Note

ECOLOGICAL STUDY OF SOLAR RADIATION AND CANCER MORTALITY IN JAPAN

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***Abstract*—Geographic observation of the increased mortality of some cancers at higher latitudes has led to a hypothesis that vitamin D produced after exposure to solar radiation has anti-carcinogenic effects. However, it is unclear whether such association would be observed in countries like Japan, where fish consumption, and therefore dietary vitamin D intake, is high. Pearson correlation coefficients were calculated between averaged annual solar radiation levels for the period from 1961 through 1990 and cancer mortality in the year 2000 in 47 prefectures in Japan, with adjustments for regional per capita income and dietary factors. A moderate, inverse correlation with solar radiation was observed for cancers of the esophagus, stomach, colon, rectum, pancreas, and gallbladder and bile ducts in both sexes (correlation coefficient, ranging from −0.6 to −0.3). The results of this study support the hypothesis that increased exposure to solar radiation reduces the risk of cancers of the digestive organs.**
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Key words: cancer; radiation, cosmic; mortality; exposure, population

INTRODUCTION

STUDIES OF the geographical distribution of cancers have shown that certain types of cancer mortality increase with decreasing intensity of solar radiation, including cancers of the colon (Garland and Garland 1980; Gorham et al. 1989; Grant 2002), breast (Gorham et al. 1989; Garland et al. 1990; Grant 2002), prostate (Hanchette and Schwartz 1992; Grant 2002), and ovary (Lefkowitz and Garland 1994; Grant 2002). Since the association is not fully explained by known risk factors, including diet, one hypothesis that has been proposed is that increased exposure to solar radiation helps to prevent cancers through the augmented synthesis of vitamin D (Garland and Garland 1980). This hypothesis is biologically plausible, since vitamin D analogs are reported to affect cell proliferation and differentiation (Lointier et al. 1987; Brehier and Thomasset 1988).

Previous studies in Japan have detected increased mortality from cancers of certain digestive organs at high latitudes (Kato et al. 1985; Watanabe and Arimoto 1990). These findings suggest the existence of an association between solar radiation and cancer, even in countries like Japan where fish consumption, and therefore dietary vitamin D intake, is high (FAOUN 1996). Geographically, Japan extends across a wide region from north to south, with major cities in its 47 prefectures ranging from 26°N to 43°N latitude. Its islands feature mountain ranges running through their center. Together, these two characteristics result in significant meteorological variations. The present study sought to investigate whether levels of solar radiation at various sites in Japan over the past 30 y are associated with cancers of the digestive organs and sex-hormone-related organs. The potential confounding effect of diet was assessed using data from a national nutritional survey.

MATERIALS AND METHODS

We chose the prefecture ($n = 47$) as the unit of ecological observation. Sex-specific age-standardized mortality rates according to prefecture for the year 2000 (SID 2002) were obtained for cancers of the colon, rectum, prostate, breast (female), and ovary (Appendix A1), for which a relation with solar radiation or latitude has been suggested; and cancers of the esophagus, stomach, pancreas, and gallbladder and bile ducts, for which higher mortality has been reported in northern regions or in regions of Japan with cloudy and snowy winters.

We obtained data of average annual hours of solar radiation received from 1961 to 1990 for the central city of each prefecture (Japan Meteorological Agency 2001), except for two prefectures, for which data on solar radiation was available for another major city (Saitama: Kumagai City, Shiga: Hikone City). The mean average annual solar radiation during 1961–1990 for the prefectures was 3.59 KWh h d^{-1} (range: 3.29–4.01).

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We regarded income and nutritional factors as potential confounding factors. Prefectural income per person was obtained from the 1990 Report on Prefectural Economic Calculation (The Cabinet Office 1990). Data on nutrition were obtained from the 1990 National Nutritional Survey (Bureau of Public Health, Ministry of Health and Welfare 1992), in which subjects were selected at random from the general population. Mean intake of food groups and nutrients was available only for 12 geographical districts, each composed of one to six prefectures (Appendix B1). Therefore, dietary intake for a district was assigned to prefectures that compose the district. The dietary factors initially considered included animal protein, total fat, and fish of any kind (excluding processed food) for cancers of the colon, breast, and prostate; and salt for stomach cancer. Soy products in relation to hormone-related cancers and fiber in relation to colon cancer were not considered because recent ecological studies in Japan have not detected significant associations for these factors (Nagata 2000; Nakaji et al. 2003). Among dietary factors considered, intakes of fat and salt, which were inversely associated with solar radiation (correlation coefficient, −0.49 and −0.26, respectively), were adjusted in the analysis, while intakes of fish and animal protein, which were materially unrelated to solar radiation (correlation coefficient, 0.09 and 0.08, respectively), were not adjusted.

The Pearson correlation coefficient between solar radiation and cancer mortality was calculated for all prefectures ($n = 47$). Partial correlation coefficient was estimated by including terms of income and fat intake in the analysis of cancers of the colon, rectum, prostate, breast, and ovary; and for income and salt intake in the analysis of stomach cancer. The analysis was then repeated while excluding prefectures with large metropolitan areas (Kanto area: Saitama, Tokyo, Chiba, Kanagawa; Hanshin area: Kyoto, Osaka, Hyogo; Aichi; Fukuoka). This exclusion was made to account for the potential effects of large migration from other prefectures and reduced exposure to sunlight due to the shadows cast by buildings. Low levels of serum 25-hydroxyvitamin D concentrations in elderly persons, especially those who are sun-deprived, have been reported, suggesting a reduced sun exposure in cities (Gloth et al. 1995). Further analysis excluded Okinawa prefecture at 26°N, which is situated 5 degrees latitude south of the prefecture with the second southern-most latitude in Japan. The reasons for excluding this prefecture included unique dietary and disease patterns in Okinawa. For example, so-called westernized foods including bread, beef, and coffee were consumed more heavily, while the frequency of salted food intake was remarkably low in Okinawa (Tsugane et al. 2001). The importance of such dietary factors is further suggested by the observation that the mortality of stomach cancer is only half of the average mortality in Japan (SID 2002).

RESULTS

In men, a significant inverse association was observed between solar radiation and age-adjusted mortality rates from cancers of the digestive organs: the esophagus, stomach, colon, rectum, pancreas, gallbladder and bile ducts (Table 1). In women, significant associations were also observed for these sites, although the strength of the associations was generally weaker than in men (Table 2). In both sexes, the associations for cancers of the colon, rectum, and stomach remained significant after controlling for income and the above-mentioned dietary factors. In contrast, there was virtually no association between solar radiation and mortality for cancers of the prostate, breast, and ovary. Excluding prefectures with major urban areas and Okinawa prefecture did not materially change the results, except for cancers of the stomach and pancreas in women, for which the correlation coefficients became non-significant after these exclusions.

DISCUSSION

We found a moderate, inverse relation between solar radiation and cancer mortality involving cancers of the digestive organs. The findings for colon cancer are consistent with previous ecological analyses (Garland and Garland 1980; Gorham et al. 1989; Grant 2002). Increased mortality from cancers of the esophagus, stomach, and pancreas in areas of Japan with low solar radiation is also consistent with previous spatial observations, including those in Japan (Kato et al. 1985; Watanabe and Arimoto 1990). The present study also

Table 1. Correlation coefficient (r) between solar radiation (1961–90) and cancer mortality (2000) in men, Japan.

Cancer site	Age-adjusted yearly mortality (min, max) per 100,000 person	r	r^a	r^b
Esophagus	10.4 (6.0, 16.5)	-0.42^c	-0.45^c	
Stomach	39.1 (21.7, 51.5)	-0.50^c	-0.48^c	-0.44^c
Colon	14.4 (10.8, 19.2)	-0.55^c	-0.53^c	-0.41^c
Rectum	9.3 (6.7, 11.7)	-0.54^c	-0.53^c	-0.40^c
Colorectum	23.7 (18.0, 29.6)	-0.63^c	-0.61^c	-0.49^c
Pancreas	12.4 (7.0, 17.2)	-0.51^c	-0.53^c	
Gallbladder and bile duct	8.2 (6.6, 12.6)	-0.31^d	-0.55^c	
Prostate	8.6 (5.9, 11.6)	−0.04	−0.01	−0.07

[a] Adjusted for income.
[b] Additionally adjusted for fat intake (colon, rectum, prostate) or salt intake (stomach).
[c] $p < 0.01$.
[d] $p < 0.05$.

Table 2. Correlation coefficient (*r*) between solar radiation (1961–90) and cancer mortality (2000) in women, Japan.

Cancer site	Age-adjusted yearly mortality (min, max) per 100,000 person	r	r^a	r^b
Esophagus	1.3 (0.5, 1.8)	-0.45^c	-0.41^c	
Stomach	15.3 (7.7, 19.2)	-0.37^d	-0.32^d	-0.35^d
Colon	9.5 (7.3, 12.3)	-0.51^c	-0.46^c	-0.33^d
Rectum	4.1 (2.7, 5.3)	-0.47^c	-0.47^c	-0.39^c
Colorectum	13.6 (10.4, 17.6)	-0.58^c	-0.54^c	-0.42^c
Pancreas	7.2 (4.0, 9.9)	-0.32^d	-0.31^d	
Gallbladder and bile duct	6.3 (4.7, 8.5)	-0.44^c	-0.50^c	
Breast	10.7 (7.1, 13.4)	−0.20	−0.09	−0.06
Ovary	4.3 (2.1, 5.4)	−0.17	−0.06	−0.04

[a] Adjusted for income.
[b] Additionally adjusted for fat intake (colon, rectum, breast, ovary) or salt intake (stomach).
[c] $p < 0.01$.
[d] $p < 0.05$.

suggests that cancers of the gallbladder and bile ducts are associated with levels of solar radiation. In contrast, cancers of the prostate, breast, and ovary did not significantly correlate with solar radiation.

As previously hypothesized, one plausible explanation for the present inverse association is that exposure to solar radiation reduces the risk of cancer through photo-initiation of vitamin D production. Vitamin D is synthesized in skin on exposure to ultraviolet B, then metabolized in the liver and kidney to vitamin 1,25-D_3. The synthesis of 1,25-D_3 from the precursor 25-D_3 also occurs at tissue levels (Schwartz et al. 1998). 1,25-D_3 not only promotes cell differentiation and reduces proliferation (Lointier et al. 1987; Brehier and Thomasset 1988) but also inhibits tumor growth in xenografts (Eisman et al. 1987) and induces apoptosis of various cancer cells, including colon (Vandewalle et al. 1995). Furthermore, there is evidence, although not always consistent, that elevated levels of serum vitamin D analog are associated with reduced risk of cancer or cancer precursors (Garland et al. 1989; Platz et al. 2000). These findings suggest that vitamin D may be involved in several stages of carcinogenic process.

The Japanese consume large amounts of fish, a food source rich in vitamin D. Although fish consumption in the present data set was relatively equal among regional populations subject to different levels of solar radiation intensity, the intake of fatty fish, which are especially rich in vitamin D, tends to be greater in northern regions (Bureau of Public Health, Ministry of Health and Welfare 1992). Consistent with this observation, recent national nutritional survey estimated greater intake of vitamin D for Japan's northern districts (The Study Circle for Health and Nutrition Information 2003); the mean dietary intakes of vitamin D were 11.4 mg and 6.5 mg for the most northern district and the most southern district, respectively. Without this gradient in dietary intake of vitamin D opposite to that of solar radiation, the effects of the latter may well have been greater. However, without population data showing serum vitamin D levels across the nation, we can neither refute nor adopt the proposed hypothesis involving vitamin D.

Other factors may account for the present association. Mortality rates from suicide, more frequent among those who are clinically depressed, are inversely associated with intensity of solar radiation in Japan (Terao et al. 2002). Depression has been suggested to cause immune suppression (Miller et al. 1993) and has been proposed as a predisposing condition for diseases that develop more easily under decreased surveillance activity of the immune system, including cancer. Several, but not all, epidemiological studies have reported an increased risk of cancer among those who are depressed (Penninx et al. 1998). Thus, it is possible that the exposure to solar radiation may indirectly reduce cancer risks through positive effects on mood that intensify immune surveillance systems. However, since there is no direct evidence linking digestive cancers to immune suppression, further research is required to judge the plausibility of this mechanism as an explanation for the inverse association between solar radiation and digestive cancers.

The present study found no association between solar radiation and sex hormone-related cancers (prostate, breast, and ovary), a finding at odds with previous ecological studies (Gorham et al. 1989; Garland et al. 1990; Hanchette and Schwartz 1992; Lefkowitz and Garland 1994; Grant 2002). Although these cancers have steadily increased in Japan over recent decades, their resulting incidence rates remain at the lowest levels among developed countries (Parkin et al. 2002). Studies have indicated that intake of soy products (rich in isoflavones) and fish (rich in ω-3 fatty acid), staples of the traditional Japanese diet, are associated with reduced risk of cancers of the breast and prostate, respectively (Terry et al. 2001; Yamamoto et al. 2003). High consumption of these foods among the Japanese may mask the effects of solar radiation on these cancers. Alternatively, since hormone-related cancers tend to originate early in life (Swerdlow et al. 2002), an adequate study might require information on lifetime exposure to solar radiation. The increasing gap between cancer incidence and mortality has been observed especially for hormone-related cancers. If people living in northern prefectures have a greater availability of medical care service than those living in southern prefectures, it is possible that an association between solar radiation and these cancers would be masked due to a better prognosis of cancer patients in northern areas. In reality, however, medical care cost tends to be higher in southwest districts than northeast districts in Japan (MHLW 1999), indicating that such bias is a less likely explanation for the lack of the association for these cancers.

Ecological studies are apt to suffer from the ecological fallacy. We adjusted for fat intake in our analysis for colon and rectal cancers and for salt intake in our analysis for stomach cancer. The results indicate that these dietary factors do not fully explain the inverse relationship with solar radiation. Smoking, a possible risk factor of some digestive cancers (Mizoue et al. 2000), did not show a latitudinal gradient in Japan (Bureau of Public Health, Ministry of Health and Welfare 1992). Internal migration or large population increase in some prefectures may dilute the association between solar radiation and cancer. The amount of time that people spend indoors may affect the result. If a snowy winter confines people inside the home, the difference in exposure to solar radiation across the nation would be enhanced. Women showed a slightly weaker association between solar radiation and cancer mortality than men. One possible reason is that women, who may stay longer hours indoors than men, and whose clothing habits may further restrict exposure of the skin, have a smaller geographical difference in exposure levels to solar radiation than men. We used mean solar radiation levels for the period from 1961 through 1990 and mortality data in 2000. Not knowing the minimum exposure period and latent period for the development of cancer, we cannot assess the validity of these periods. An analysis using appropriate exposure and lag periods should yield a stronger association between solar radiation and cancer risk.

CONCLUSION

The present study adds evidence to the hypothesis that solar radiation reduces mortality from cancers of the digestive organs. The lack of association found in this study between solar radiation and sex-hormone-dependent cancers warrants further investigation.

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APPENDIX A1. Solar radiation, income, and age-standardized cancer mortality by prefecture in Japan. Abbreviations: M, male; F, female.

	Name of prefecture	Solar radiation[b] (KWh/ hour-day)	Income[c] (thousand yen/person)	Age-standardized cancer mortality[a] (/100,000) esophagus		stomach		colorectum		colon		rectum		pancreas		gall bladder and bile duct		breast	ovary	prostate
				M	F	M	F	M	F	M	F	M	F	M	F	M	F			
01	Hokkaido	3.45	2382	11.8	1.3	36.9	13.4	26.4	14.3	16.9	9.9	9.5	4.4	15.8	8.2	9.9	6.7	11.7	4.1	8.8
02	Aomori-ken	3.36	2217	13.2	1.4	45.8	16.2	28.7	14.8	17.0	10.1	11.7	4.7	17.2	8.0	10.5	6.4	11.5	3.5	9.7
03	Iwate-ken	3.44	2239	11.3	1.8	35.6	12.9	24.8	15.4	14.6	10.5	10.2	4.9	11.7	6.3	10.2	5.8	8.8	5.2	10.7
04	Miyagi-ken	3.38	2549	12.8	1.7	37.9	15.2	26.4	13.6	15.7	9.9	10.7	3.7	13.0	8.1	8.9	6.5	12.8	4.4	8.7
05	Akita-ken	3.29	2278	16.5	1.7	51.5	19.2	29.6	17.6	19.2	12.3	10.4	5.3	13.5	7.9	12.6	7.3	10.1	3.7	8.2
06	Yamagata-ken	3.41	2333	11.6	1.7	50.4	18.5	23.1	16.4	13.0	11.6	10.1	4.8	13.9	7.9	9.2	7.7	9.8	3.6	9.1
07	Fukushima-ken	3.44	2474	10.6	0.7	38.5	17.0	23.6	12.2	14.1	8.9	9.5	3.4	13.2	5.8	9.4	8.3	9.0	4.4	10.2
08	Ibaraki-ken	3.47	2938	10.6	1.3	43.8	16.6	21.9	13.0	13.0	9.1	9.0	3.8	11.7	8.0	8.6	7.4	10.2	4.5	9.4
09	Tochigi-ken	3.44	2894	10.7	1.6	47.2	15.6	23.2	14.0	13.7	9.9	9.5	4.1	13.0	6.6	7.6	7.1	8.7	4.8	7.9
10	Gumma-ken	3.54	2811	10.1	1.1	40.2	14.3	21.1	13.2	12.0	8.7	9.1	4.5	12.3	6.5	8.2	7.6	10.8	3.8	10.0
11	Saitama-ken	3.58	3008	10.6	1.5	42.1	17.1	24.8	14.1	15.2	10.2	9.5	3.9	12.3	6.8	8.1	6.6	11.9	4.9	7.8
12	Chiba-ken	3.55	3129	10.2	1.4	40.4	15.4	24.4	14.2	14.4	10.1	10.0	4.1	11.5	7.1	7.8	5.6	11.5	5.3	8.8
13	Tokyo-to	3.34	4452	13.3	1.7	38.2	15.2	26.0	15.0	15.9	10.6	10.1	4.4	11.6	7.4	6.6	6.1	13.4	5.4	9.0
14	Kanagawa-ken	3.50	3210	12.4	1.5	39.2	14.5	26.3	14.3	16.0	10.0	10.4	4.4	11.9	6.9	6.8	5.4	12.0	5.1	9.3
15	Niigata-ken	3.32	2576	14.4	1.3	47.1	15.4	23.8	14.9	14.1	9.9	9.7	5.0	14.0	7.3	9.2	7.7	9.8	4.3	7.4
16	Toyama-ken	3.33	2855	8.6	1.0	41.7	15.2	22.8	12.9	13.6	8.3	9.2	4.6	14.3	6.3	7.3	7.5	10.0	3.3	5.9
17	Ishikawa-ken	3.44	2757	6.5	1.2	42.1	15.0	22.4	13.0	15.0	8.4	7.4	4.7	14.7	7.9	10.1	7.0	10.6	3.8	8.2
18	Fukui-ken	3.35	2598	6.5	0.7	30.7	16.1	24.9	10.9	16.2	7.9	8.7	3.0	11.4	8.4	8.7	8.5	10.5	2.1	7.0
19	Yamanashi-ken	3.76	2726	10.2	1.1	36.5	13.4	21.4	10.5	13.1	7.3	8.4	3.2	10.8	7.6	7.4	5.2	11.0	2.9	7.0
20	Nagano-ken	3.58	2888	8.1	1.1	34.5	12.3	20.4	12.3	12.8	8.3	7.6	4.0	12.7	7.1	8.4	5.2	9.4	4.5	10.0
21	Gifu-ken	3.80	2791	6.9	0.6	39.9	18.8	24.3	14.3	14.7	10.6	9.5	3.8	13.4	8.1	6.8	6.8	10.7	3.9	8.5
22	Shizuoka-ken	3.66	2920	8.2	1.0	34.0	13.8	22.9	12.7	12.6	8.6	10.3	4.1	12.1	7.1	8.0	6.2	9.9	4.0	8.9
23	Aichi-ken	3.65	3496	7.4	1.0	37.8	18.3	22.4	14.7	13.6	10.4	8.8	4.3	12.1	7.2	7.6	6.0	10.5	4.2	8.1
24	Mie-ken	3.72	2777	7.3	0.5	40.7	16.4	20.8	13.6	12.9	10.0	7.9	3.6	14.0	6.1	7.6	5.2	11.2	4.1	9.1
25	Shiga-ken	3.55	2979	7.6	0.9	37.3	16.1	20.1	14.2	11.5	10.2	8.7	4.0	12.0	8.2	7.8	6.3	8.9	2.9	7.2
26	Kyoto-fu	3.41	2812	8.4	1.7	38.1	17.3	23.5	14.6	13.9	10.9	9.6	3.8	12.9	7.2	8.5	6.4	8.9	3.8	8.1
27	Osaka-fu	3.58	3346	11.3	1.6	43.2	16.7	26.0	14.4	16.4	10.4	9.6	4.0	12.1	7.6	7.9	6.3	10.8	4.3	7.8
28	Hyogo-ken	3.66	2776	11.2	1.6	42.4	15.9	23.6	13.3	14.1	8.6	9.5	4.7	12.6	7.8	7.2	5.6	10.4	4.4	6.9
29	Nara-ken	3.66	2709	7.5	1.1	46.1	15.3	20.4	13.2	13.1	10.0	7.3	3.2	13.2	6.6	7.7	4.8	8.8	3.3	9.5
30	Wakayama-ken	3.77	2182	8.6	1.5	45.7	18.0	23.7	14.0	14.5	9.4	9.1	4.6	11.5	9.9	8.0	5.0	7.6	4.2	8.1
31	Tottori-ken	3.44	2393	10.6	0.7	43.0	19.1	22.6	13.7	12.3	9.5	10.2	4.2	12.0	7.7	8.7	8.2	7.8	4.0	8.0
32	Shimane-ken	3.52	2202	10.5	1.0	40.7	14.5	26.0	13.0	14.8	8.4	11.2	4.6	13.8	8.4	7.1	4.8	7.5	2.6	8.2
33	Okayama-ken	3.69	2688	8.6	1.4	32.0	16.3	20.5	11.7	11.6	8.3	8.9	3.4	12.1	6.3	8.7	5.6	9.7	4.8	8.1
34	Hiroshima-ken	3.88	2893	8.1	1.0	36.2	14.1	23.0	12.2	14.8	8.5	8.2	3.6	10.7	6.5	7.6	4.7	9.3	3.7	9.0
35	Yamaguchi-ken	3.66	2532	9.9	1.6	37.6	16.8	21.4	12.7	14.6	8.3	6.8	4.4	11.8	7.2	8.1	6.5	9.1	4.0	9.0
36	Tokushima-ken	3.74	2440	8.4	1.1	37.0	12.6	21.7	11.9	11.9	7.9	9.8	4.0	9.5	7.2	7.2	7.1	9.9	3.3	6.7
37	Kagawa-ken	3.80	2582	6.6	1.1	37.5	17.2	18.4	11.6	10.9	8.1	7.5	3.5	13.7	6.9	7.4	6.6	10.5	3.2	9.2
38	Ehime-ken	3.80	2251	6.0	0.9	40.2	15.5	20.9	12.0	12.8	7.9	8.1	4.1	11.6	6.4	8.2	4.9	11.0	4.1	7.0
39	Kochi-ken	3.85	2051	9.2	0.5	35.0	13.9	18.8	10.8	10.9	8.0	7.8	2.8	11.9	7.5	8.2	6.0	9.4	3.5	6.2
40	Fukuoka-ken	3.54	2445	10.8	1.1	37.6	14.8	23.0	13.8	15.3	9.9	7.7	4.0	11.3	7.3	7.9	6.7	11.2	3.7	9.1
41	Saga-ken	3.62	2208	8.6	1.2	39.2	14.3	22.6	11.6	13.2	8.9	9.4	2.7	13.4	7.3	9.5	7.6	10.2	4.2	10.9
42	Nagasaki-ken	3.67	2060	10.1	1.1	37.3	16.0	24.2	11.4	14.1	7.3	10.1	4.1	11.7	7.1	9.2	7.1	11.0	3.7	8.3
43	Kumamoto-ken	3.72	2319	7.1	0.9	26.8	11.6	18.0	11.2	11.3	8.0	6.7	3.3	11.2	8.3	8.4	6.3	9.7	3.1	9.7
44	Oita-ken	3.61	2317	6.2	1.4	31.2	11.8	22.0	11.5	13.3	7.5	8.7	3.9	11.2	6.1	10.0	5.6	7.1	3.5	8.3
45	Miyazaki-ken	3.85	1996	11.4	0.9	33.5	12.9	18.9	13.7	10.8	9.1	8.1	4.6	13.4	6.0	9.7	5.9	8.4	3.6	11.6
46	Kagoshima-ken	3.69	2060	12.5	0.8	28.4	11.6	20.4	11.7	11.9	7.7	8.5	4.0	12.2	5.8	8.9	7.4	9.9	4.2	9.2
47	Okinawa-ken	4.01	1984	12.1	0.9	21.7	7.7	20.6	10.4	12.8	7.5	7.9	3.0	7.0	4.0	9.2	7.1	9.3	3.6	9.0

[a] Age-adjusted death rates by prefecture, Special Report on Vital Statistics 2000.
[b] Japan Meteorological Table (the mean average annual values during 1961–1990).
[c] Prefectural Economic Calculation (1990).

APPENDIX B1. Daily intake of selected foods or nutrients by district in Japan.

District number	Prefecture number[a]	Fat (g)[b]	Animal protein (g)[b]	Salt (g)[b]	Fish (g)[b]	Vitamin D (mg)[c]
1	01	56.7	44.2	12.7	50.1	11.4
2	02,03,04,05,06,07	57.1	41.5	13.5	49.6	10.9
3	11,12,13,14	59.5	42.3	12.5	40.7	8.5
4	08,09,10,19,20	55.5	39.9	13.6	40.4	10.2
5	15,16,17,18	56.8	39.5	12.8	45.2	8.4
6	21,22,23,24	55.9	39.8	12.1	40.1	7.8
7	26,27,28	57.5	42.6	11.8	39.3	8.4
8	25,29,30	57.5	43.6	13.4	42.9	9.5
9	31,32,33,34,35	56.6	41.8	12.5	48.0	7.3
10	36,37,38,39	55.6	42.4	12.3	44.0	7.7
11	40,41,42,44	54.7	39.5	11.6	42.6	6.2
12	43,45,46,47	53.5	40.8	13.0	55.8	6.5

[a] Refer to the first column of Appendix A1.
[b] The National Nutrition Survey in Japan 1990.
[c] The National Nutrition Survey in Japan 2000.