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## Mortality in relation to tar yield of cigarettes: a prospective study of four cohorts

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### Abstract

**Objective**—To investigate relation between tar yield of manufactured cigarettes and mortality from smoking related diseases.

**Design**—Prospective epidemiological study of four cohorts of men studied between 1967 and 1982.

**Setting**—Combined data from British United Provident Association (BUPA) study (London), Whitehall study (London), Paisley-Renfrew study (Scotland), and United Kingdom heart disease prevention project (England and Wales).

**Subjects**—Of the 56255 men aged over 35 who were included in the studies, 2742 deaths occurred among 12400 smokers. Average follow up was 13 years.

**Main outcome measures**—Relative mortality from smoking related diseases according to tar yields of cigarettes smoked.

**Results**—Age adjusted mortality from smoking related diseases in smokers of filter cigarettes was 9% lower (95% confidence interval 1% to 17%) than in smokers of plain cigarettes ( $P=0.047$ ). Mortality from smoking related diseases consistently decreased with decreasing tar yield. Relative mortality in cigarette smokers for a 15 mg decrease in tar yield per cigarette was 0.75 (0.52 to 1.09) for lung cancer, 0.77 (0.61 to 0.97) for coronary heart disease, 0.86 (0.50 to 1.50) for stroke, 0.78 (0.40 to 1.48) for chronic obstructive lung disease, 0.78 (0.65 to 0.93) for these smoking related diseases combined, and 0.77 (0.65 to 0.90) for all smoking related diseases.

**Conclusion**—About a quarter of deaths from lung cancer, coronary heart disease, and possibly other smoking related diseases would have been avoided by lowering tar yield from 30 mg per cigarette to 15 mg. Reducing cigarette tar yields in Britain has had a modest effect in reducing smoking related mortality.

### Introduction

The average tar yield of cigarettes in Britain has steadily reduced from 32 mg per cigarette in 1965 to 14 mg in 1987.<sup>1</sup> Nicotine levels have also declined. However, because of compensation—cigarettes with

lower tar yields being smoked more intensely—the reduction in risk of smoking related diseases is likely to be less than expected from the reduction in tar yield.<sup>2</sup> In addition, some other toxic components of cigarette smoke have not been reduced in the same proportion as tar.<sup>1</sup> It is therefore important to quantify the likely effects of reduction in tar yield on mortality from smoking related diseases.

It is reasonably certain that lower tar yields are associated with reduced mortality from lung cancer.<sup>3-9</sup> The position is less clear with other smoking related diseases, particularly coronary heart disease.<sup>3,7,10-12</sup> We describe the results of the tar pooling project, in which data from four prospective studies were combined to investigate the effects of tar yield on smoking related diseases.

### Subjects and methods

#### INDIVIDUAL STUDIES

We collected data on men from four prospective studies—the British United Provident Association (BUPA) study (London), the Whitehall study (London), the Paisley-Renfrew study (Scotland), and the United Kingdom heart disease prevention project (England and Wales). Table 1 shows details of the studies: the BUPA study recruited predominantly business and professional men who attended the BUPA Medical Centre in London for a comprehensive medical examination; the Whitehall study consisted of civil servants; the Paisley-Renfrew cohort was drawn from population registers of the relatively socio-economically deprived towns of Renfrew and Paisley in the west of Scotland; and the men in the United Kingdom heart disease prevention project were middle aged industrial workers from the south of England, south Wales, the Midlands, and Manchester. These studies are described in more detail elsewhere.<sup>13-16</sup>

#### DEFINITION OF SMOKING CATEGORIES AND TAR GROUPS

Information on smoking was collected through a self administered questionnaire completed on entry to each study. Men were classified into four categories—lifelong non-smokers, former smokers, smokers of manufactured cigarettes, and other smokers. Lifelong non-smokers had never regularly smoked tobacco of

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any form (more than one cigarette a day, or more than two cigars a week, or more than ¼ ounce of tobacco a week for as long as one year). Former smokers had previously smoked some form of tobacco but had given up completely. Smokers of manufactured cigarettes smoked only manufactured cigarettes at entry to the study. Men who smoked hand rolled cigarettes, cigars, or pipes were grouped as other smokers regardless of whether they also smoked manufactured cigarettes.

Smokers of manufactured cigarettes were further categorised according to whether the cigarettes were plain or filter. A tar yield was estimated for each smoker from the cigarette brand that was smoked the longest (was currently smoked in the BUPA study) using the tar yields published in *UK Smoking Statistics*.<sup>1</sup> The classification of tar yields was based on the values at entry to the study. Men for whom the number or tar yield of cigarettes smoked was not known were

excluded. The analysis of relative mortality in smokers of plain and filter cigarettes was based on 14 327 men, and the analysis of mortality according to tar yield was based on 12 400 smokers.

#### DEFINITION OF CAUSES OF DEATH

Men from each cohort were flagged at the Office of Population Censuses and Surveys or the National Health Service Central Records (Scotland), which notified all deaths and causes of death. For this analysis, the causes of death were coded according to the *International Classification of Diseases, eighth revision (ICD-8)*. Lung cancer (ICD code 162), ischaemic heart disease (codes 410-414), chronic obstructive lung diseases (codes 491-492, 519), and stroke (codes 430-438) were grouped as "four major smoking related diseases." Twenty other diseases for which excess mortality in smokers was suggested by the International Agency for Research on Cancer to be partly or wholly attributable to smoking<sup>17</sup> were grouped as "other smoking related diseases." "All smoking related diseases" consisted of both the four major smoking related diseases and the 20 other smoking related diseases. Other causes of death were grouped as "the remaining causes."

#### STATISTICAL ANALYSIS

Relative risks were estimated with proportional hazards regression analysis to adjust for potential confounding factors such as age and the number of cigarettes smoked. For each relative risk, 95% confidence intervals were calculated, and intervals that excluded 1.00 were significant ( $P < 0.05$ ).

## Results

#### NUMBER OF SUBJECTS AND DEATHS

Table 2 shows the number of men in each study according to smoking habits. Of the total of 56 255 men, 38% were from the BUPA study, 34% from the Whitehall study, 12% from the Paisley-Renfrew study, and 16% from the heart disease prevention project. At entry to the studies, 11 794 (21%) of the men were lifelong non-smokers, 15 996 (28%) were former smokers, 14 327 (25%) were smokers of manufactured cigarettes, and 14 138 (25%) were other smokers. Of the smokers of manufactured cigarettes, 11 708 (82%) smoked filter cigarettes and 2619 (18%) smoked plain cigarettes. No data on smoking were available for 45 men.

There were 8251 deaths observed during an average of 13 years of follow up, of which 5995 were from smoking related causes.

#### RELATIVE MORTALITY ACCORDING TO FOUR MAJOR SMOKING CATEGORIES

Table 3 shows the number of deaths from specific

**Table 1**—Selected details of the four individual studies of the tar pooling project

	BUPA study	Whitehall study	Paisley-Renfrew study	Heart disease prevention project	Total
	Professional and business men	Civil servants	Residents	Factory workers	
Population					
No of men	21 398	19 167	6591	9099	56 255
Age at entry (years)	35-64	36-78*	45-64	40-60	35-78
Date of recruitment	1975-82	1967-70	1972-6	1971-3	1967-82
Length of observation (years):					
Maximum	15.3	19.4	14.5	10.0	19.7
Mean	11.5	16.4	10.8	9.6	12.8
Total person years	245 443	314 702	71 243	87 604	718 992
No of deaths	1240	4730	1451	830	8251
Standardised mortality†	6.4	14.0	15.0	10.1	11.5
Tar yield (mg/cigarette)‡:					
Range	1-35	18-38	4-36	18-38	1-38
Mean	16.0	24.2	19.9	22.0	20.5
Men who smoked > 18 mg/day (%)	48	100	82	100	80

\*96% of subjects were within age range 40-64.

†No of deaths per 1000 person years standardised for age.

‡Information on tar yields could be determined for 12 400 of 14 372 smokers of manufactured cigarettes.

**Table 2**—Numbers of men in tar pooling project according to study and smoking status

Study	Lifelong non-smokers	Former smokers	Smokers of manufactured cigarettes		Other smokers	Total
			Plain	Filter		
BUPA	6 365	6 586	262	3 666	4 519	21 398
Whitehall	3 110	5 275	1 216	4 458	5 108	19 167
Paisley-Renfrew	1 245	2 124	614	2 346	262	6 591
Heart disease prevention project	1 074	2 011	527	1 238	4 249	9 099
Total	11 794	15 996	2 619	11 708	14 138	56 255

**Table 3**—Relative mortality (95% confidence interval) of smokers compared with non-smokers from specific causes (adjusted for age and study)

Cause of death	No of deaths	Lifelong non-smokers	Former smokers	Smokers of manufactured cigarettes		
				Plain	Filter	Other smokers
All causes	8251	1.0	1.23 (1.13 to 1.33)	2.34 (2.12 to 2.58)	2.23 (2.06 to 2.41)	1.68 (1.55 to 1.82)
Lung cancer	836	1.0	3.16 (1.94 to 5.14)	13.58 (8.31 to 22.18)	12.85 (8.08 to 20.43)	8.57 (5.37 to 13.68)
Coronary heart disease	2931	1.0	1.21 (1.06 to 1.38)	2.05 (1.73 to 2.42)	1.94 (1.70 to 2.21)	1.56 (1.36 to 1.78)
Stroke	489	1.0	1.00 (0.73 to 1.36)	1.98 (1.36 to 2.88)	1.62 (1.19 to 2.21)	1.17 (0.85 to 1.61)
Chronic obstructive lung disease	283	1.0	2.18 (1.16 to 4.09)	6.84 (3.55 to 13.16)	6.44 (3.55 to 11.71)	3.95 (2.13 to 7.35)
Other smoking related diseases	1456	1.0	1.21 (1.00 to 1.46)	2.61 (2.07 to 3.30)	2.32 (1.92 to 2.79)	1.80 (1.49 to 2.18)
Remaining causes	2256	1.0	1.16 (1.02 to 1.33)	1.64 (1.35 to 1.99)	1.77 (1.54 to 2.02)	1.32 (1.14 to 1.52)
Four major smoking related diseases*	4539	1.0	1.30 (1.16 to 1.45)	2.72 (2.38 to 3.11)	2.53 (2.26 to 2.83)	1.90 (1.69 to 2.13)
All smoking related diseases†	5995	1.0	1.27 (1.15 to 1.40)	2.69 (2.39 to 3.02)	2.47 (2.25 to 2.72)	1.87 (1.70 to 2.06)

\*Lung cancer, coronary heart disease, stroke, and chronic obstructive lung disease.

†Four major smoking related diseases plus other smoking related diseases.

**Table 4—Relative mortality (95% confidence interval) of smokers of filter cigarettes compared with smokers of plain cigarettes from specific causes (adjusted for age, study, and number of cigarettes smoked a day)\***

Cause of death	No of filter cigarettes smoked a day			
	1-10	11-20	> 20	All
All causes	0.83 (0.68 to 1.00)	0.93 (0.83 to 1.05)	1.04 (0.90 to 1.21)	0.94 (0.87 to 1.02)
Lung cancer	0.99 (0.47 to 2.12)	1.01 (0.73 to 1.39)	0.87 (0.61 to 1.22)	0.94 (0.75 to 1.18)
Coronary heart disease	0.76 (0.56 to 1.03)	0.91 (0.75 to 1.11)	1.11 (0.84 to 1.46)	0.93 (0.80 to 1.07)
Stroke	1.06 (0.54 to 2.09)	0.74 (0.46 to 1.19)	0.77 (0.43 to 1.36)	0.81 (0.59 to 1.12)
Chronic obstructive lung disease	0.76 (0.33 to 1.76)	0.87 (0.77 to 1.45)	1.33 (0.61 to 2.92)	0.94 (0.64 to 1.37)
Other smoking related diseases	0.76 (0.48 to 1.19)	0.87 (0.66 to 1.15)	0.94 (0.66 to 1.33)	0.87 (0.72 to 1.06)
Remaining causes	0.87 (0.59 to 1.30)	1.03 (0.82 to 1.31)	1.32 (0.94 to 1.85)	1.08 (0.90 to 1.28)
Four major smoking related diseases†	0.83 (0.64 to 1.06)	0.91 (0.78 to 1.06)	1.00 (0.82 to 1.24)	0.92 (0.82 to 1.02)
All smoking related diseases‡	0.81 (0.65 to 1.01)	0.90 (0.79 to 1.03)	0.98 (0.83 to 1.16)	0.91 (0.83 to 0.99)

\*Smokers of manufactured cigarettes only.

†Lung cancer, coronary heart disease, stroke, and chronic obstructive lung disease.

‡Four major smoking related diseases plus other smoking related diseases.

causes and the mortality rates (adjusted for age and study) for the four smoking categories expressed relative to the lifelong non-smokers. In current smokers (of tobacco of any form) mortalities from all causes, lung cancer, ischaemic heart disease, stroke, chronic obstructive lung diseases, and the group of the 20 other smoking related diseases were significantly higher than those observed for lifelong non-smokers. Ischaemic heart disease and stroke showed an interaction with age. The relative risk of both diseases in cigarette smokers compared with lifelong non-smokers declined with increasing age: the risk of ischaemic heart disease was 2.66 (95% confidence interval 2.1 to 3.4) in those aged < 50, 1.53 (1.3 to 1.8) in those aged 50-59, and 1.30 (1.1 to 1.6) in those aged 60 or more, while the risk of stroke was 2.2 (1.0 to 4.8), 1.46 (0.99 to 2.1), and 1.06 (0.7 to 1.6) in the three age groups.

#### RELATIVE MORTALITY IN PLAIN AND FILTER CIGARETTE SMOKERS

Table 4 shows the relative mortality rates (adjusted for age, study, and number of cigarettes smoked a day) in smokers of filter and plain cigarettes according to levels of cigarette consumption. Point estimates for mortality from each category of smoking related diseases were consistently lower in smokers of filter cigarettes than in smokers of plain cigarettes, but only the relative mortality for all smoking related diseases was significantly different ( $P=0.047$ ).

#### RELATIVE MORTALITIES ACCORDING TO TAR YIELD

Table 5 shows the relative mortalities due to a decrease in tar yield of 15 mg per cigarette. In the American Cancer Society study low tar cigarettes were defined as having, on average, 17.6 mg of tar per cigarette and high tar cigarettes had, on average, 25.8 mg per cigarette.<sup>3</sup> In our study the mean difference in tar yield between high and low tar cigarettes

was about 15 mg per cigarette. This prompted us to express relative mortalities in terms of the same tar difference. There was a consistent trend of decreasing mortality from smoking related diseases with decreasing tar yields; this was significant for coronary heart disease, four major smoking related diseases combined, all smoking related diseases, and all causes. The relative mortality from all smoking related diseases due to a decrease of 15 mg tar yield per cigarette was 0.77 (0.65 to 0.90). The decrease in lung cancer mortality was not significant (0.75 (0.52 to 1.09)) because of the relatively small number of deaths from lung cancer (366). No trend was evident for mortality from causes not related to smoking.

#### Discussion

Mortality from all smoking related diseases was 9% lower in smokers of filter cigarettes than that in smokers of plain cigarettes (95% confidence interval 1% to 17%). A decrease in tar yield of 15 mg per cigarette was associated with a 23% (10% to 35%) decrease in relative mortality. We found a 25% decrease (48% decrease to 9% increase) in relative mortality rate from lung cancer associated with a decrease in tar yield of 15 mg per cigarette, which is consistent with other studies. In the 12 years of follow up of 120 000 male cigarette smokers aged over 40, the same reduction in tar yield was associated with a 20% reduction in mortality from lung cancer.<sup>3 18</sup>

A review of the evidence on lower tar yield cigarettes and ischaemic heart disease concluded that, apart from one study (the largest, the American Cancer Society study), reductions in tar and nicotine yields had little effect on the risk of coronary disease.<sup>19</sup> Since then the accumulation of further data has clarified the position. Two case control studies indicated a reduced risk with lower tar yields.<sup>12 20</sup> Petitti and Friedman reported that a 5 mg decrease in tar yield was associated with a 13% decrease in risk of cardiovascular disease.<sup>11</sup> Parish *et al* showed that cigarette smokers with average tar yields of 7.5 mg had a 10% lower risk of non-fatal myocardial infarction than smokers with average tar yields of 13.3 mg.<sup>21</sup> Our findings have resolved the uncertainty. The relative mortality from ischaemic heart disease was reduced by 23% (3% to 39%) by a reduction in tar yield of 15 mg per cigarette.

The original uncertainty over the effects of lower tar cigarettes on heart disease was prompted by two findings. Firstly, in the early 1970s unventilated filter cigarettes with lower tar yields than plain cigarettes had higher carbon monoxide yields.<sup>22</sup> Secondly, the results of the Framingham study showed that smokers of filter cigarettes did not have a lower mortality from myocardial infarction than smokers of plain cigarettes.<sup>10</sup> During the 1960s and early 1970s there was an

**Table 5—Relative mortality from specific causes due to decrease in tar yield of 15 mg per cigarette**

Causes of death	No of deaths	Relative mortality (95% confidence interval)	P value
All causes	2742	0.80 (0.70 to 0.92)	0.0014
Lung cancer	366	0.75 (0.52 to 1.09)	0.13
Coronary heart disease	917	0.77 (0.61 to 0.97)	0.026
Stroke	163	0.86 (0.50 to 1.50)	0.61
Chronic obstructive lung disease	127	0.78 (0.41 to 1.48)	0.45
Other smoking related diseases	486	0.73 (0.53 to 1.02)	0.060
Remaining causes	683	0.93 (0.70 to 1.23)	0.64
Four major smoking related diseases*	1573	0.78 (0.65 to 0.93)	0.0051
All smoking related diseases†	2059	0.77 (0.65 to 0.90)	0.0008

\*Lung cancer, coronary heart disease, stroke, and chronic obstructive lung disease.

†Four major smoking related diseases plus other smoking related causes.

almost complete switch from plain to filter cigarettes, so that comparisons between plain and filter became less relevant. By the late 1970s most of the differences between smokers in tar yield reflected differences in filter cigarettes alone, and among filter cigarettes there was, and still is, a high correlation between yields of tar, nicotine, and carbon monoxide.

Data on the effect of tar yield on the risk of chronic obstructive lung diseases,<sup>23,24</sup> stroke, and other smoking related diseases are sparse. In our study death rates from these diseases were associated with tar yield, but the association was not significant. The position therefore remains uncertain.

#### POTENTIAL SOURCES OF BIAS

Two sources of bias may have underestimated the association between tar yield and mortality in our study. Firstly, smokers often do not identify their brand of cigarette with sufficient accuracy,<sup>25</sup> and brands with similar names can have different tar yields. Secondly, in the studies we used, tar yields were higher before entry into the study and in the earlier years of the subjects' smoking history. The studies recorded only the tar yields of cigarette smoked at entry to the study, yet the subsequent tendency was to switch to lower yield cigarettes. With the reduction in the average tar yield of cigarettes sold in Britain over the past two decades, the range of tar yields would also have become narrower. The range of death rates from smoking related diseases that were recorded were therefore incorrectly related to the range of tar yield on entry to the study rather than to the narrower range during follow up. This may be important since recent exposure to cigarette smoke is more relevant to risk.<sup>26</sup>

Confounding by social class did not seem to be a problem. Data from the Whitehall and the Renfrew-Paisley studies indicated that social class had little effect on the estimate of the effects of tar yield on mortality.

#### CONCLUSION

About a quarter of deaths from lung cancer, coronary heart disease, and possibly other smoking related diseases could be avoided by switching from higher tar cigarettes (30 mg/cigarette) to lower tar ones (15 mg/cigarette). This is consistent with studies of compensatory smoking; switching to cigarettes of half the tar yield reduces tar intake by about a quarter rather than a half.<sup>2</sup>

#### Key messages

- It is reasonably certain that smoking low tar cigarettes rather than high tar cigarettes reduces risk of lung cancer, but the position is less clear with other smoking related diseases, particularly coronary heart disease
- We used data from four large British cohort studies to investigate effect of lowering tar yield on smoking related diseases
- Mortality from smoking related diseases was reduced by about 23% for a reduction in tar yield of 15 mg per cigarette
- Mortality from ischaemic heart disease was also reduced by 23%, and mortality from lung cancer was reduced by 25%
- Britain's policy of reducing the tar yield of cigarettes has been associated with modest benefits, but these benefits are much less than that associated with stopping smoking completely

Our results indicate that the reduced tar yield of British cigarettes over recent decades has reduced mortality from smoking related diseases. The potential for further reductions in mortality from further tar yield reductions may be more limited. Very low tar cigarettes have not been widely accepted.<sup>27</sup> In Britain, in spite of the increasing number and advertising of low tar brands, the percentage of smokers who smoke cigarettes of tar yield below 10 mg per cigarette has remained small and has hardly changed since 1978.<sup>1</sup> Tar yields from British cigarettes are currently limited by regulation to 15 mg per cigarette, and this will fall to 12 mg per cigarette at the end of 1997. Future public health policy would be best directed mainly towards preventing cigarette smoking through public education, tobacco taxation, stricter legislation (including control over advertising of cigarettes), and measures that will discourage children and young adults from taking up the habit.

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