Projected mortality from lung cancer in South Korea, 1980–2004

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Background	In recent years, mortality from lung cancer has increased rapidly in Korea, a South East Asian country with a high prevalence of smoking. The objectives of this study are to examine how age, period, and birth cohort effects contributed to trends in lung cancer mortality in Korea 1980–1994, and to predict lung cancer mortality rates for 1995–2004.
Methods	Age- and sex-specific lung cancer mortality rates were obtained from annual reports of the National Office of Statistics in Korea. Poisson regression models were used to estimate age, period and cohort effects.
Results	Among men, age-adjusted annual mortality rates from lung cancer (per 100 000) increased from 3.7 in 1980 to 17.8 in 1994; corresponding rates for women were 1.4 and 7.0. As age increased, mortality rates from lung cancer increased more rapidly in men than in women. Within the same age group, the mortality of younger cohorts was higher than older cohorts. The average annual number of lung cancer deaths projected for the years 2000–2004 among men and women will be 15 441 and 3572 respectively, while the average annual age-adjusted mortality rates from lung cancer (per 100 000) will be 65.4 for men and 15.1 for women. These rates correspond to 17.7- and 10.7-fold increases over the 1980 mortality rates in men and women, respectively.
Conclusion	These results, in conjunction with trends in tobacco consumption, indicate that mortality from lung cancer in both men and women will increase substantially through the early part of the 21st century in Korea.
Keywords	Lung cancer, age-period-cohort analysis, tobacco consumption
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Cancer has been a leading cause of mortality in South Korean adults in the 20th century. Cancer-related deaths increased from 13.8% of total deaths in 1980 to 21.4% in 1994. From 1980 to 1994, total cancer-related deaths increased 2.7-fold in men (from 49.5 to 134.2 per 100 000 population) and 2.3-fold in women (from 32.6 to 76.1 per 100 000 population).[1] Among South Korean adult men, stomach, liver, and lung cancer accounted for over 65% of all cancer deaths from 1984 to the present. Although stomach cancer contributed the largest number of cancer-related deaths, mortality from stomach cancer has been steadily decreasing over the past 10 years. Since 1980, lung cancer has been the most rapidly increasing cause of cancer-related deaths among South Koreans.

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Smoking is widely recognized as the primary risk factor for developing lung cancer and accounts for 80–90% of lung cancer deaths, at least in economically developed countries.[2] During the past 50 years, aggregate tobacco consumption in South Korea has increased 8.6-fold, from a total of 12.4 thousand million cigarettes in 1945 to 106.3 thousand million cigarettes in 1994 while the South Korean population has increased just 1.5-fold.[3] Despite public health efforts to discourage cigarette smoking, rates of smoking have remained high. In 1980, 69.4% of men were current smokers,[4] while 70.2% of men smoked in 1994.[5] Smoking remains uncommon in women; in 1980; just 3.4% of South Korean women smoked. The persistently high rates of tobacco consumption in men and low rates of consumption in women allow prediction of subsequent smoking-related health outcomes, using models that incorporate observed age, cohort and period effects.[6]

The objectives of this study are to examine how age, period and birth cohort effects contributed to lung cancer mortality in South Korea between 1980 and 1994, and to predict lung cancer mortality rates for 1995–2004 using an age, period and cohort model.

Table 1 Lung cancer mortality rates (per 100 000) and lung cancer deaths for South Korean men by age and year

Age group		Calendar period														
		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
30–34	Rate	0.68	1.04	1.46	1.76	1.35	1.47	1.85	1.81	1.79	1.67	1.53	1.54	2.09	1.22	1.73
	Deaths	9	14	20	25	20	23	32	33	34	33	32	33	46	27	38
35–39	Rate	0.68	1.29	1.96	3.39	2.79	3.86	3.21	2.97	3.28	3.97	3.47	3.64	3.31	4.37	4.29
	Deaths	8	15	23	41	35	50	44	42	48	61	54	61	66	83	86
40–44	Rate	3.33	1.49	5.93	5.81	7.96	8.43	6.42	6.57	8.86	8.48	8.56	10.05	8.81	9.26	8.50
	Deaths	37	17	69	68	92	96	75	78	108	107	110	132	118	126	120
45–49	Rate	7.79	9.77	12.19	11.79	14.56	16.26	19.07	21.37	19.58	22.77	20.52	20.86	22.15	20.91	20.08
	Deaths	67	90	118	119	152	174	210	240	222	258	230	233	249	241	241
50–54	Rate	13.01	16.85	20.93	26.03	25.29	31.78	35.72	35.05	40.37	39.11	42.55	44.83	46.78	45.88	44.09
	Deaths	79	106	139	184	191	259	309	320	386	388	434	468	502	496	474
55–59	Rate	24.43	29.27	38.95	49.16	50.46	68.99	65.14	67.42	72.08	74.18	123.79	110.08	91.88	91.64	98.07
	Deaths	129	156	208	264	275	385	383	418	475	523	593	884	781	823	917
60–64	Rate	40.57	45.57	62.43	68.21	70.60	76.49	99.34	109.96	118.38	134.45	137.09	148.65	164.14	166.84	186.64
	Deaths	155	180	256	294	317	397	453	508	554	644	680	773	911	986	1174
65–69	Rate	40.30	60.22	62.45	77.11	91.41	110.33	129.58	155.45	165.87	185.26	192.08	211.29	234.03	256.51	259 35
	Deaths	106	162	173	219	266	331	403	499	554	641	728	805	894	1003	1040
70–74	Rate	40.12	59.52	94.22	78.97	103.93	121.55	126.5	136.95	174.15	209.61	211.54	231.56	287.40	339.78	202.11
	Deaths	65	100	163	139	185	220	253	278	357	436	495	565	730	914	574
75–79	Rate	41.89	58.02	86.59	77.64	103.45	120.39	134.91	137.96	165.77	210.81	202.42	219.85	321.74	338.02	145.52
	Deaths	31	47	71	66	90	124	143	149	184	234	251	288	444	480	211
80+	Rate	15.56	26.83	38.09	97.67	113.33	68.52	109.26	101.82	138.59	177.58	167.61	220.83	261.84	305.0	95.12
	Deaths	7	11	16	42	51	37	59	56	79	103	119	159	199	244	78

Methods

Annual lung cancer death statistics for South Korea, 1980–1994, were obtained from the National Office of Statistics of Korea. Data on aggregate annual cigarette consumption in South Korea were obtained from the Korean Corporation of Ginseng and Tobacco, which had a monopoly on the distribution of cigarettes until 1988. Tables 1 and 2 present rates for age-specific mortality from lung cancer in Korean men and women. The minimum age group for study was 30–34 years, because lung cancer deaths are rare in people under 30. For men and women separately, the number of deaths and person-years were stratified by 5-year age group and 5-year calendar period (1980–1984, 1985–1989, 1990–1994). Together, the age groups and calendar periods defined birth cohorts. Person-years at risk were approximated by mid-year population estimates.

In an age, period and cohort model (APC model), mortality is summarized by three sets of parameter values, obtained by a fitting procedure. An age value corresponds to each age group, a period value to each calendar period of death, and a cohort value to each cohort represented in the Table. These are fitted so that their products in all age-period groups are as close as possible to the observed rates. The APC multiple classification model has the following specific structure:[6]

$$Y_{ij} = \alpha_i + \beta_j + \gamma_{a-i+j}, \text{ for } i = 1,2, \ldots ,a \text{ and } j = 1,2, \ldots ,p$$

where, $Y_{ij} = f(O_{ij}/N_{ij})$ represents function of the observed rate r_{ij}, α_i is the fixed effect of the ith age category, β_j is the fixed effect of the jth period category, γ_{a-i+j} is the fixed cohort effect

associated with ith age category and jth period category, a is a total number of 5-year age groups, and p is a total number of 5-year calendar period groups. The model is then fit to the data by maximum likelihood methods. A linear dependency $(k = a - i + j)$ exists among the three factors age, period, and cohort effect parameters. A number of solutions have been proposed for this non-identifiability problem. Most solutions involve constraints to be placed on the parameters; however, the parameter estimates have been shown to be sensitive to the choice of constraint.[6–10] Since no analysis in cancer epidemiology can ignore age, we considered age-period and age-cohort models.[9,10] Poisson regression models were fitted to the observed mortality rates. Log-likelihood ratio statistics (deviance) were used to assess the goodness-of-fit of the models. The selected model had the lowest residual deviance and included terms for sex, age, cohort, and the interaction of age and sex (Table 3). Indirectly, this model also reflects period effects.

To predict lung cancer mortality in 1995–2004, we assumed that the age and birth cohort pattern of lung cancer risk will persist into the future.[11] Data from the National Office of Statistics of Korea were used to estimate the South Korean population by age and gender between 1995 and 2004. The population age structure by sex for 1995–2004 was projected on the basis of modelling the population changes before these years.[12] The estimates of cohort parameters were extrapolated into the future using an unweighted linear regression on all cohort parameters. The predictions for average annual numbers of deaths were derived by combining the predicted mortality rates and person-years.

Table 2 Lung cancer mortality rates (per 100 000) and lung cancer deaths for South Korean women by age and year

Age group		Calendar period														
		1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994
30–34	Rate	0.66	0.89	0.94	1.92	1.25	1.29	1.51	1.23	1.71	1.20	1.25	1.12	1.57	1.27	1.13
	Deaths	8	11	12	25	17	19	24	21	31	23	25	23	33	27	24
35–39	Rate	1.26	1.55	2.01	3.04	1.56	2.10	1.99	2.33	2.33	1.73	2.60	1.82	2.12	2.41	2.07
	Deaths	14	17	22	34	18	25	25	30	31	24	38	29	36	44	40
40–44	Rate	1.59	1.92	2.51	3.12	3.87	3.29	3.48	3.62	4.42	3.85	3.61	4.73	4.80	3.41	4.11
	Deaths	17	21	28	35	43	36	38	40	50	45	44	59	61	44	55
45–49	Rate	1.89	3.53	4.67	5.22	4.96	5.54	5.99	5.25	6.97	6.72	7.59	5.71	8.91	6.85	6.74
	Deaths	17	33	45	52	51	58	64	57	76	73	82	61	96	76	78
50–54	Rate	2.37	4.42	7.19	7.55	8.24	8.58	9.48	10.21	8.34	10.51	11.89	10.46	11.97	13.09	14.95
	Deaths	17	33	56	61	69	75	86	96	81	105	121	109	128	141	160
55–59	Rate	5.64	7.78	8.08	10.80	11.38	12.57	14.82	11.98	17.14	15.87	17.52	16.09	20.77	19.79	22.15
	Deaths	34	48	51	70	76	87	107	90	134	129	150	143	190	186	214
60–64	Rate	7.27	9.78	12.83	16.63	14.99	19.33	20.38	24.03	22.48	25.00	23.22	27.30	31.66	31.47	35.04
	Deaths	33	46	63	86	82	110	118	143	138	159	153	187	227	236	274
65–69	Rate	9.14	11.83	17.97	18.07	19.45	25.42	24.24	25.11	30.79	34.14	48.66	38.85	51.09	54.83	52.97
	Deaths	33	44	69	71	78	105	103	112	145	169	255	209	282	312	312
70–74	Rate	10.61	13.97	17.73	23.37	20.34	30.79	32.17	40.62	43.43	45.07	45.03	50.53	65.31	70.15	73.68
	Deaths	28	38	50	68	60	93	101	130	142	151	163	190	256	289	322
75–79	Rate	13.49	17.37	14.62	21.71	19.78	25.37	34.74	30.45	47.56	51.97	50.82	64.17	75.47	88.60	103.62
	Deaths	22	29	25	38	36	52	74	67	107	119	124	163	200	241	286
80+	Rate	9.67	12.50	19.70	27.74	26.57	24.22	37.58	30.18	40.57	49.72	49.03	52.09	66.22	101.75	71.19
	Deaths	12	16	26	38	38	39	62	51	71	90	101	112	147	233	168

Table 3 Poisson regression models of lung cancer mortality in South Korea, 1980–1994

Model	Residual		Change in		
	Deviance	d.f.	Deviance	d.f.	P-value
1. Intercept	22 220.9	65			
2. Intercept + Sex	18 914.8	64	3306.1	1	<0.001
3. Intercept + Sex + Age	1753.4	54	17 191.4	10	<0.001
4a. Intercept + Sex + Age + Period	304.9	52	1448.5 [a]	2	<0.001
4b. Intercept + Sex + Age + Cohort	218.3	42	1535.1[a]	12	<0.001
5a. Intercept + Sex + Age + Cohort + Sex*Cohort	69.5	30	148.8[b]	12	<0.001
5b. Intercept + Sex + Age + Cohort + Sex*Age [c]	36.5	32	181.8[b]	10	<0.001

[a] Change from model 3.

[b] Change from model 4b.

[c] Model 5b used to predict lung cancer mortality.

Results

Between 1980 and 1994, lung cancer mortality and the number of lung cancer deaths increased substantially. In 1994, there were 6137 deaths from lung cancer among South Korean men and 2059 deaths among South Korean women, corresponding to an 8.5-fold increase in lung cancer deaths for men and an 8.0-fold increase for women between 1980 and 1994. Age-adjusted lung cancer mortality per 100 000 men rose from 3.7 in 1980 to 17.8 in 1994 (a 5.1-fold increase), while corresponding mortality rates in women rose from 1.4 in 1980 to 7.0 in 1994 (a 5.0-fold increase).

Between 1980–1984 and 1990–1994, the predicted numbers of deaths corresponded well to the observed numbers (Figure 1).

Subsequently, our model predicts that lung cancer mortality will increase substantially among both men and women. The predicted average annual number of lung cancer deaths between 2000 and 2004 will be 15 441 deaths for men and 3572 for women. Average annual, age-adjusted lung cancer mortality per 100 000 population between 2000 and 2004 will be 65.4 for men and 15.1 for women. The increase in lung cancer mortality rates will be more marked among men than among women. Age was the most significant predictor of mortality in Poisson regression models (Table 3), and its effects were different in men and women. Specifically, there was a significant interaction between gender and age such that as age increased, men had higher mortality rates than women (P < 0.001, comparison of models 4b and 5b).
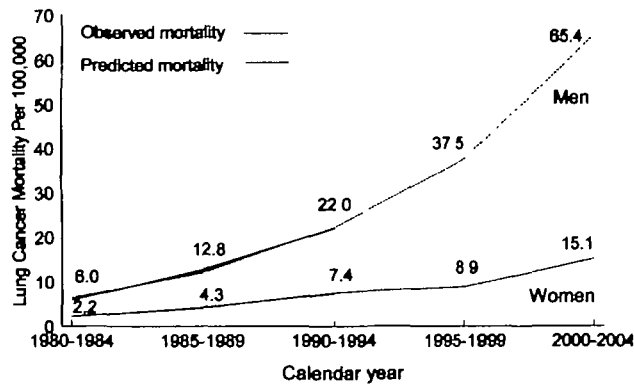
Figure 1 Observed and predicted lung cancer deaths in South Korea (1980–2004)
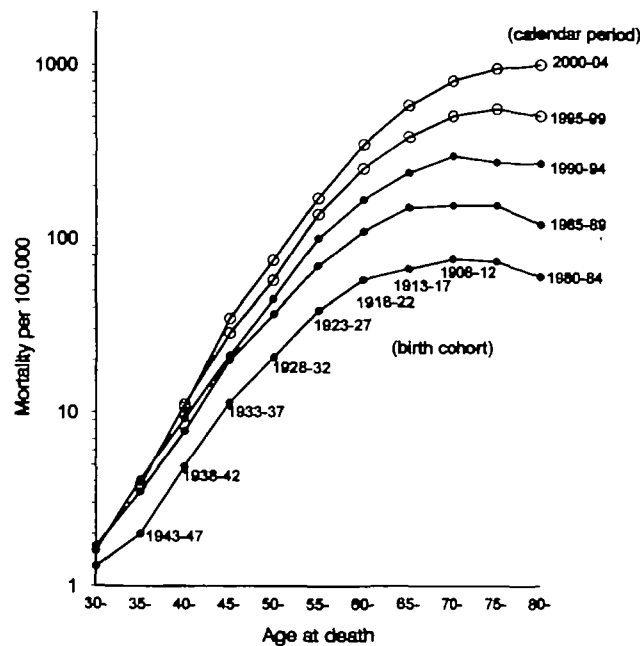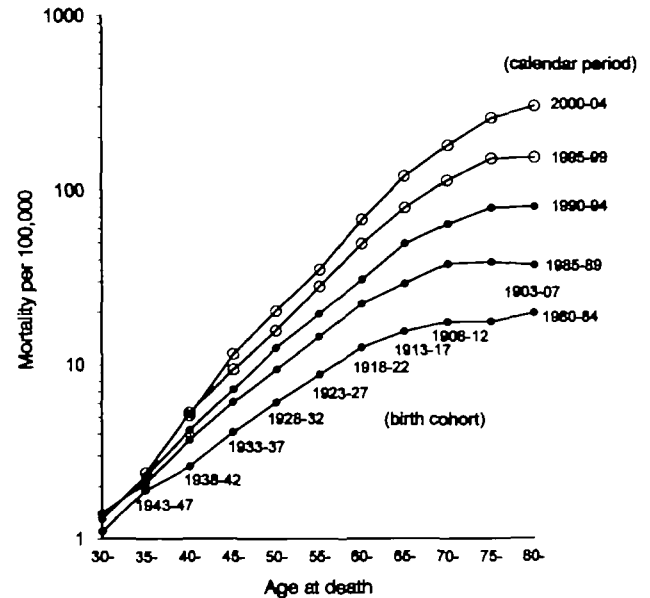

Figure 2 Age-specific lung cancer mortality rates in men in 5-year periods and birth cohorts in South Korea. Actual rates (closed symbols), Predicted rates (open symbols)

Figures 2 and 3 display actual age-specific mortality rates from 1980 to 1994 and predicted mortality rates to 2000–2004 in men and women. In each age group and in each gender, mortality from lung cancer will increase. In 1980–1984, mortality rates per 100 000 men increased from 1.3 in the 30–34 year age group to 76.1 in the 70–74 year age group, then decreased to 60.2 at ages ≥80 years. A similar pattern is present in the years 1985–1989 and years 1990–1994. However, in 2000–2004, mortality from lung cancer will increase through all age groups, including those ≥80 years. Patterns were similar among women, except that there was no reduction of mortality in women ≥80 years.

Within the same birth cohorts, lung cancer mortality increases with age. Recent birth cohorts will have substantially

Figure 3 Age-specific lung cancer mortality rates in women in 5-year periods and birth cohorts in South Korea. Actual rates (closed symbols), Predicted rates (open symbols)

higher lung cancer mortality rates by age group than older birth cohorts. Cohort trends will be similar in men and women.

Discussion

Results from this study indicate that mortality from lung cancer will increase substantially through the early part of the 21st century. Specifically, the predicted average annual number of lung cancer deaths in the years 2000–2004 is 15 441 deaths among men and 3572 deaths among women. The magnitude of predicted mortality is alarming and will result in a substantial burden to Korean society in terms of medical costs, not to mention individual suffering.

Cigarettes were first introduced into Korea in the 1930s, but average per capita tobacco consumption remained <3 cigarettes per day from 1945 until the late 1960s. In the 1970s, mass production of tobacco and easy access to cigarettes increased tobacco consumption. The opening of Korean markets to foreign cigarette manufacturers in 1988 rapidly increased overall tobacco consumption. Changing values and increasing economic affluence in the 1980s may also have contributed to the increase in smoking among young men and women. By the 1990s, tobacco consumption per capita had increased to >6 cigarettes per day.[13]

Compared with other countries, current mortality from lung cancer in Korea is relatively low, as a result of the lag period between the exposure (smoking) and the onset of disease (lung cancer). Trends in lung cancer mortality are thus affected by smoking patterns 20–30 years previously.[14] To this end, a simultaneous plot of aggregate cigarette consumption and lung cancer mortality (actual and predicted) is illustrative (Figure 4). It is evident that the current and emerging epidemic of lung cancer largely reflects patterns of cigarette smoking 20–30 years ago.
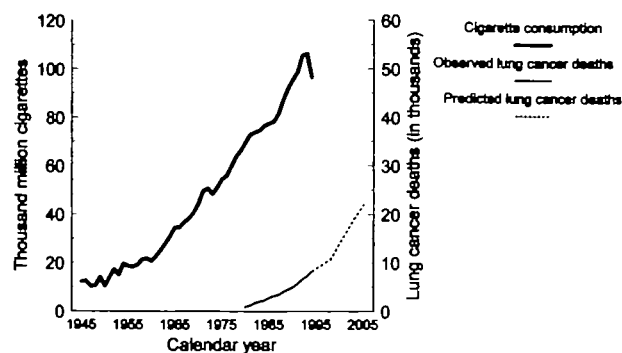
Figure 4 Cigarette consumption and lung cancer deaths in South Korea (both sexes combined)

Annual tobacco consumption increased approximately three-fold from 20 thousand million cigarettes in the 1950s to 70 thousand million cigarettes in the 1980s, while mortality from lung cancer is expected to increase by as much as three times in the future. In fact, age-adjusted lung cancer mortality rates during this period increased much more than we expected (5.1 times in men and 5.0 times in women).

Only aggregate cigarette consumption data across both sexes and all ages are available from past time periods (1945–1994). Thus, it is not possible to apply models based on sex- and age-specific cigarette consumption. In the absence of such data, the application of age-sex-cohort models provide a satisfactory means to estimate subsequent smoking-related mortality. The present predictions are based on the assumption that the trends in age, birth cohort and calendar period parameters observed in the past will continue into the future. Thus, they reflect a situation that would likely occur if there were no marked changes in overall patterns of cigarette consumption, i.e. starting age, quitting age, and smoking pattern. Hence, present predictions give a point of departure or a baseline against which the effect of anti-smoking measures could be assessed.

As mentioned previously, the observed risks of dying from lung cancer can be interpreted as a reflection of smoking in the past.[15-17] The risk of dying from lung cancer grew with increasing age mainly because the lifetime number of cigarettes increased with age. The decline in mortality in old age (>75 years) among men may have resulted from relatively higher mortality among younger cohorts compared to older cohorts, as a result of increased cigarette consumption in the younger cohorts.

In conclusion, lung cancer mortality will increase substantially through the early 21st century. The burden on Korean society is of sufficient magnitude to warrant a major commitment of public health resources in order to avert this emerging epidemic of smoking-related disease. In other South East Asian countries

with a high prevalence of smoking, these data provide a glimpse of a major epidemic that will likely occur in this region of the world.

Acknowledgements

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