LUNG CANCER AND BRONCHITIS IN RELATION TO CIGARETTE SMOKING AND FUEL CONSUMPTION IN TWENTY COUNTRIES

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In their report on "Smoking and Health", the Royal College of Physicians (1962) concluded that cigarette smoking was a cause of lung cancer but that smoking was not the only cause of this disease. The report on the same subject by the Surgeon General's Advisory Committee of the United States Public Health Service (1964) concluded that: "Cigarette smoking is causally related to lung cancer in men; the magnitude of the effect of cigarette smoking far outweighs all other factors".

The phrase "far outweighs" has been wrongly taken by some to imply that the other factors are of little consequence in their total effect but, when dealing with a disease responsible for some 30,000 deaths a year in the United Kingdom, a fraction of only one-fifth due to other factors would account for 6,000 deaths and such a number could hardly be regarded as unimportant. The first tentative estimates of one-fifth were derived from very small numbers of non-smokers, and studies of more adequate data have shown that in some large urban areas the contribution of other causes to the total deaths must be a good deal higher. For example, it was estimated in 1955 that about half the deaths of men from lung cancer in Liverpool arose from cigarette smoking and about three-eighths must have been due to factors only slightly present in neighbouring rural areas (Stocks and Campbell, 1955).

In classical studies of lung cancer mortality related to histories of past residence and smoking of men and women in the United States, Haenszel and his co-workers (Haenszel, Loveland, and Sirken, 1962; Haenszel and Taeuber, 1964) have analysed in great detail the periods of life-time spent, by those who died of the disease, in towns of different population size and in rural and farm areas. Standardized mortality ratios based on 100 for all white males, and adjusted both for their age and

smoking history, were, for all durations of residence combined, 65 in farm areas increasing by stages according to the size of town lived in to 123 in cities of half a million population or over; and for white females the mortality ratios increased from 69 in the farm areas to 132 in the large cities. When durations of residence between 10 and 40 years only were considered, the corresponding mortalities were 77 and 122 for males, 70 and 149 for females. This disposes of the idea that the urban excess of lung cancer could be explained away by more cigarette smoking in town than country.

Another study of male mortality in Canada according to smoking history, comparing those who had lived for 5 years or more in cities with those who had not, showed an overall ratio of 1·50 for lung cancer contrasted with 1·12 for all causes of death (Department of Health and Welfare, Canada, 1966). A recent evaluation of the urban excess for lung and stomach cancer and bronchitis in English conurbations compared with surrounding areas, during periods from 1921–30 to 1951–60, has shown that the excess, which continues to be large, cannot be explained either by smoking differences or by the social factors affecting the three diseases, and must be attributed to air pollution in the case of lung cancer and bronchitis for lack of any other conceivable explanation (Stocks, 1966).

Comparisons between lung cancer death rates in whole countries with good standards of diagnosis and cause certification have become possible in recent years, and Nielsen and Clemmesen (1954) demonstrated a rough correspondence between the crude rates in eight countries about the year 1950 and the annual consumption of tobacco per inhabitant 20 years previously. Improvement in reliability of death rates and in availability of trade figures of cigarette consumption made possible a study of death rates at different ages in 1958–9 in

nineteen countries in relation to the cigarette consumption per adult over 15 in the population in various years back to 1937 (Stocks, 1966). Furthermore, a series of reports by the United Nations providing data for the same countries of the consumption of solid and liquid fuels in each year made it feasible to relate the death rates with cigarettes in conjunction with these fuels and to estimate the apparent contributions of each to the lung cancer mortality. Whereas cigarette consumption was correlated more strongly with the rates at younger ages than at more advanced ages, the relation with solid fuel became most evident at ages after 55 when it was even stronger than that with cigarettes. With liquid fuel consumption, however, associations were negative. Consumption of coal appeared to account in the average country for about one-third of the deaths and that of cigarettes for about two-thirds (Stocks, 1966).

Since death rates for more recent years (1962-3) have now become available, this study has been repeated in the present paper for male death rates from lung cancer at ages 35-44 and 55-64 in those years, and male death rates from bronchitis at 55-64 in 1960-1 have been examined for comparison, the data being taken from the useful compilations of international rates by Segi and Kurihara (1966) and Segi, Kurihara, and Tsukahara (1966). The annual numbers of cigarettes consumed in the

twenty countries per person over age 15 have been compiled by Todd (1963), and figures for the consumption of solid and liquid fuel *per capita* are taken from the United Nations reports for 1955-8 (UNO, 1960).

The outcome of relating these with the death rates is shown graphically in Figs 1 and 2, and the numerical data are set out in the Table.

The twenty countries have been ranked in descending order of solid fuel consumption in 1955-8, which ranged from 4,129 kg. *per capita* annually in the United Kingdom to 138 kg. *per capita* in Portugal. The cigarettes consumed in the same years ranged from 3,422 per adult in the United States to 545 in Norway. The consumption of liquid fuel per kg. coal-equivalent is shown also in the second column, ranging from 3,168 in the United States to 189 in Portugal.

Fig. 1 shows how the death rates of men from lung cancer in 1962-3 were related to the cigarettes being consumed by all adults 6 years earlier. At ages 35-44 there was a correlation of +0.634, equivalent to an increase of 30 per million in the death rate for each 1,000 of the cigarette consumption, as indicated by the regression line. At ages 55-64, however, the correlation was considerably lower at +0.380, the regression line rising by 369 per million living for each 1,000 cigarettes consumed by all adults annually in the period 6 years before.

TABLE

MALE DEATH RATES FROM LUNG CANCER (1962-3) AND BRONCHITIS (1960-1) RELATED TO CONSUMPTION OF CIGARETTES PER ADULT OVER 15 AND OF SOLID AND LIQUID FUEL *PER CAPITA* (1955-8)

No.	Country	Annual Consumption, 1955-8			Death Rate per million by Age*			
		Fuel kg./cap.		Cigarettes per Adult	Lung Cancer, 1962-3		Bronchitis, 1960-1	
		Solid	Liquid		35-44	55-64	55-64	
1	United Kingdom	4129	743	2568	157	3049 (2709)	1932	(1834)
2	Germany, West	3047	318	1195	65	1850 (2022)	379	(454)
3	Belgium	2748	780	1390	93	2154 (2222)	460	(504)
4	Australia	2396	1136	1955	68	1404 (1195)	527	(479)
5	United States	2260	3168	3422	114	1459 (729)	69	(0)
6	South Africa	2226	258	937	75†	1501† (1769)	390	(507)
7	France	1713	575	1257	65	1110 (1439)	62	(127)
8	Canada	1708	2590	2590	63	1293 (950)	170	(19)
9	Netherlands	1589	852	1672	100	2321 (2321)	377	(375)
10	Denmark	1290	1188	1217	74	1478 (1638)	103	(173)
11	Austria	1231	406	1475	65	2335 (2403)	93	(122)
12	Sweden	742	1967	1035	35	708 (939)	68	(169)
13	New Zealand	638	996	1765	82	1440 (1401)	601	(584)
14	Finland	625	522	2132	124	2471 (2296)	145	(68)
15	Ireland	621	506	2485	110	1319 (1014)	1207	(1073)
16	Switzerland	580	716	1910	78	1553 (1461)	126	(86)
17	Japan	565	205	1642	25	457 (463)	2	(5)
18	Norway	411	1093	545	43	676 (1287)	103	(284)
19	Italy	232	383	1197	92	1291 (1462)	716	(791)
20	Portugal	138	189	812	32	421 (734)	715	(853)
Means		1445		1660	78	1513 (1513)	425	(425)

* Numbers in parentheses are corrected for cigarette consumption by regression formula.

† Rate in 1960-1.

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FIG. 1.—Death rates from lung cancer (1962-3) and bronchitis (1960-1) related to cigarettes consumed per adult (1955-8) in twenty countries.

In the previous paper, where death rates in 1958-9 were related at five different age groups with cigarette consumption 6, 11, 16, and 21 years previously, the strength of correlation was found to be always greatest at ages 35-44 and to become weaker at higher ages, and certain inferences were drawn from this which need not be discussed here. It will suffice to mention that, amongst men dying at ages 35-44 in 1958-9, coefficients as high as $+0.75$ were found with cigarette consumption during the period when these men had been adolescents to young adults.

By way of comparison, the death rates from bronchitis in 1960-1 amongst men aged 55-64 were, as shown in the Figure, not so strongly related with cigarette consumption as were the lung cancer rates at those ages, the coefficient being $+0.246$ and the regression 162 for each 1,000 of cigarette consumption. It has to be remembered that chronic bronchitis as a cause of death is not always so described in some of the countries reviewed.

Fig. 2 shows first the countries ranked as in the Table according to the solid fuel consumed in 1955-8, and then the death rates from lung cancer and bronchitis among men aged 55-64, after correction for cigarette consumption in the same period by means of the regression coefficients, resulting in the figures given in parentheses in the Table. The mean value of the corrected rates is indicated in each portion of the diagram, and it is evident that the lung cancer rates adjusted for the smoking differences tend to be higher in countries with high coal consumption than in countries using small amounts of solid fuel. Of the first six countries, four had corrected rates above the average line, whereas all of the last six countries had rates below that line. Although there are irregularities in the column heights among countries with medium coal consumption, with the Netherlands, Austria, and Finland showing rates which seem inexplicably high, the mean column heights of successive groups of five countries were 2,353, 1,587, 1,610, and 1,041. The correlation

FIG. 2.—Death rates from lung cancer (1962-3) and bronchitis (1960-1) corrected for cigarettes consumed during 1955-8 in twenty countries ranked according to their solid fuel consumption in 1955-8.

coefficient with cigarettes held constant by this process of adjustment was $+0.446$, indicating a significant association between lung cancer mortality in men aged 55-64 and solid fuel consumption 6 years before.

The various coefficients with cigarettes and solid fuel were as follows:

Cause of Death	Lung Cancer		Bronchitis
	35-44	55-64	
Age Group			55-64
Cigarettes consumed in 1955-8.. ..	0.634	0.380	0.246
Solid fuel consumed in 1955-8.. ..	0.470	0.599	0.369
Solid fuel, with cigarettes constant	0.282	0.446	0.341

For all cancer except of the lung and bronchus at ages 55-64 there was no positive correlation with solid fuel, the coefficient being -0.111 .

The death rates from lung cancer of men aged 35-44 were more closely related to cigarettes than to solid fuel consumed by the population 6 years before, but the reverse was true at the later ages 55-64, when it appeared that air pollution was a more important factor than smoking even after holding the latter constant to eliminate its effect. For bronchitis at ages 55-64, the coefficients are greatly influenced by the very high mortality from that disease in the United Kingdom and there is, in fact, no appreciable relationship with solid fuel to be seen in the other nineteen countries, perhaps because of international differences in diagnostic description of the condition and its selection as the principal cause of death, when associated with other conditions.

Liquid fuel consumption levels as shown in the Table give no positive association with either lung cancer or bronchitis mortality in men aged 55-64. Thus, when the twenty countries are ranked according to diminishing use of liquid fuel during 1955-8, the average corrected death rates in the first and last

ten are for lung cancer 1,518 and 1,409 per million, and for bronchitis 442 and 409; it appears that this factor is not important in determining the mortality in these countries.

SUMMARY

These results suggest that, while cigarette smoking is the most important factor in determining national death rates of men from lung cancer before age 45, air pollution by coal smoke is as important as cigarette smoking in determining the rates at ages over 55, and that the two factors are sufficient to account for the rate variation in twenty countries, except in Finland, Austria, and the Netherlands where additional unknown factors seem to be operating.

REFERENCES

Department of Health and Welfare, Canada (1966). "A Canadian Study of Smoking and Health". Ottawa.

- Haenszel, W., Loveland, D. B., and Sirken, M. G. (1962). *J. nat. Canc. Inst.*, **28**, 947.
 — and Taeuber, K. E. (1964). *Ibid.*, **32**, 803.
 Nielsen, A., and Clemmensen, J. (1954). *Dan. med. Bull.*, **1**, 194.
 Royal College of Physicians of London (1962). "Smoking and Health". Pitman Medical Publishing Co., London.
 Segi, M., and Kurihara, M. (1966). "Cancer Mortality from Selected Sites in 24 Countries", No. 4. Tokohu, Sendai, Japan.
 —, —, and Tsukahara, Y. (1966). "Mortality from Selected Causes in 30 Countries, 1950–61". Kosei Tokei Kyokai, Tokyo, Japan.
 Stocks, P. (1966). *Brit. J. Cancer*, **20**, 595.
 — and Campbell, J. M. (1955). *Brit. med. J.*, **2**, 923.
 Todd, G. F. (1963). "Tobacco Consumption in Various Countries". Research Paper No. 6. Tobacco Research Council, London.
 UNO (1960). "World Energy Supplies, 1955–58". UN Statistical Papers Series J, No. 3.
 U.S. Department of Health, Education, and Welfare (1964). "Smoking and Health". Publ. Hlth Serv. Publication No. 1103. Government Printing Office, Washington, D.C.