PRELIMINARY REPORT

**An Exploratory Analysis of
Mortality with an Age-Period Model
and its Application to Stomach
Cancer in Japan**

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SUMMARY

Applying a log-linear model, we analyzed stomach cancer mortalities during 1973-90 for 47 prefectures in Japan. The model we dealt with is based on a poisson distribution in which the expected number of deaths from stomach cancer is expressed as $n_{r,ij} \exp(\mu_r + \alpha_i + \tau_{rj})$, for i th age group and j th calendar year, for prefecture c ; here $n_{r,ij}$ denotes the population size of (i,j) category in region r . Risk of stomach cancer mortality decreases almost exponentially in prefectures in this period for both sexes; the decreasing rate in female is larger than that in male for all prefectures. High correlation between risk of stomach cancer mortality in male and that in female exists. Two geographical clusters of high risk for stomach cancer mortality exist; the one of them is west side of Tohoku area, and the other is southwest part of Kinki area. There is a trend such that the risk decreases more rapidly in the area of higher risk especially for male.

1 Introduction

In the case of analyzing the trend of mortality, age-adjusted mortality by direct method or by indirect method (e.g. Chiang, 1961) used to be calculated, and its change used to be observed until now. In that method, standard group is established, and adjustment is carried out with its population or its mortality. Therefore, the results of such analysis turn out to be quite dependent upon the standard group, so the problem of establishing the suitable standard group becomes a subject of discussion. Breslow and Day (1975) have proposed a new age-adjustment method, applied multiplication model, not to establish standard group to region-age-specific mortality. We intended to extend their new method so as to apply it to region-age-period-specific mortality. And we could estimate a cohort effect, a kind of interaction effect associated with age and period, from obtaining ratio of the observed deaths to the expected deaths based on main-effect model at each birth

Key words: Poisson model; Age-period model; Stomach cancer

cohort. For example, we analyzed the trend of mortality of stomach cancer by prefecture from 1973 to 1990 (18 years) in Japan. We illustrate our method and that results below.

2 Materials

Population data were obtained from census (1970, 75, 80, 85) and estimates with those census data on occasion that census was not taken. Age- and sex-specific stomach cancer mortality by prefecture was obtained from Japanese Vital Statistics List (1973-1990). All data were summarized into a two way, age by period(year) contingency table. Age was divided into 16 quinquennia 15-19,20-24,...,85-89.

3 Method of analysis

3.1 Poisson model for number of deaths

The expected mortality rate in region r for i -th age group and j -th calendar year is assumed to be expressed as

$$(1) \quad \lambda_{rij} = \exp(\mu_r + \alpha_{ri} + \tau_{rj}), \quad i = 1, \dots, \ell; j = 1, \dots, m,$$

where $\sum_{i=1}^{\ell} \alpha_{ri} = \sum_{j=1}^m \tau_{rj} = 0$. Then the expected number of deaths is given by

$$(2) \quad n_{rij} \lambda_{rij} = n_{rij} \exp(\mu_r + \alpha_{ri} + \tau_{rj}), \quad i = 1, \dots, \ell; j = 1, \dots, m,$$

with the population size n_{rij} , for (i,j) -category. Under the additional assumption that occurrence of deaths are mutually independent, we obtain the likelihood based on the Poisson distribution as follows,

$$(3) \quad L(\mu_r, \{\alpha_{ri}\}, \{\tau_{rj}\}) = \frac{\prod_{i=1}^{\ell} \prod_{j=1}^m \{n_{rij} \exp(\mu_r + \alpha_{ri} + \tau_{rj})\}^{y_{rij}}}{y_{rij}!} \times \exp\{n_{rij} \exp(\mu_r + \alpha_{ri} + \tau_{rj})\},$$

where $\{y_{rij}\}$ are observed number of deaths. Applying maximum likelihood method, we may estimated the unknown parameters $\mu_r, \{\alpha_{ri}\}, \{\tau_{rj}\}$ in (3). Here, we are interested in comparison of the values μ_r 's and $\{\tau_{rj}\}$'s for different region r 's. Therefore, we further assume $\{\alpha_{ri}\}$ are common for all regions to make the comparison of the estimates μ_r and $\{\tau_{rj}\}$ easy. Thus we assume $\alpha_{ri} = \alpha_i, i = 1, \dots, \ell$ in the process of parameter estimation. This model is an age-period model (e.g. Kupper et al.), which is an extension of the method due to Breslow and Day (1975) who specified an indirect method for age-standardization. Now the estimates of α_i 's, μ_r 's and τ_{rj} 's are given by as the solution of maximum likelihood method with the likelihood function,

$$(4) \quad L(\{\mu_r\}, \{\alpha_i\}, \{\tau_{rj}\}) = \frac{\prod_r \prod_{i=1}^{\ell} \prod_{j=1}^m \{n_{rij} \exp(\mu_r + \alpha_i + \tau_{rj})\}^{y_{rij}}}{y_{rij}!} \times \exp\{n_{rij} \exp(\mu_r + \alpha_i + \tau_{rj})\},$$

3.2 Relative Risk by Region

The following quantity may be given as an index showing age-adjusted relative risk of death for region r ,

$$(5) \quad \theta_r = \exp(\mu_r - \mu_s),$$

where $\mu_s = \frac{1}{N_r} \sum_r \mu_r$ with the number of regions N_r . From Formula (5), it is clear that $\theta = 1$ when $\mu_r = \mu_s$. The estimate $\hat{\theta}_r = \exp(\hat{\mu}_r - \hat{\mu}_s)$ of θ_r is referred to as “RRR (Relative Risk by Region)”.

3.3 Mean rate of annual change of mortality

Let β_r be mean rate of annual change of mortality for region r during observed period when the trend of mortality have an almost linear shape. Then we can estimate β_r by regressing $\{\hat{\tau}_{rj}\}$ on $\{j\}$ with a straight line model. Thus we obtain

$$(6) \quad \hat{\beta}_r = \frac{\sum_{j=1}^m (j - \frac{m+1}{2}) \hat{\tau}_{rj}}{\sum_{j=1}^m (j - \frac{m+1}{2})^2}.$$

3.4 An index for degree of cohort effect

The following index may be given as an index showing age-adjusted relative risk of death for k -th birth cohort,

$$(7) \quad \delta_{rk} = \frac{\sum_{j=k+2}^v w_{jk} y_{r[(j-k+2)/5]+1j} + (1 - w_{jk}) y_{r[(j-k-2)/5]+2j}}{\sum_{j=k+2}^v w_{jk} Q_{r[(j-k+2)/5]+1j} + (1 - w_{jk}) Q_{r[(j-k-2)/5]+2j}}$$

where $v = \min(1990 - k, 82)$, $[z] = \text{int}(z)$, $Q_{rij} = n_{rij} \exp(\hat{\mu}_r + \hat{\alpha}_i + \hat{\tau}_{rj})$ and $w_{jk} = 1 - \text{mod}(j - k - 2, 5)/5$. The estimation of cohort effect by this method is based upon age-period model (e.g. Kupper et al., 1985), and its effect turns to a index for the simple interpretation. The index δ_{rk} is a ratio of interperated observed number of deaths in cohort k in region r to the expected number of deaths due to the age-period model. About the estimation of cohort effect, Hirotsu (1988) reported a model which applied the method of ANOVA, Akai and Shibuya (1988) reported a model which took note of the second difference, and Tango and Kurashina (1987) reported a model which focused on the estimation of its non-linear components.

4 Results

Figures 1, 2 and 3 presents the results of the analysis for the whole of Japan. Figure 1 shows the age-dependence of estimated risk of death from stomach cancer, expressing that the estimated risk increases monotonously with age. Figure 2 gives the time trend of the estimated risk, indicating that the risk decreases nearly exponentially in this period for both sexes; the rate for female decreases more rapidly then that for male does. Figure 3 shows the estimated birth cohort effects. From this figure, it can be seen that there is small peak around the birth cohorts for 1930's for only male population. The value of

Figure 1. Estimated age dependence of stomach cancer mortality

Figure 2. Trend of annual change of stomach cancer mortality

Figure 3. Estimated birth cohort effect

Figure 4. Map of RRR of stomach cancer in Japan by prefecture (1973-1990)

Table 1. RRR and beta (Mean annual change rate) of stomach cancer by prefecture (1973-1990)

Prefecture		Male		Female	
		RRR	beta	RRR	beta
1	Hokkaidou	0.98	-0.0319	0.93	-0.0417
2	Aomori	1.04	-0.0287	0.97	-0.0356
3	Iwate	0.81	-0.0255	0.80	-0.0370
4	Miyagi	0.99	-0.0322	0.97	-0.0440
5	Akita	1.29	-0.0366	1.22	-0.0459
6	Yamagata	1.25	-0.0372	1.20	-0.0409
7	Fukushima	1.10	-0.0303	1.05	-0.0373
8	Ibaragi	1.09	-0.0298	1.08	-0.0362
9	Tochigi	1.15	-0.0323	1.11	-0.0332
10	Gunmma	1.04	-0.0356	0.99	-0.0473
11	Saitama	1.07	-0.0343	1.06	-0.0431
12	Chiba	1.05	-0.0355	1.05	-0.0429
13	Tokyou	1.00	-0.0306	0.99	-0.0409
14	Kanagawa	0.97	-0.0318	0.98	-0.0431
15	Niigata	1.24	-0.0280	1.25	-0.0409
16	Toyama	1.22	-0.0330	1.26	-0.0399
17	Isgikawa	1.08	-0.0395	1.15	-0.0445
18	Fukui	0.90	-0.0397	1.04	-0.0439
19	Yamanashi	0.99	-0.0296	0.95	-0.0444
20	Nagano	0.99	-0.0347	0.95	-0.0403
21	Gifu	0.98	-0.0320	1.08	-0.0418
22	Shizuoka	0.84	-0.0248	0.86	-0.0360
23	Aichi	0.98	-0.0318	1.07	-0.0406
24	Mie	0.99	-0.0341	1.04	-0.0400
25	Shiga	1.01	-0.0324	1.08	-0.0419
26	Kyoto	0.99	-0.0325	1.02	-0.0325
27	Osaka	1.09	-0.0309	1.07	-0.0386
28	Hyougo	1.00	-0.0317	1.01	-0.0372
29	Nara	1.18	-0.0374	1.20	-0.0455
30	Wakayama	1.16	-0.0334	1.07	-0.0351
31	Tottori	1.07	-0.0296	1.06	-0.0417
32	Shimane	0.94	-0.0282	0.97	-0.0467
33	Okayama	0.86	-0.0324	0.92	-0.0416
34	Hirishima	0.92	-0.0346	0.93	-0.0436
35	Yamaguchi	0.96	-0.0325	0.97	-0.0401
36	Tokushima	0.88	-0.0284	0.96	-0.0428
37	Kagawa	1.02	-0.0363	1.06	-0.0462
38	Ehime	0.99	-0.0336	1.01	-0.0468
39	Kouchi	0.87	-0.0236	0.87	-0.0387
40	Fukuoka	0.99	-0.0345	1.00	-0.0452
41	Saga	1.10	-0.0372	1.07	-0.0494
42	Nagasaki	0.93	-0.0285	0.94	-0.0361
43	Kumamoto	0.75	-0.0277	0.75	-0.0408
44	Oita	0.91	-0.0343	0.89	-0.0429
45	Miyazaki	0.85	-0.0304	0.81	-0.0389
46	Kagoshima	0.70	-0.0276	0.64	-0.0391
47	Okinawa	0.55	-0.0349	0.43	-0.0438

Figure 5. Map of mean annual change rate of stomach cancer mortality in Japan (1973-1990)

Figure 6. RRR of stomach cancer mortality by prefecture

Figure 7. Mean annual changing rate vs RRR

δ 's shows that observed number of deaths is larger than the expected value with several percents at the peak.

Almost same results as given from the analysis for the whole of Japan are obtained from every prefecture data set. That is, the estimated reisk of stomach cancer mortality decreases nearly exponentially in every prefecture in this period for both sexes; dexcreasing rate for female is larger than that for male. Table 1 shows the summary of the results of the analysis by prefecture. Figure 4 visualizeds the geographical feature of RRR by sex. In this figure "shaded" indicates $RRR \geq 1.15$ and "dotted" shows $RRR \leq 0.85$, respectively. It can be seen that two major geographical clusters of high risk for stomach canecr exist; the one of them is west side Touhoku area, and the other is south west part of Kinki area. Figure 5 is map of mean annual change rate of stomach cancer mortality by sex. No clear feature can be observed from this figure. Figure 6 is plot of the estimated RRR for female versus that for male for 47 prefectures. High correlation between the two RRR's can be observed. Figure 7 is plot of the estimated mean rate of annual change of mortality versus the RRR for 47 prefectures. There is a trend such that the risk decreases more rapidly in the area of higher RRR especially for male.

5 Discussion

In the analysis model for age-period-specific mortality, we thought that age-period-cohort model was effective. But as far as we intended to descript it as linear model, the fatal error that was lacking in the uniqueness of model expression was pointed out (e.g. Kupper et al., 1985; Tango and Kurashina, 1987). So we analyzed with age-period model as second-best measure. And in our model, birth-cohort effect which was estimated from two-stages process (7), could be also interpreted as a kind of index of fitness against age-period model. In this analysis, we could not see the birth-cohort that had the high risk to stomach cancer, but we think this fact showing that age-period model was occasionally fitted to data well.

Stomach cancer is known to the most important one of all cancer in Japan. In fact, according to Vital Statistics in 1990, deaths caused by stomach cancer occupied 20 percentage (22.3 percent in male, 19.5 percent in female) in all deaths caused by all cancer (Ministry of Health and Welfare, 1990). However, according to previous reports, it is known that mortality of stomach cancer is rapidly decreasing in the advanced countries including Japan recently. But, it is not sufficiently explicated as to the causes why mortality of stomach cancer is rapidly decreasing (Doll and Peto, 1981).

Kuroishi et al. (1981) researched the geographical distribution of unevenness to mortality of stomach cancer, prefecture-specific mortality from 1973 to 1977, by the indirect method (SMR) with establishing the standard group all over the country. In that research, they reported that mortality of stomach cancer at the coastal region of Tohoku district and the southern part of Kinki district was high, and that that mortality at Iwate Prefecture and the southern part of Kyusyu district was low. These results were in agreement with our results of analysis well. Therefore, we knew that the geographical distribution of unevenness to mortality of stomach cancer in the midlle of 1970's is continuously maintained until 1990.

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