CLINICAL RESEARCH

Trends in tar, nicotine, and carbon monoxide yields of UK cigarettes manufactured since 1934

NICHOLAS WALD, RICHARD DOLL, GRAHAM COPELAND

Abstract

The tar, nicotine, and carbon monoxide yields of cigarettes manufactured in the United Kingdom between 1934 and 1979 were studied. Over this period the average tar yield decreased by 49%, the nicotine yield by 31%, the carbon monoxide yield by 11%, all estimated on a sales-weighted basis. The average tar yield decreased progressively after the second world war, owing both to the introduction of filter cigarettes and to changes in the manufacture of plain cigarettes. The average nicotine yield increased initially, decreased by 43% from about 1950 to 1974, but increased again by 9% between 1974 and 1979. The average carbon monoxide yield started to decrease after about 1961; while it decreased substantially in plain cigarettes, the rapid increase in sales of filter cigarettes at this time, at the expense of plain cigarettes, largely offset the reduction in carbon monoxide yield that would otherwise have occurred. As with nicotine, carbon monoxide yield showed a small rise in later years (4% between 1976 and 1979).

The trends in tar yield may well explain the reduction in lung cancer in the UK better than has been suspected hitherto. The trends in nicotine and carbon monoxide yields are probably not sufficiently different to distinguish which of them might be the more likely cause of cardiovascular disease.

Introduction

In the United Kingdom, as elsewhere, cigarettes sold during the past few decades have changed considerably. Figures published by the Tobacco Research Council[1] show that the sales-weighted average tar yield of cigarettes in 1975 was 17·9 mg compared with 31·4 mg in 1965, a reduction of 43%. Over the same period the average nicotine yield decreased from 2·08 mg to 1·35 mg, a reduction of 35%. The only published data on tar and nicotine yields before 1965 are those from one sample of Gold Flake cigarettes manufactured in 1935 and tested 40 years later.[2] The tar and nicotine yields of this sample were 32·8 and 3·0 mg respectively. No comparable figures are available for the sales-weighted average carbon monoxide yield, but figures for cigarettes smoked by a sample of men in London for one year (1976) have been published.[3] The average carbon monoxide yield was 19·0 mg for ordinary unventilated filter cigarettes (without perforations in the tip), 15·2 mg for plain cigarettes, and 12·3 mg for ventilated filter cigarettes (with perforations in the tip).

There is great interest in studying trends in cigarette yields to see how they compare with changes in the incidences of diseases associated with smoking, such as coronary heart disease, lung cancer, and chronic bronchitis. When one of us (RD) mentioned in a lecture that we were trying to collect old cigarettes to measure their tar, nicotine, and carbon monoxide yields this was widely publicised in the press. The public responded generously and sent us many thousands of old cigarettes, which they had either kept as a memento or stumbled on when clearing out a cupboard or attic. We describe here the results of tests performed on these old cigarettes manufactured from 1934 to 1971, on cigarettes stored by the Government Chemist since 1972, and on brands tested regularly since that date.

Methods and results

The year of manufacture of the cigarettes was established by reference to the original manufacturer when necessary. After the cigarettes had been reconditioned according to standard methods[4] the nicotine, tar, and carbon monoxide yields were determined by the Laboratory of the Government Chemist using the same standard smoking procedure and analytical techniques used in the production of the Health Department's tar and nicotine tables.[5,6] The market share of each brand of cigarette sold in any particular year was obtained from figures supplied by the manufacturers for cigarettes sold before 1962; and thereafter from sales figures obtained from tables published each year by Maxwell,[7] augmented for 1979 by other estimates.[8]

ICRF Cancer Epidemiology and Clinical Trials Unit, Radcliffe Infirmary, Oxford OX2 6HE
NICHOLAS WALD, MRCP, member of ICRF scientific staff
RICHARD DOLL, FRS, director

Laboratory of the Government Chemist, London SE1 9NQ
GRAHAM COPELAND, BSC, head of smoking products

The table shows the sales-weighted average tar, nicotine, and carbon monoxide yields of cigarettes manufactured between 1934 and 1979 and the percentage of the market occupied by the brands tested. In any one period the brands tested accounted for at least 42% of total cigarette sales. Filter cigarettes began to be smoked on an appreciable scale in the late 1950s, and thereafter their sales increased rapidly as the sales of plain cigarettes declined.

Plain cigarettes—From our data it appears that from 1934 to 1979 the average tar yield of plain cigarettes decreased by 43% to 18·7 mg per cigarette. The average nicotine yield changed more irregularly over time. Between 1934 and 1954 there was a small increase from 2·00 to 2·23 mg per cigarette, then a decrease to 1·72 mg in 1973, an increase to 1·96 in 1976, and a further decrease to 1·54 mg in 1979. The average carbon monoxide yield changed little until the 1960s but decreased substantially from 20·6 mg during 1955-61 to 10·9 mg in 1979.

Filter cigarettes—The earliest filter cigarettes that we were able to test and that collectively represented more than 10% of the total market for any year were all made after 1966; these yielded, on average, less tar than plain cigarettes, although the few earlier ones had yields as high or higher than those of plain cigarettes. The average tar yield of unventilated filters further decreased by 25% from the 1962-8 period to 1979. Ventilated filter cigarettes were introduced in the early 1970s and had an even lower average tar yield. The sales-weighted average tar yield of all filter cigarettes in 1979 was 16·7 mg, a reduction of 31% compared with 1962-8. The average nicotine yield of unventilated filter cigarettes fell between 1962-8 and 1973, and then increased, the total change representing a reduction of 12·5%. The introduction of ventilated filter cigarettes with even lower nicotine yields meant that the sales-weighted reduction between 1962-8 and 1979 was even greater (18%). The average carbon monoxide yield of the earliest filter cigarettes that we were able to test was marginally higher than that of plain cigarettes sold in the same period (1962-8). The carbon monoxide yield of these filter cigarettes may have been an underestimate because cigarettes made in the early part of the period were underrepresented and had a higher average yield than those sold in the later part. The average carbon monoxide yield did not change materially between 1962 and 1979, despite the increasing introduction of ventilated filter cigarettes.

All cigarettes—Between 1934 and 1979 the sales-weighted average tar yield decreased by 49%, nicotine yield by 31%, and carbon monoxide yield by 11%. The patterns of decrease, however, appear to have been different. The average tar yield decreased progressively, at first slowly and from 1961 to 1976 rapidly, owing both to the introduction of filter cigarettes and to changes in plain cigarettes. The average nicotine yield started to decrease some 20 years later, after 1954, decreased by 43%, and then increased by 9% between 1974 and 1979. The average carbon monoxide yield started to decrease only after about 1961, and, while for plain cigarettes the decrease was substantial, the rapid increase in sales of filter cigarettes at the expense of plain cigarettes largely offset the reduction in the average carbon monoxide yield that would otherwise have occurred. The average carbon monoxide yield showed a small rise (4%) between 1976 and 1979.

Discussion

Todd[2] assumed that the average tar yield started to decrease from about 1965, but our data suggest that this fall may have started some 20 or 30 years earlier. If this is true then the pattern of mortality from lung cancer in Britain shows a closer correlation with cigarette consumption expressed in terms of constant-tar cigarettes than has hitherto been found.

Todd *et al*[9] compared the cigarette smoking patterns of successive five-year cohorts of men and women born in the UK from 1856 to 1956 with their mortality from lung cancer. Cigarette smoking was recorded as the cumulative consumption of constant-tar cigarettes by five-year cohorts—that is, the lifetime consumption of cigarettes by these cohorts. To calculate the figure Todd *et al* assumed that the reduction in the tar yields of cigarettes affected only those manufactured after 1965. On this basis the cumulative consumption of constant-tar cigarettes by men reached a peak in most age groups in cohorts born around 1915 and 1920. The 1930 cohort had a lower consumption, and this decrease continued in later cohorts. Lung cancer mortality in men showed a similar "peak," increasing in each cohort born up to about 1900 and decreasing in cohorts after 1920.

The similar pattern of lung cancer mortality and cumulative consumption of constant-tar cigarettes suggested that the reduction in the total amount of tar delivery to smokers from both a decrease in consumption and a decreased yield per cigarette could account for most of the reduction in lung cancer mortality in men. Some cohorts, however, showed a reduction in lung cancer mortality a few years *before* their reduction in cigarette consumption, and this was interpreted to mean that other factors such as a reduction in air pollution must have contributed to the decline in lung cancer mortality. Since we found that the sales-weighted average tar yield began to decline after 1945 rather than after 1965, there is less need to invoke a factor other than smoking that might have contributed to the changing patterns of lung cancer mortality.

While evidence exists showing that the carcinogenic effect of cigarette smoking resides in the tar, which constituent(s) of tobacco smoke cause coronary heart disease is much less clear. Both nicotine and carbon monoxide have been considered. Unfortunately, the changing patterns of their average yields over time are not sufficiently different to suggest which might be the more important agent, particularly as the disease has important causes other than cigarette smoking. Nevertheless, two observations are worth noting. Firstly, the greatest effect of smoking on the heart is apparent in people aged under about 55 years, and in this age group mortality from coronary heart disease has not fallen, although a reduction in the rate of

*Sales-weighted tar, nicotine, and carbon monoxide (CO) yields (mg/cigarette), market share, and proportion of market of cigarettes tested according to year of manufacture**

Year of manufacture	Plain brands					Unventilated filter brands					Ventilated filter brands					All brands			
	Market share (%)	Proportion tested (%)	Tar	Nicotine	CO	Market share (%)	Proportion tested (%)	Tar	Nicotine	CO	Market share (%)	Proportion tested (%)	Tar	Nicotine	CO	Proportion tested (%)	Tar	Nicotine	CO
1934–40	>99	79	32·9	2·00	18·6	<1					0					79	32·9	2·00	18·6
1941–7	>99	68	32·2	2·14	19·2	<1					0					68	32·2	2·14	19·2
1948–54	99	62	29·5	2·23	20·3	1					0					62	29·5	2·23	20·3
1955–61	90	76	30·4	2·03	20·6	10					0					69	30·4	2·03	20·6
1962–8	50	42	29·0	2·03	18·4	50	62	24·0†	1·68†	18·9†	0					52	26·0‡	1·82‡	18·7‡
1969	25	90	29·0	1·99	17·2	75	26	22·0	1·51	16·0	0					42	25·7	1·76	16·6
1970	22	97	29·4	1·96	17·4	78	66	21·2	1·34	17·0	0					73	23·6	1·52	17·1
1971	20	96	28·5	1·91	17·1	80	90	20·6	1·32	17·0	<1					91	22·3	1·44	17·0
1972	18	98	28·0	1·82	16·6	80	95	19·5	1·25	17·2	1	>90	12	0·8	13	94	21·0	1·35	17·0
1973	17	94	26·5	1·72		79	96	18·9	1·22		4	>90	11·0	0·75		96	19·9	1·29	
1974	16	94	25·4	1·76		78	98	18·8	1·24		6	98	9·4	0·65		98	19·3	1·28	
1975	13	99	25·3	1·91		80	96	18·5	1·27		7	96	9·3	0·76		96	18·8	1·32	
1976	12	97	24·7	1·96	13·7	77	>99	18·0	1·31	17·1	11	95	9·3	0·81	10·7	99	17·9	1·33	16·0
1977	11	97	24·6	1·95	13·6	74	98	18·2	1·28	17·6	15	96	9·8	0·86	11·1	97	17·6	1·28	16·1
1978	10	98	22·3	1·81	12·8	76	98	18·3	1·44	18·0	14	97	9·8	0·89	11·5	98	17·5	1·40	16·5
1979	9	98	18·7	1·54	10·9	77	99	17·9	1·46	18·1	14	96	9·7	0·85	12·0	98	16·8	1·39	16·6

*Data relating to individual brands sold between 1934 and 1972 may be obtained on application to NW.
†Most of the filter cigarettes tested in this period were made in 1967-8, so the cited means correspond with about 1967 rather than the midpoint of the period 1962-8.
‡Since filter cigarettes were made around 1967 and the plain cigarettes from around 1965, the cited means correspond with about 1966 rather than the midpoint of the period 1962-8.

increase occurred in men after 1960. Secondly, the decrease in the average nicotine yield started in about 1950, some 10 years before the decrease in the average carbon monoxide yield, and the decrease was greater for nicotine than for carbon monoxide.

The rise in the sales-weighted average nicotine and carbon monoxide yields in the past few years is notable. The rise in nicotine yield was due mainly to an increase in the yields of brands sold continuously during the period over which the change occurred. The rise in carbon monoxide yield, however, appears to have been caused mainly by the greater sales of king-size filter cigarettes, which began in 1976 in anticipation of the harmonisation of the structure of the UK tobacco tax with that of other EEC countries (1 January 1978). This meant that cigarettes were taxed on a per cigarette basis plus a percentage of the retail price instead of largely on the weight of tobacco. The market share occupied by king-size filter cigarettes rose from about 10% of all cigarettes two years before the tax changed to about 60% two years after the change.

An element of uncertainty is introduced by our failure to obtain brands that accounted for a substantial proportion of the total market in certain periods. We suspect that this was not a serious problem because we established that from 1965, the first year for which tar and nicotine yields of all brands were available from the Tobacco Advisory Council, our figures were reasonably representative of the market as a whole. For example, in 1969, when brands that accounted for only 42% of the market could be tested, the sales-weighted average tar yield of the cigarettes we tested was 22·3 mg per cigarette compared with 23·9 mg for the whole market, in both cases using Tobacco Advisory Council figures.

We are confident that the changes in the average yields that we observed for cigarettes made after 1968 are correct because they were based on many hundreds of estimations. Results on older cigarettes were based on smaller numbers (177, 376, 131, 191, and 225 cigarettes from 15, 19, 14, 19, and 29 packets or tins manufactured, respectively, in the five seven-year periods shown in the table), and the average yields must therefore be interpreted more cautiously.

The extent to which our data are valid depends principally on whether cigarettes stored for some 40 years have not undergone any irreversible changes and can be reconditioned to produce the same results, on average, that would have been obtained had they been tested when new. Two pieces of evidence bear on this problem. Firstly, we tested cigarettes of the same manufacturing date but packed in either vacuum-sealed drums of 50 or cardboard packets of 10 or 20. Cigarettes released from the drums were still at their packed moisture and quite "smokeable" after 40 years of storage, whereas those from the packets were dry and brittle. After reconditioning the tar, nicotine, and carbon monoxide yields from the samples packed in both ways were found to be similar. Secondly, several samples of cigarettes manufactured and tested in 1971 and 1972 had been kept in their original packs. After reconditioning and smoking in 1980 the tar and nicotine yields were generally within 1 mg and 0·1 mg, respectively, of the original 1972 values. Thus, while storage for eight years did not apparently affect the tar and nicotine yields of cigarettes, it must remain an assumption that longer periods of storage do not materially affect these yields, as we obtained only indirect evidence of this.

Sales-weighted average tar and nicotine yields based on tobacco industry data have been published by the Tobacco Research Council for 1965-75.[1] Our figures agreed reasonably closely with theirs except during 1962-8. In this period the sales-weighted average tar yield of the brands made after 1964 that we tested was 28·7 mg using tobacco industry data (provided by the Tobacco Advisory Council), which was 14% greater than our own figure of 25·2 mg. Possibly cigarettes stored since before 1968 yielded spuriously low tar levels, but for the reasons given above we believe that this is unlikely. If this did occur, however, it would mean that the average tar yield of cigarettes made in early years was higher than that we observed, and hence the reduction in the average tar yield over time was even greater than our estimate.

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ONE HUNDRED YEARS AGO The Jermyn Street Hamman—Among things which are better done in England than elsewhere must be reckoned the Turkish. With some little personal experience of Eastern travel, and a good deal of interest in Turkish baths, we can endorse the story which the *Athenaeum* tells of the Hamman in Jermyn Street. At a dinner-table in Stamboul we heard a French Secretary request an Arab Sheikh from the Hauran, to tell him where he could find the best Turkish bath—whether at Cairo or at Jerusalem, at Constantinope or Damascus? "God is great, and Effendis are wise," said the Sheikh; "but if you ask your servant, he must say the best bath of all is to be found near Piccadilly, in London." In scrupulous cleanliness in all its annexed parts, in spacious accommodation, freshness of the air, and luxurious comfort, the Turkish bath in Jermyn Street has no rival in the East. Like many other successful works, it is the product of the energy, faith, and militant enthusiasm of a fanatic. "The Turkish bath a cure for cancer, I believe; and for consumption, I am sure," said Mr Urquhart; and to a mild expression of doubts on those heads, he replied indignantly, "All my life I have been opposed by publicans and apothecaries." As a luxury in health, however, as a means of warding off or curing gouty, rheumatic, catarrhal, renal, and dyspeptic affections, the Turkish bath has secured for itself what may now be considered a permanent place in popular esteem, confirmed and opposed by medical experience. We learn that the bath in Jermyn Street is about to be still further extended and improved by the addition of new hot rooms, with direct radiating heat and adequate ventilation. Medical men are admitted now at all hours, on producing their cards, at two shillings, or a series of twelve tickets are furnished for one pound. This is one-half the usual rates before seven in the evening. These baths are largely used by medical men who find in them depurating and bracing influences, a more or less adequate antidote to the sedentary life which many are obliged to lead. (*British Medical Journal*, 1881.)