality reflect cause and effect has been discussed previously.[17 23] Midway through the study, the results from the 1978 questionnaire confirmed the well known association between smoking and drinking,[24] but showed little or no relation between smoking and either obesity or blood pressure (table 2), so these particular factors cannot help to account for the excess vascular mortality among smokers. The excess mortality from "external" causes—accidents, injury, and poisoning—among smokers is unlikely to be due chiefly to smoking (although two men did die from fire because of smoking in bed) but, rather, is likely to be due to other behavioural factors with which smoking is associated, such as the heavy consumption of alcohol or a willingness to take risks. Such external causes, however, account for less than 3% of the overall excess mortality among cigarette smokers. A quarter of the excess mortality among smokers is accounted for by lung cancer and chronic obstructive lung disease and another quarter by ischaemic heart disease; most of the rest involves other neoplastic, respiratory, or vascular diseases that could well be made more probable (among the survivors at a given age) by smoking.

Some of the 11 relations in table 1 have been increased by confounding, most notably with alcohol (which can increase the risk of developing cirrhosis of the liver and cancers of the mouth, pharynx, larynx, and oesophagus) and with personality (in the case of accidents, injury, and poisoning). Confounding, however, can act in two directions, as alcohol consumption—which is higher among smokers than among non-smokers (table 2)—can also decrease the risk of ischaemic heart disease and perhaps of some other conditions.[24] Another important factor, not previously much emphasised, is the possibility of "reverse

Table 2 Characteristics in 1978 of smokers, ex-smokers, and smokers born in 20th century (aged 48-78 at 1978 survey). Means and prevalences are standardised to age distribution of all 12 669 respondents to 1978 questionnaire

	Current smoker (n=3866)	Ex-smoker for <10 years (n=1787)	Ex-smoker for ≥10 years (n=4074)	Never smoker (n=2942)
Means of some vascular risk factors				
Alcohol consumption (units/week)	19.0	18.1	14.8	8.3
Body mass index*	24.5	24.7	24.3	24.1
Blood pressure, systolic (mm Hg)	136.9	137.6	137.2	135.6
Blood pressure diastolic (mm Hg)	83.1	84.3	83.5	83.1
Prevalences (%) of various replies				
Quit for vascular disease	NA	12.2	3.9	NA
Quit for respiratory disease	NA	14.0	8.3	NA
Any vascular disease	18.6	29.2	20.8	15.7
Short of breath hurrying†	17.2	20.2	13.8	9.1
Phlegm in winter†	25.5	12.4	8.6	5.5

NA=not applicable.
*Body mass index=weight (kg)/(height(m)^2).
†Are you short of breath when hurrying; and, do you usually bring up phlegm from your chest during the winter?

causality"—that is, some reduction in the apparent risk of death among current smokers because of a tendency for people to give up smoking after they begin to be affected by some life threatening condition (table 2), whether or not their illness was caused by smoking.

When all 11 categories in table 1 are added together, however, yielding overall mortality, the combined effects of all these non-causal factors—acting to increase or decrease the apparent hazards among smokers—are unlikely to have influenced greatly the absolute difference between the overall mortality rates of cigarette smokers and lifelong non-smokers. This difference, we conclude, provides a reasonably quantitative estimate of the extent to which, at particular ages, cigarette smoking caused death in this population.

Trends over time: successive birth cohorts

19th and 20th century births

In table 3, the relations between smoking and mortality at ages 60 and over are shown separately for the cohort of men born late in the 19th century and for the cohort born early in the 20th century. (Restriction to ages 60 and over is necessary because the study began in 1951, so for those born in the 19th century it provides little information on mortality at earlier ages.)

Cigarette smoking had become common among young men in Britain by the end of the first world war (1914-1918) and remained so for half a century,[18] reinforced by the issue of low cost cigarettes to young military conscripts from 1939. As a result, men who were born in the first, second, and, particularly, the third decade of the 20th century and were still smoking cigarettes after the age of 60 had been smoking substantial numbers throughout adult life. This would not have been as much the case for men who were born in the last decades of the 19th century, even if they too were smoking cigarettes after the age of 60.

The smoker versus non-smoker relative risks in table 3 are, therefore, much more adverse for smokers born in the 20th century than for those born earlier, particularly for cigarette smokers. For the cohort born in the 19th century the cigarette smoker versus non-smoker relative risk when they were over 60 years of age was only 1.46 (excess mortality 46%), but for the cohort born in the 20th century it was 2.19 (excess mortality 119%). For heavy cigarette smokers (25 or more a day at their last reply) the smoker versus non-smoker relative risk was 1.83 for the cohort born in the 19th century and 2.61 for the cohort born in the 20th century, corresponding, respectively, to 83% and 161% excess mortality among the smokers.

The patterns of survival from age 60 in these two birth cohorts among lifelong non-smokers and among those who smoked only cigarettes since 1951 are shown in figure 1, which gives the proportions of 60 year olds who would be expected to be still alive at ages 70, 80, 90, and 100. The substantial improvement among non-smokers is apparent, as is the lack of substantial improvement among smokers, corresponding to the increasing effects, from one century of birth to the next, of cigarette smoking on overall mortality. The comparisons in table 3 and figure 1 involve only about a 20 year difference between the times when the mortality rates at a given age are being compared—for, although the median years of birth for all men in the two cohorts differed by 26 years, the median years of birth of those who died differed less.

1900-1930 births

Subdivision of the younger participants by decade of birth (1900-1909, 1910-1919, or 1920-1929; only one was born in 1930) shows that, even among those born in the 20th century, the hazards associated with cigarette smoking differ substantially from one birth cohort to another (fig 2). For those born in the

Table 3 Relative risks of smokers versus non-smokers by century of birth: overall mortality among men aged 60 and over. In each century of birth (19th or 20th), relative risks are standardised indirectly for age and for study year (1951-2001)

		Risk relative to lifelong non-smokers born in same century (No of deaths)								
			Cigarette smokers (no other smoking habit previously reported)					Other smokers		Standardised tests for trend (χ^2 on 1 df)*
					Current (cigarettes/day)					
Century of birth	No of deaths at age ≥60	Lifelong non-smokers	Former	Current	1-14	15-24	≥25	Former	Current	N/X/C†	Amount†
19th	9671	1.00 (903)	1.07 (1733)	1.46 (1913)	1.33 (819)	1.44 (626)	1.83 (468)	1.17 (2091)	1.12 (3031)	102	117
20th	12 770	1.00 (1656)	1.31 (3198)	2.19 (1621)	1.79 (403)	2.17 (641)	2.61 (577)	1.24 (3383)	1.48 (2912)	475	576

*See notes for table 1.
†See notes for table 1.

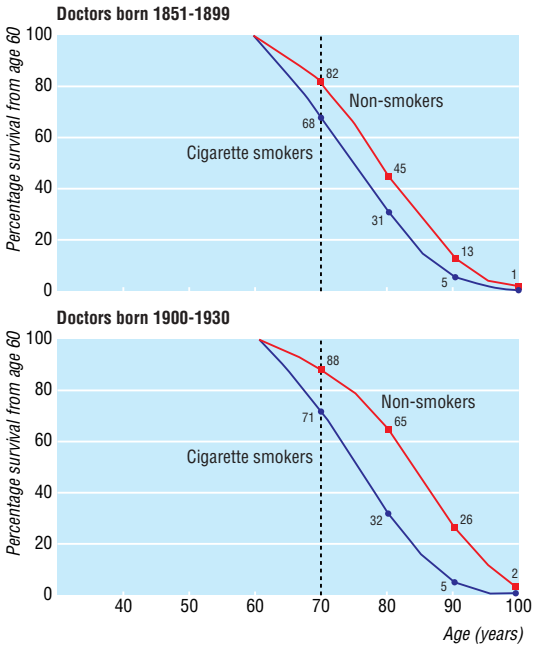

Fig 1 Survival from age 60 for continuing cigarette smokers and lifelong non-smokers among UK male doctors born 1851-1899 (median 1889) and 1900-1930 (median 1915), with percentages alive at each decade of age

first decade of the century the difference between cigarette smokers and non-smokers in the probability of surviving from age 35 to age 70 was only 18% (58% *v* 76% (corresponding to a twofold death rate ratio)), but it was 28% (57% *v* 85% (a threefold death rate ratio)) for those born in the third decade. This comparison again involves only a 20 year time difference.

Trends over time: successive study decades

If we compare mortality at ages 70-89 during the five separate decades of the study (1951-2001) then the effects of a 40 year time difference (1950s *v* 1990s) can be studied, as the ages of the original respondents varied from only 21 to 100. Some 2000 men were already aged 70-89 at the start of the study, and some 4000 of the younger respondents eventually survived to reach their 70th birthday during the fifth decade of the study. Thus, in each study decade we can observe the death rates of men in their 70s and 80s and can calculate the probability that, at the age specific death rates prevailing in that particular decade, a 70 year old man would survive to age 90 (table 4).

Over the five decades there is both a progressive reduction in the mortality of elderly never smokers and, counterbalancing this, a progressive maturing of the epidemic of the effects of cigarette smoking on mortality in old age. Table 4 shows a halving of the standardised mortality rate at ages 70-89 among non-smokers and almost a tripling of their probability of surviving from age 70 to age 90, which was 12% at the non-smoker death rates of the 1950s and 33% at those of the 1990s. (The mean years of birth for those who died at ages 70-89 in the 1950s and the 1990s were, respectively, 1875 and 1915.)

These reductions in mortality of the lifelong non-smokers were presumably due both to prevention of, and, particularly, to improvements in the treatment of, various diseases in elderly people. (For example, one of the present authors who is a participant in the study acquired a pacemaker 10 years ago.) But, among successive birth cohorts of cigarette smokers the increasing effects of cigarette smoking completely eliminated the great reductions in overall mortality at ages 70-89 that were occurring among non-smokers (table 4). Among those born in about the 1870s and observed at ages 70-89 during the 1950s, the cigarette smoker versus non-smoker death rate ratio was only 1.16 (92.9/80.1), whereas for those born in about the 1910s and observed at ages 70-89 during the 1990s the death rate ratio was 2.83 (113.1/39.9).

Hazards among cigarette smokers born 1900-1930

By decade of birth

For those born in 1900-1909, annual mortality among non-smokers was, both in middle and in old age, about half that among cigarette smokers. (These twofold death rate ratios are calculated from the logarithms of the probabilities of surviving from 35-70, 70-80, and 80-90 in figure 2 (top graph).) Taking, as before, the excess overall mortality among these smokers as an approximate measure of the excess mortality actually caused by smoking, this twofold ratio indicates that about half of the persistent cigarette smokers born in 1900-1909 would eventually be killed by their habit.

For those born in 1920-1929 the probability of death in middle age (35-69) was 15% in non-smokers and 43% in cigarette smokers, corresponding to a threefold death rate ratio

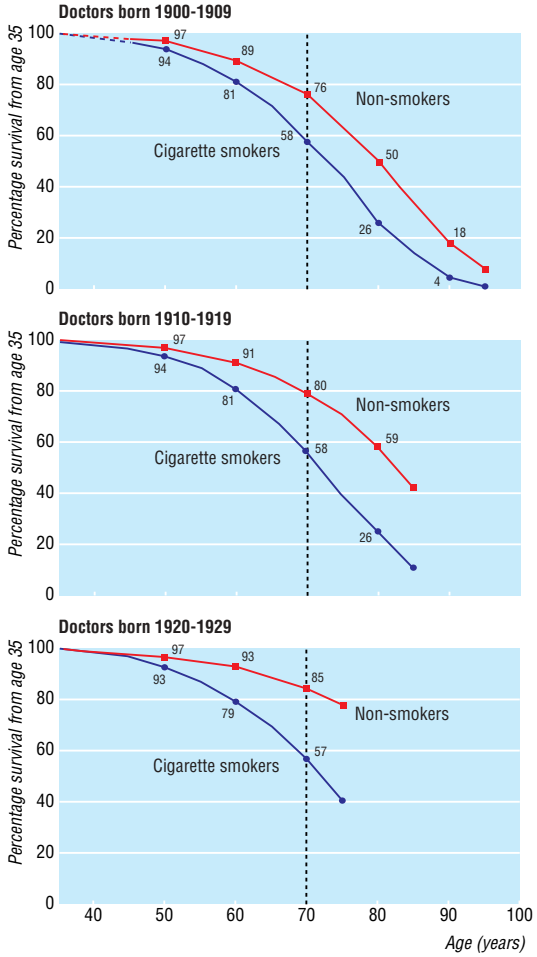

Fig 2 Survival from age 35 for continuing cigarette smokers and lifelong non-smokers among UK male doctors born 1900-1909, 1910-1919, and 1920-1929, with percentages alive at each decade of age

Table 4 Trends during 1951-2001 in overall mortality at ages 70-89 among lifelong non-smokers and continuing cigarette smokers (men born November 1861-1930 who survived to age 70)

Study decade (November to October)	No of deaths at ages 70-89		Age standardised mortality per 1000 men aged 70-89*			Probability (%), at current death rates, of a 70 year old surviving to age 90	
	Lifelong non-smoker	Cigarette smoker*	Lifelong non-smoker	Cigarette smoker*	Ratio of rates	Lifelong non-smoker	Cigarette smoker*
1951-61	232†	544	80.1	92.9	1.16	12	10
1961-71	230	508	72.0	112.5	1.56	17	6
1971-81	319	390	63.3	103.3	1.63	20	7
1981-91	470	478	49.6	106.7	2.15	26	7
1991-2001	596†	227	39.9	113.1	2.83	33	7

*Standardised directly to a population with 40%, 30%, 20%, and 10% respectively at ages 70-74, 75-79, 80-84, and 85-89 (that is, to a mean age of 75-79), but not standardised for study year within study decade.
†For these non-smokers who died during the first and last decades of the study, the mean years of birth were 1875.6 and 1915.1 respectively.

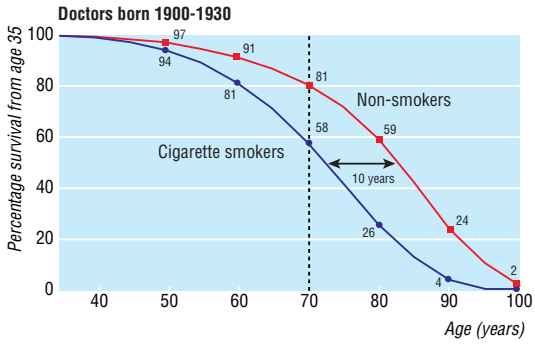

Fig 3 Survival from age 35 for continuing cigarette smokers and lifelong non-smokers among UK male doctors born 1900-1930, with percentages alive at each decade of age

(calculated from the logarithms of the survival probabilities in figure 2 (bottom graph)). Extrapolation of the trends in table 4 suggests that these men will also have about a threefold smoker versus non-smoker death rate ratio in old age (70-89). This indicates that about two thirds of the persistent cigarette smokers born in the 1920s would eventually be killed by their habit.

Over whole 30 year period

Figure 3 averages the findings in figure 2 for all men born in 1900-1930, distinguishing between lifelong non-smokers and continuing cigarette smokers. (Among the latter, the median age when they began smoking was 18, and at the start of the study their median age was 36 and their mean self reported cigarette consumption was 18 a day.) The results suggest a shift of about 10 years between the overall survival patterns of the continuing cigarette smokers and the lifelong non-smokers in this particular generation. That is not to say that all such smokers died about 10 years earlier than they would otherwise have done: some were not killed by their habit, but about half were, thereby losing on average more than 10 years of non-smoker life expectancy. Indeed, some of those killed by tobacco must have lost a few decades of life.

Mortality on stopping smoking

A high proportion of the doctors who had been smoking in 1951 stopped during the first decades of this study, after it had become generally accepted by the British medical profession that cigarette smoking was a cause of most of the UK mortality from lung cancer.[25 26] We can, therefore, examine mortality for some decades after stopping smoking (table 5). As the benefits of stopping cigarette smoking can be assessed directly only in a population where the hazards of continuing to smoke cigarettes are already substantial, our main analyses of cessation are again restricted to the men born in 1900-1930. Among them, those who stopped and those who continued smoking differed little in obesity and blood pressure and differed only moderately in mean alcohol consumption (table 2).

But, although many stopped when still relatively young and healthy during the 1950s and '60s, some who stopped in later middle age did so because they were already ill (table 2). This removal of some imminent deaths of smokers from the current to the ex-smoker category reduces the apparent mortality among current smokers and may substantially inflate the apparent mortality of recent ex-smokers. For example, mortality at ages 55-64 among those who stopped smoking at ages 55-64 was spuriously somewhat greater than mortality among continuing smokers in that age group. Although the death rates for ex-smokers in table 5 are given only for the age ranges after the range in which smoking stopped, they too may still be somewhat affected by such reverse causality (see above for definition).

Mortality by age stopped smoking

Nevertheless, table 5 shows a steady trend in mortality at older ages (65-74 or 75-84) between lifelong non-smokers, ex-cigarette smokers who stopped at ages 35-44, 45-54, or 55-64, and

Table 5 Overall mortality among never smokers, ex-smokers, and continuing cigarette smokers in relation to stopping smoking at ages 35-64 (men born 1900-1930 and observed during 1951-2001)

Age range (years)	Annual mortality per 1000 men* (No of deaths)					Mortality ratio (cigarette smoker *v* non-smoker)
	Lifelong non-smokers	Ex-cigarette smokers, by age stopped			Continuing cigarette smokers	
		35-44	45-54	55-64		
35-44	1.6† (55)	—	—	—	2.7 (150)	1.6†
45-54	3.8 (145)	5.4† (95)	—	—	8.5 (487)	2.3
55-64	8.4 (290)	9.0 (132)	16.4† (229)	—	21.4 (703)	2.5
65-74	18.6 (528)	22.7 (262)	31.7 (331)	36.4 (250)	50.7 (722)	2.7
75-84	51.7 (666)	53.1 (316)	69.1 (370)	78.9 (299)	112.2 (453)	2.2

Division of the rate by the square root of the number of deaths indicates its standard error.
*Mean of two five yearly age specific rates.
†Marked rates are P<0.001, significantly lower than in continuing cigarette smokers (P<0.00001 for all unmarked non-smokers and ex-smoker rates).

continuing cigarette smokers. Thus, stopping earlier is associated with greater benefit.

Mortality for ex-smokers is shown in figure 4, which (bearing in mind the possible relevance of reverse causality) indicates that even a 60 year old cigarette smoker could gain at least three years of life expectancy by stopping (fig 4 (bottom graph)). In figure 4, the mortality rates that would be seen at ages 60-64 among those who stop at about age 60 had to be interpolated (half way between the smoker and non-smoker rates), as they could not be assessed directly (partly because of reverse causality and partly because in this study there was often a delay of a few years before the next questionnaire arrived and cessation could be reported). This, however, makes little difference to the long term survival differences between continuing and ex-cigarette smokers.

Those who stopped at about age 50 gained about six years of life expectancy; those who stopped at about age 40 gained about nine years; and those who stopped before middle age gained about 10 years and had a pattern of survival similar to that of men who had never smoked (fig 4 (top graph)).

The mean cigarette consumption in 1951 (or when last smoked, if this was before 1951) was similar to that in continuing smokers for those who stopped at 45-64 and was only slightly lower for those who stopped at 25-34 or 35-44. Thus, the latter had, on average, had substantial exposure to cigarette smoking for about 20 years before giving up the habit, yet they still avoided most of the excess mortality that they would have suffered if they had continued to smoke.

Lung cancer mortality

Table 6 describes the age specific mortality just from lung cancer among the same non-smokers, ex-smokers, and current cigarette smokers, comparing the observed numbers with the numbers that would have been expected if they had had the age specific lung cancer death rates of lifelong non-smokers. For statistical stability, these lung cancer death rates for non-smokers are taken from a much larger prospective study, which began in 1981 in the United States (see footnote to table 6).[19] At these US rates, 19.5 lung cancer deaths at ages 35-84 would have been expected among the lifelong non-smokers in the present study, and 18 were observed, which is a reasonably good match (mortality ratio 0.9). For the current cigarette smokers the corresponding mortality ratio was 15.9 (13.7 expected and 218 observed).

There was a steady trend in this lung cancer mortality ratio between lifelong non-smokers, ex-smokers who had stopped at 25-34 (see table 6 footnote), 35-44, 45-54, or 55-64, and continuing smokers. This trend confirms the findings from case-control studies[27] that there is substantial protection even for those who stop at 55-64, and progressively greater protection for those who stop earlier. None the less, those who had smoked until about 40 years of age before they stopped had some excess risk of lung cancer at older ages.

By combining the penultimate columns of tables 5 and 6, we calculated the annual lung cancer mortality rates per 1000 continuing cigarette smokers at ages 45-54 through to 75-84 to be 0.6 (that is, 8.5×33/487), 1.8, 6.2 and 8.7 respectively. At ages 45-64 these rates are somewhat lower than in the general UK population born around 1915, which includes a mixture of non-smokers, ex-smokers, and current smokers, and at ages 65-84 they are similar. Hence, the lung cancer death rates among male cigarette smokers must have been even greater in the general UK population than in this study.

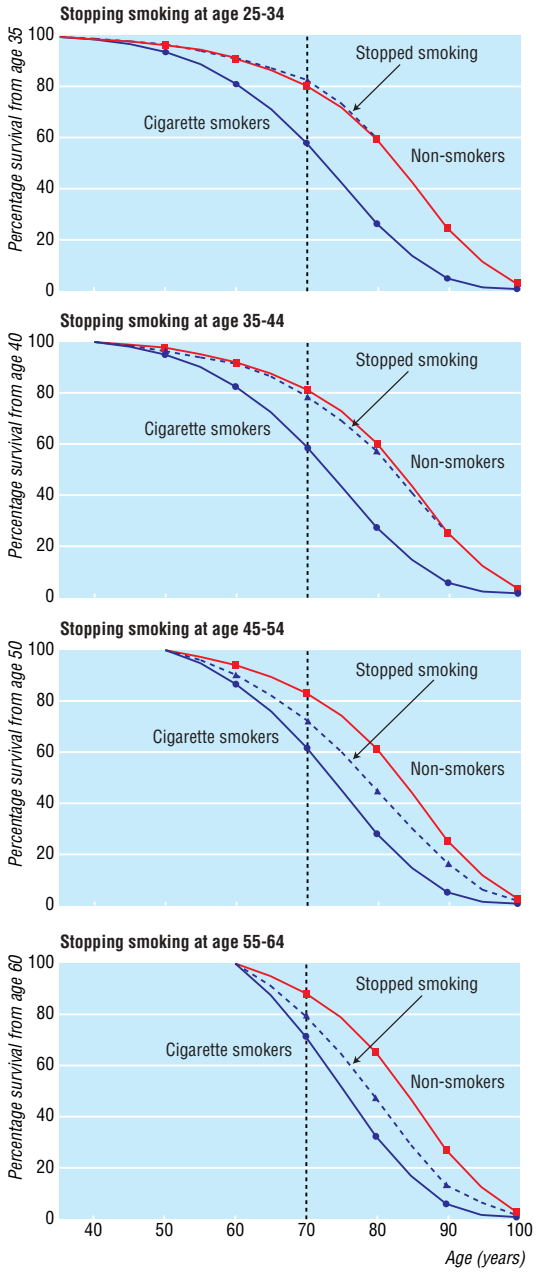

Fig 4 Effects on survival of stopping smoking cigarettes at age 25-34 (effect from age 35), age 35-44 (effect from age 40), age 45-54 (effect from age 50), and age 55-64 (effect from age 60)

Discussion

Emergence of full hazards for persistent cigarette smokers

In many populations nowadays the consumption of substantial numbers of cigarettes begins in early adult life and then continues. But the full eventual effects of this on mortality in middle and old age can be studied directly only in a population, such as British males, in which cigarette consumption by young adults was already substantial when those who are now old were young.

The generation of men born in Britain during the first few decades of the 20th century is probably the first major population in the world of which this is true. Daily cigarette consumption per UK adult (one, two, four, and six a day in 1905,

1915, 1933, and 1941 respectively—mostly consumed by men) was three times as great in the second world war (1939-45) as in the first world war (1914-18).[28] Hence, men born in the 1920s may well have had even more intense early exposure than those born a decade or two earlier, as in the United Kingdom widespread military conscription of 18 year old men, which began again in 1939 and continued for decades, routinely involved provision of low cost cigarettes to the conscripts. This established in many 18 year olds a persistent habit of smoking substantial numbers of manufactured cigarettes, which could well cause the death of more than half of those who continued.

Many, however, avoided the greater part of the risk by stopping smoking: although 70% of all UK males born around 1920 were smoking manufactured cigarettes in 1950 (at ages 25-34), only 29% were still doing so in 1985 (at ages 50-64).[28] Hence, as UK males born in 1900-1930 reached extreme old age at the end of the 20th century—or, for those born in the 1920s, in the early years of the 21st century—they provide the first opportunity to assess directly the hazards of persistent cigarette smoking and, correspondingly (in comparison with those who continued), the long term benefits of cessation.

Trends in mortality from smoking, and trends among non-smokers

The experience of the 24 000 men in this study who were born in 1900-1930 shows persistent cigarette smoking to be more hazardous than had appeared in previous analyses of this, or any other, study (figs 2 and 3), and shows correspondingly greater long term benefits from cessation (fig 4). Those who continued to smoke cigarettes lost, on average, about 10 years of life compared with non-smokers, while those who stopped at around age 60, 50, 40, or 30 gained, respectively, about 3, 6, 9, or 10 years of life expectancy compared with those who continued. Moreover, among those born in 1900-1930 the absolute difference between cigarette smokers and non-smokers in the probability of death in middle age increased from 18% (42% *v* 24%, a twofold death rate ratio) for those born in the first decade of the century to 28% (43% *v* 15%, a threefold death rate ratio) for those born in the 1920s (fig 2).

In old age (table 4) the difference between cigarette smokers and non-smokers in the probability of a 70 year old surviving to 90 increased from only 2% (10% *v* 12%) at the death rates seen during the first decade of the study (among men born, on average, around 1875) to 26% (7% *v* 33%) at the death rates seen during the fifth decade of the study (among men born, on average, around 1915), indicating that the corresponding difference will be still greater for those born in the 1920s. If so, then about two thirds of the persistent cigarette smokers among them would be killed by their habit. Both in middle and in old age, the increasing difference between the mortality of cigarette smokers and non-smokers arises because the large progressive decrease in the mortality of non-smokers in recent decades has, for the cigarette smokers, been wholly counterbalanced by the increasing death rate ratio of smokers versus non-smokers.

Applicability of findings

Our 1994 report of the 40 year findings concluded that "Results from the first 20 years of this study, and of other studies at that time [the 1970s], substantially underestimated the hazards of long term use of tobacco.[17] It now [in the 1990s] seems that about half of all regular cigarette smokers will eventually be killed by their habit." Ten years later, the 50 year findings show that for the continuing cigarette smokers in this study who were born in the first, second, and third decades of the 20th century, the eventual risks vary from about one half to about two thirds (fig 2), although the mortality rates among them from lung cancer were, if anything, somewhat lower than among their contemporaries in the general UK population who smoked.

It is a new finding that the risk of being killed by tobacco can be as great as two thirds, but this applies directly only to the hazards suffered by this particular group of professional British men during the past half century. If these results are to be used indirectly to help predict the risks that male, female, rich, poor, British, and non-British populations of persistent cigarette smokers are likely to face over the next half century, then it may be more appropriate to retain the previous semiquantitative conclusion that "smoking kills about one half." For, although we have found a population in which persistent cigarette smoking killed somewhat more than half (fig 2), there may be other circumstances in which it kills somewhat less than half.

Changes in cigarette manufacture might somewhat limit the eventual hazards, as might favourable changes in the prevention or treatment of neoplastic, respiratory or, particularly, vascular disease. But, unless such changes produce much bigger proportional reductions in mortality among smokers than among non-smokers, they will not make the age specific smoker versus non-smoker death rate ratios much less than 2, so the statement that about half are killed by their habit will not be an exaggeration. Moreover, the death rate ratios in table 5 (which underlie figure 3) are actually somewhat greater than 2, and the tendency in some populations for intense cigarette smoking to be established before the median age of 18 that was seen in this study can only exacerbate the eventual risks.

The general statement that in many very different populations the future risk of death from persistent cigarette smoking will still be about one half is therefore a reasonable one, and the results thus far in a widening range of studies in other developed[19 20] and developing country populations such as

Table 6 Mortality from lung cancer among never smokers, ex-smokers, and continuing cigarette smokers, in relation to stopping smoking at ages 35-64 (men born 1900-1930 and observed 1951-2001), compared with that expected at death rates for US male non-smokers

	Observed (expected US rate*)					Mortality ratio (UK continuing cigarette smoker *v* US lifelong non-smoker)
		Ex-cigarette smokers, by age stopped				
Age range (years)	Lifelong non-smokers	35-44	45-54	55-64	Continuing cigarette smokers	
35-44	1 (0.8)	—	—	—	3 (1.3)	2
45-54	3 (2.2)	1 (1.0)	—	—	33 (3.3)	10
55-64	3 (4.3)	1 (1.8)	7 (1.7)	—	58 (4.1)	14
65-74	5 (6.7)	4 (2.7)	11 (2.5)	14 (1.6)	89 (3.4)	26
75-84	6 (5.5)	10 (2.5)	6 (2.2)	10 (1.6)	35 (1.7)	21
Total†; mortality ratio	18 (19.5); 0.9	16 (8.1); 2.0	24 (6.4); 3.8	24 (3.2); 7.5	218 (13.7); 15.9	16

*Among US male non-smokers in the five year range starting at a given age, the annual lung cancer death rate is taken to be 11.2 times the fourth power of (age/1000). This is based on a large US prospective study in the 1980s, but similar results were seen in a large US prospective study in the 1960s, indicating that US non-smoker lung cancer death certification rates have been approximately constant over the past few decades.[19]

†Total for ex-cigarette smokers who stopped at ages 25-34 is observed 7, expected 4.7; mortality ratio is 1.5.

What is already known on this topic

About half of all persistent cigarette smokers are killed by their habit—a quarter while still in middle age (35-69 years)

After a large increase in cigarette smoking by young people, the full effects on national mortality rates can take more than 50 years to mature

British men born in the first few decades of the 20th century could be the first population in the world in which the full long term hazards of cigarette smoking, and the corresponding benefits of stopping, can be assessed directly

What this study adds

Among the particular generation of men born around 1920, cigarette smoking tripled the age specific mortality rates

Among British men born 1900-1909, cigarette smoking approximately doubled the age specific mortality rates in both middle and old age

Longevity has been improving rapidly for non-smokers, but not for men who continued smoking cigarettes

Cessation at age 50 halved the hazard; cessation at 30 avoided almost all of it

On average, cigarette smokers die about 10 years younger than non-smokers

Stopping at age 60, 50, 40, or 30 gains, respectively, about 3, 6, 9, or 10 years of life expectancy

China[29–31] and India[32 33] seem consistent with it (as long as the prolonged delay between cause and full effect is properly appreciated). If so, then on current worldwide smoking patterns (whereby about 30% of young adults become smokers) there will be about one billion tobacco deaths in this century, unless there is widespread cessation.[34–36] For, with low tar cigarettes still involving substantial hazards,[37] the quantitative conclusion from this study that seems most likely to be robust is that, even among middle aged smokers, cessation is effective and cessation at earlier ages is even more so.

PowerPoint versions of the figures are available on www.ctsu.ox.ac.uk

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