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Are health inequalities increasing in Japan? The trends of 1955 to 2000

Yoshiharu Fukuda*, Hiroyuki Nakao, Yuichiro Yahata, Hirohisa Imai

Department of Epidemiology, National Institute of Public Health, 2-3-6 Minami, Wako, Saitama, Japan.

SUMMARY **This study aimed to elucidate trends in socioeconomic inequalities in health during the past half century in Japan. Association of life expectancy and age-adjusted mortality with per capita income was examined using data on prefectures and municipalities in Japan of 1955 to 2000 via the slope index of inequality (SII) and Poisson regression. Although there were a few differences among health indicators and sex, health inequalities by prefecture, measured by the SII, decreased from 1955 to 1995. However, health inequalities increased from 1995 to 2000 both for life expectancy and mortality. Similar trends were found in municipal analyses: the association between income and mortality, measured by the rate ratio from Poisson regression, decreased until 1995 but increased from 1995 to 2000. In the past half century, and especially until 1995, geographical health inequalities decreased in Japan, while from 1995 to 2000 health inequalities appeared to increase. Recent social conditions including the possible increase in social inequalities may have contributed to this increase. Careful monitoring and elimination of social and health inequalities should be encouraged.**

Key Words: Health inequalities, socioeconomic factors, life expectancy, ecological study

Introduction

Elimination of health inequalities has been a great challenge in international and domestic public health policy. A large number of studies have demonstrated health inequalities attributable to socioeconomic conditions, including income, educational attainment, social class, and other factors (*1-4*). The degree of socioeconomic inequalities in society is closely linked to the health of the population (*5,6*).

Japan has shown marked improvement in the health of the population in the past half century. Major health indicators such as life expectancy and infant mortality have been ranked as some of the world's highest (*7*). In addition to economic growth and improved living standards, decreased socioeconomic inequalities and an egalitarian social system are considered to contribute to the health improvement of Japanese (*6,8-11*).

This egalitarian society, however, may be changing. Researchers in the fields of economics, sociology, and education are extremely concerned about increasing socioeconomic inequalities in Japan, and especially in the past decade (*12-14*). Although more discussion is needed, the social conditions underlying the increasing inequalities include economic recession and recent economic, taxation, and social security policies (*12-14*). Little is known about the influence of the possible increase in socioeconomic inequalities in health, leading to the question of if health inequalities are increasing in Japan.

This study elucidated the trends in health inequalities during the past half century in Japan. To this end, an ecological approach was taken at the prefectural and municipal levels to gather data in order to facilitate further debate on health inequalities.

Methods

Populations studied and observation period

The populations studied were prefectures and municipalities. These are basic administrative divisions in Japan: the prefecture is the higher level and consists of municipalities. There are currently 47 prefectures, an increase from 46 after 1972 with the reversion of

**Correspondence to:* Department of Epidemiology, National Institute of Public Health, 2-3-6 Minami, Wako, Saitama 351-0197, Japan;
e-mail: fukuday@niph.go.jp

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Table 1. Mean and coefficient of variance (CV) of per capita income, life expectancy, and age-adjusted mortality of 46 prefectures in Japan, 1955 to 2000

Year	Per capita income (thousand yen)		Life expectancy (years)				Age-adjusted mortality (per 100,000)			
			Men		Women		Men		Women	
	Mean	(CV)	Mean	(CV)	Mean	(CV)	Mean	(CV)	Mean	(CV)
1955	68.7	(22.0)	62.95	(2.03)	67.13	(1.93)	-		-	
1960	112.2	(26.6)	65.19	(1.66)	70.07	(1.37)	-		-	
1965	215.5	(23.4)	67.49	(1.44)	72.88	(1.01)	632.0	(9.31)	375.9	(6.37)
1970	495.4	(21.7)	69.41	(1.35)	75.05	(0.71)	566.7	(10.64)	321.8	(5.84)
1975	1019.1	(14.2)	71.44	(1.06)	76.84	(0.64)	459.1	(9.65)	255.0	(5.50)
1980	1575.0	(12.7)	73.34	(0.92)	78.92	(0.54)	402.0	(9.92)	206.2	(6.06)
1985	1960.9	(14.6)	74.82	(0.80)	80.73	(0.53)	365.2	(9.50)	176.6	(6.46)
1990	2634.7	(15.9)	75.96	(0.78)	82.10	(0.47)	335.5	(9.01)	155.2	(5.57)
1995	2865.5	(13.2)	76.66	(0.76)	83.30	(0.54)	319.9	(10.38)	148.9	(9.12)
2000	2867.6	(12.4)	77.62	(0.75)	84.70	(0.48)	297.7	(8.82)	135.6	(6.28)

CV = Standard deviation/Mean × 100

Okinawa Prefecture to Japan. Okinawa Prefecture was excluded from the current analyses to ensure comparability of time trends.

Municipalities include cities ("shi"), towns ("machi"), villages ("mura"), and wards ("ku"). The number of municipalities fluctuated and numbered almost 3350 during the observed periods because of mergers and dissolutions of municipalities.

The entire observation period was 1955 to 2000, but the analytical period depended upon variables because of limited data availability.

Data

Health indicators were life expectancy (LE) and mortality. In prefectural analyses, LE and age-adjusted mortality among populations aged 20 to 64 years were used. The data were obtained from the Prefectural Life Table and Vital Statistics (*15-18*).

In municipal analyses, the observed number of deaths was obtained from Vital Statistics (*19,20*) and aggregated in intervals of five consecutive years (1973-77, 1978-82, 1983-87, 1988-92, 1993-97, and 1998-2000). The expected number of deaths was estimated using the age-specific population of the municipality and age-specific mortality of the entire country (*19-21*). Analysed municipalities numbered 3346, 3348, 3356, 3346, 3361, and 3356, respectively, for the five observation periods.

Per capita income served as a socioeconomic indicator. Per capita income by prefecture and municipality was obtained from a published database (*21,22*).

Analyses

In prefectural analyses, the slope index of inequality (SII) served as a measure of the association between health indicators and income. The SII is estimated from the slope of the linear regression line between income ranking and health indicator and the mean of the health indicator (*23*). Since the SII is independent of absolute values of health and its predictive variables, it is useful for comparison of the magnitude of health inequalities, and especially for comparing time trends and different indicators (*23*).

First, the prefectures were ranked according to per capita income, and ranking values ranging from 0 (lowest income) to 1 (highest income) were assigned to prefectures. Then, the linear regression line was fitted with the health indicator as the dependent variable and the ranking value as the explanatory variable. The SII was estimated by dividing the slope by the mean of the heath indicators and presented as a percentage (× 100). The observation period was 1955 to 2000 for LE and 1965 to 2000 for mortality.

In municipal analyses, Poisson regression was used with the number of observed and expected deaths and per capita income, and the rate ratio (RR) of income for mortality was estimated. Two income variables were separately introduced. First, per capita income was introduced as a continuous variable (in units of a million yen). Second, an ordinal variable was used: the lowest decile = 0.05 to the highest decile = 0.95. The observation period was 1975 to 2000. Municipal per capita income in 1975 was not available, so that in 1980 was used for the 1975 analysis.

SPSS 15.0J was used for linear regression analysis and MLwiN 2.02 for Poisson regression analysis.

Results

Table 1 summarizes the health indicators and per capita income of 46 prefectures from 1955 to 2000. Income markedly increased, and especially until 1990, with narrowing of the variation in accordance with the coefficient of variance (CV). LE continuously increased with narrowing variation. Age-adjusted mortality continuously decreased but was not accompanied by narrowing variation.

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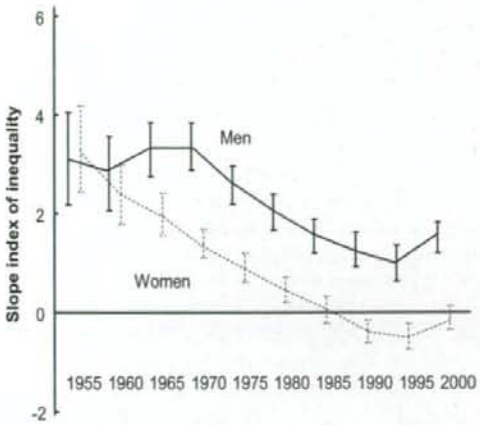

Figure 1. Slope index of inequality for income and life expectancy for 46 prefectures in Japan, 1955 to 2000. Vertical lines show the 95% confidence interval.

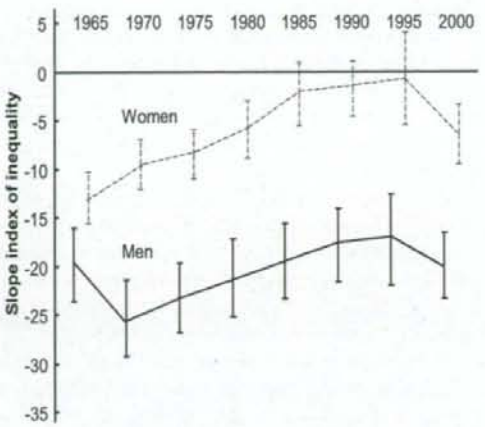

Figure 2. Slope index of inequality for income and age-adjusted mortality for 46 prefectures in Japan, 1965 to 2000. Vertical lines show the 95% confidence interval.

Figure 1 shows the SII for LE and per capita income in prefectural analyses from 1955 to 2000. A positive sign means that a prefecture with higher incomes had a longer LE. The SII decreased during 1955 to 1995 for women and during 1970 to 1995 for men. In contrast, the SII increased for both men and women from 1995 to 2000.

The SII for age-adjusted mortality and per capita income from 1965 to 2000 is shown in Figure 2. A negative sign means that a prefecture with higher incomes had a lower mortality rate. According to the SII, the association between income and mortality decreased until 1995 but increased from 1995 to 2000.

Table 2 shows the results of municipal analyses, demonstrating the RR of per capita income for mortality. An RR of less than 1.0 means that municipalities with higher incomes had a lower mortality rate. There were some differences in absolute values between continuous and categorical variables due to the different units, but the time trends were similar. The association between income and mortality decreased until 1995. For women in 1990 and 1995, the RR was more than 1.0, showing that municipalities with higher incomes had a higher mortality rate. From 1995 to 2000, RR increased in both men and women.

Discussion

This paper demonstrated the possibility of health inequalities increasing from 1995 to 2000 in Japan. An increase in health inequalities over the past few decades has been found in other industrial countries (*24-26*). The current findings offer the first suggestion of a recent increase in health inequalities in Japan.

Until 1995, the association between income and health indicators decreased, as shown in previous studies (*8,9,27*). The decrease in health inequalities was accompanied by significant LE extension and a decline in mortality. Possible contributors to the improved health of the Japanese population have been noted. An egalitarian social system and culture appears to contribute substantially through compulsory education, universal health insurance coverage, public health services, income adjustment policy, and strong social relationships (*6,8-10*). This is considered to be a good indication that fewer socioeconomic inequalities improve the health of the population (*6,11*).

The association of income and health indicators

Table 2. Results of poisson regression of per capita income and mortality by municipal level: rate ratio with 95% confidence interval

Year	Men		Women	
	Continuous[a]	Categorical[b]	Continuous[a]	Categorical[b]
1975	0.779 (0.766, 0.793)	0.861 (0.851, 0.872)	0.877 (0.861, 0.893)	0.945 (0.933, 0.958)
1980	0.855 (0.841, 0.870)	0.920 (0.909, 0.931)	0.938 (0.921, 0.955)	0.987 (0.975, 1.000)
1985	0.876 (0.865, 0.887)	0.913 (0.902, 0.924)	0.959 (0.946, 0.972)	0.998 (0.878, 1.134)
1990	0.950 (0.943, 0.957)	0.941 (0.940, 0.942)	1.004 (0.996, 1.012)	1.042 (1.030, 1.055)
1995	0.944 (0.936, 0.951)	0.935 (0.925, 0.945)	1.012 (1.003, 1.020)	1.035 (1.023, 1.048)
2000	0.886 (0.883, 0.889)	0.853 (0.849, 0.857)	0.975 (0.972, 0.979)	0.972 (0.967, 0.977)

[a]Per capita income was used as the continuous variable in units of a million yen.
[b]Per capita income was used as the ordinal variable: from the lowest decile of 0.05 to the highest decile of 0.95.

increased from 1995 to 2000. This increase was consistent regardless of different health indicators and different geographic levels for both men and women. The recent data invite several warnings about Japanese health status. LE of some occupational classes declined in the past few years (*28*). LE of all Japanese men also declined from 2004 to 2005 (*29*). This is not conclusive, but the increase in health inequalities may be linked to the deterioration of the health of the population.

Although the explanation for the possible increase in health inequalities in recent years is beyond the scope of this study, increasing socioeconomic inequalities are a potential contributor to increasing health inequalities. Some measures such as the Gini coefficient suggest a widening of income distribution in Japan (*14,30*). The economic recession after the collapse of the bubble economy in the early 1990s and the subsequent policies on economics, taxation, and social security might have contributed to increased socioeconomic inequalities (*12-14*). Crumbling of the lifetime employment system found in Japanese companies, the increase in unstable employment, and the increase in social security costs might have also accelerated worries about increasing socioeconomic inequalities (*12-14*).

The health care system in Japan is considered among the best in the world in terms of fairness of financial contribution, health outcomes, and other indicators (*31*). The system is believed to contribute to the healthy status of the Japanese population (*9*). However, recent figures suggest an increase in inequality in access to and use of health care in Japan. Geographic disproportions in health care, such as in the number of obstetricians, gynecologists and pediatricians, and cancer care resources are increasingly receiving attention (*32,33*). A previous ecological study showed that the lack of resources for maternal and child health is associated with higher infant mortality in Japan (*34*). Other studies have noted that the postgraduate medical training system and recent health policies, mainly in relation to the postgraduate medical training system and control of health care expenditures, might trigger geographic disproportions and widening inequalities in health care (*35*). In addition, an increasing number of people who cannot afford insurance premiums appears to be endangering universal health insurance coverage (*36*). Circumstances concerning health care may widen health inequalities and consequently threaten improvements in the health of the Japanese population.

Analyses of health inequalities often suffer from methodological problems. The selection of both health indicators and socioeconomic variables and methods of analyzing their association are critical (*37*). The findings of this study were obtained using sophisticated methods with reliable health and socioeconomic variables at two different levels. Nonetheless, a few limitations are acknowledged below.

First, the observation period is too short to conclude that health inequalities were increasing until 1995, and health inequalities should be continuously monitored. Second, another combination of health indicators and socioeconomic variables could demonstrate a different pattern from that of this study. More specified health indicators, such as cause-specific mortality, will elucidate more detailed situations including an explanation for increasing health inequalities. Area indicators representing socioeconomic conditions are critical in area-based analyses. Agreed-on area indicators have not been established in Japan, unlike in some countries where indicators such as deprivation indices have been applied (*38*). The development of area-based socioeconomic indicators is an urgent challenge for the study of health inequalities in Japan. Lastly, but of equal importance, ecological studies have methodological limitations, including confounding factors and the ecological fallacy (*39*). Nonetheless, geographical data can yield meaningful evidence on health inequalities, especially in the long term, since individual-level data are generally of limited use for such analyses (*40*). Further studies with individual-level analyses based on a system to monitor individual-level inequalities should be encouraged in order to provide more conclusive evidence.

In conclusion, this study showed a possible increase in socioeconomic inequalities in life expectancy and mortality from 1955 to 2000, following a decrease in inequalities from 1955 to 1995. Although conclusions should be carefully drawn from further studies and future monitoring, Japan's marked health improvement in the past half century may not enjoy an equal parallel in the future.

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Original Article

Different Income Information as an Indicator for Health Inequality among Japanese Adults

Yoshiharu Fukuda,[1] Hiroyuki Nakao,[1] and Hirohisa Imai.[1]

BACKGROUND: There are several alternative indicators of income information, which is a fundamental measure of individual socioeconomic position. In this study, we compared the degrees of associations of four types of income information with health variables among Japanese adults.
METHODS: Using a nationally representative sample of 29,446 men and 32,917 women aged 20 years and over, the associations between four income indicators and health variables were examined using the odds ratio in logistic regression analysis and the concentration index by sex and age group (20-59 years and 60+ years). Income indicators consisted of total household income, equivalent household income, total household expenditure, and equivalent household expenditure. Current smoking and self-rated health statuses were used as health variables.
RESULTS: A low income was associated with a high prevalence of smoking and fair/poor self-rated health, with some differences among sex and age groups and income indicators, but less difference among methods of statistical analyses. Total and equivalent incomes were similarly and more markedly associated with smoking and self-rated health statuses, whereas equivalent expenditure showed the smallest degree of health difference. For the population aged 60+ years, the degree of health differences in smoking was similar between income and expenditure.
CONCLUSIONS: Although the degree of income-related health differences is dependent on health outcome and both sex and age group, this study suggests that either crude or equivalent household income is a useful indicator for health inequality among Japanese adults.
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Key words: health inequality, income, self-rated health, smoking, socioeconomic factors.

Socioeconomic inequality in health is a major concern in public health.[1-3] Many epidemiologic studies have identified inequalities in mortality, morbidity, self-rated health, and health behavior according to individual socioeconomic position.[4-6]

Measurements of socioeconomic position are fundamental in studies of health inequality because socioeconomic factors feature both as key determinants of health and as critical confounding factors.[7-9] Income information is frequently used as a socioeconomic indicator, as well as indicators related to education and occupation.[7,10] There are several choices of measurements for income information. In addition to total household income, equivalent income, which is equivalized by household composition (number and/or age of household members), is generally used.[8,11,12] Some previous studies in Japan applied total household income,[13-17] whereas others applied equivalent household income.[18-22] Information regarding living expenditure or consumption is another alternative representing living standard, and has thus been used in previous studies of health inequality and public health.[23-26]

Although there is continuous debate about the usefulness of socioeconomic indicators,[27-29] no studies have evaluated different income information as an indicator for health inequality in Japan. In this study, we compared the degree of income-related health inequality among several indicators. The inequality was examined using different methods of statistical analyses and according to

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[1] Department of Epidemiology, National Institute of Public Health.
Address for correspondence: Yoshiharu Fukuda, Department of Epidemiology, National Institute of Public Health, 2-3-6 Minami, Wako, Saitama 351-0197, Japan. (E-mail fukuday@niph.go.jp)

sex and age group because there are several methods for determining health inequality,[8,30] and the degrees of associations between socioeconomic indicators and health variables vary according to both sex and age.[15,19,20,22] The income indicators were total household income, total household expenditure, and their equivalent values. We used current smoking and self-rated health statuses as health variables, because they were shown to strongly correlate with socioeconomic position in previous studies of the Japanese population.[14,20-22,31,32]

METHODS

Data Source

In this study, we used the 2001 Comprehensive Survey of the Living Conditions of People on Health and Welfare conducted by the Japanese Ministry of Health, Labour and Welfare. The survey comprised interviews with all household members in 5240 area units, sampled at random from all prefectures in Japan, and contained basic household and individual information such as demographics, health, and illness profiles. The total number of households sampled for basic information was 247,195, and 30,387 of these households were additionally interviewed about their income and savings.[33] Microdata files from the survey were used with official permission from the Ministry of Internal Affairs and Communication. We restricted our analyses to data of 29,227 households and their household members (29,446 men and 32,917 women) aged 20+ years whose income and health variables shown below were available.

Income Indicators

All households in the basic survey were interviewed regarding their monthly household expenditure. In the income and savings survey, the interviews included questions regarding annual household income before tax, including benefits and inheritance. In addition to the total household income and expenditure, we used equivalent income and expenditure to take into account differences in household size and composition. The total household income and total household expenditure were divided by the household's equivalent adult size, using the modified Organization for Economic Cooperation and Development (OECD) equivalent scale. This scale gave a weight to the first adult, 0.5 to the second and each subsequent person aged 14 years and over, and 0.3 to each child aged less than 14 years in the household.[11] The quintiles or decliles of the four income indicators were used in the following analyses.

Health Variables

Smoking status was surveyed using the following four categories: (1) I do not smoke; (2) I smoke every day; (3) I smoke occasionally; and (4) I have stopped smoking for more than one month. Subjects whose responses were (2) and (3) were categorized as current smokers, and (1) and (4) as noncurrent smokers. Self-rated health was determined as excellent, very good, good, fair, or poor. We formed a dichotomous variable of excellent/very good/good and fair/poor.

Analysis

We applied three approaches to determine the associations between income indicators and health variables.

First, the odds ratio (OR) with 95% confidence interval of current smoking and fair/poor self-rated health for the lowest income quintile compared with the highest income quintile was calculated using logistic regression analysis. Second, the ORs of current smoking and fair/poor self-rated health across income quintiles were calculated using logistic regression analysis with income quintiles as ordinal variables: the quintiles were assigned 0.1 (highest income), 0.3, 0.5, 0.7, and 0.9 (lowest income). This method was based on a linear trend relationship and the principle of the relative index of inequality, which can be interpreted as the odds ratio of smoking or fair/poor self-rated health for the bottom of the income hierarchy as compared with the top.[8,34] A multilevel model with individuals (level 1) nested within 47 prefectures (level 2) was used to take into account regional variation in income and health variables.[18,19] The iterative generalized least-square (IGLS) was fitted for estimation of OR with 95% confidence interval using MLwiN® 2.0.[35] Adjustment for age as a potential confounding factor was made in the above analyses.

Third, the concentration index was used.[30,36] It was defined with reference to the concentration curve, with the cumulative percentage of the sample ranked by income beginning with the poorest on the x-axis, and the cumulative percentage of the health variable corresponding to each cumulative percentage of the distribution of the income indicator on the y-axis. The concentration index was calculated as twice the area between the concentration curve and the line of equality (the 45° line running from the bottom left corner to the top right), ranging from –1.0 to 1.0. The index is zero in the absence of income-related inequality. We calculated the index using dectile categories of the income indicator.[36]

The analyses were conducted separately according to sex and age group because the relationship between socioeconomic indicators and health variables depends on sex and age.[15,19,20,22] The subjects were divided into those aged 20–59 years and those aged 60+ years, considering differences in social conditions such as employment status. Categorization of quintiles and dectiles was also conducted separately according to sex and age group.

RESULTS

Table 1 shows the proportions of current smokers and of the sample population with fair/poor self-rated health. Fifty percent of men and 12.4% of women were smokers, and 15.0% of men and 17.7% of women rated their health status as fair or poor. The younger group showed a higher proportion of smokers and a lower proportion with fair/poor self-rated health for both men and women.

Distributions of the four income indicators are shown in Table 2, showing percentiles and the Gini coefficient for the total 29,227 households included in this study. On the basis of the Gini coefficient, the total income showed the largest variation, followed by the equivalent income and the equivalent expenditure.

Table 3 shows the results of logistic regression analysis for the lowest-income quintile compared with the highest-income quintile according to different income indicators. The ORs were adjusted for age, which was significantly (p<0.05) associated with the smoking negatively and with fair/poor self-rated health positively. Household income showed the strongest association with the female smoking status, followed by the male self-rated health status. The group aged 20–59 years showed a higher OR than the group aged 60+ years, except for the male self-rated health status. The ORs of both health variables for the total and equivalent incomes were similar regardless of sex and age group. Although the OR of the smoking status for the total expenditure in the group aged 60+ years was similar to those for the total and equivalent incomes, the association of the smoking status with expenditure was generally weaker than that with income. The household expenditure for the female self-rated health status did not show a significant positive association.

Table 1. Proportions of current smokers and sample population with fair/poor self-rated health.

Age (year)	n	Current smoker (%)	Fair/poor self-rated health (%)
Male			
Total	29,446	14,699 (49.9%)	4407 (15.0%)
20-59	20,102	11,518 (57.3%)	2183 (10.9%)
60+	9344	3181 (34.0%)	2224 (23.8%)
Female			
Total	32,917	4083 (12.4%)	5828 (17.7%)
20-59	21,108	3388 (16.1%)	2633 (12.5%)
60+	11,809	695 (5.9%)	3195 (27.1%)

Table 2. Distribution of four income indicators (10,000 yen, 29,227 households).

Income-related indicator		Percentile					Gini coefficient
		5	25	50	75	95	
Household income (annual)	Total	90	267	486	800	1452	0.40
	Equivalent	66.7	166.0	262.7	395.2	720.0	0.36
Household expenditure (monthly)	Total	8	15	23	30	54	0.36
	Equivalent	5.0	9.3	12.5	16.7	30.0	0.34

Table 3. Odds ratios* (95% confidence intervals) of smoking and fair/poor self-rated health for lowest quintile compared with highest quintile, according to four income indicators.

Health variable	Sex	Age (year)	Household income		Household expenditure	
			Total	Equivalent	Total	Equivalent
Smoking	Male	20-59	1.31 (1.20-1.43)	1.36 (1.24-1.49)	1.01 (0.92-1.10)	1.02 (0.93-1.11)
		60+	1.24 (1.08-1.43)	1.26 (1.10-1.45)	1.33 (1.16-1.52)	1.36 (1.18-1.56)
	Female	20-59	2.84 (2.50-3.22)	2.29 (2.02-2.60)	1.63 (1.45-1.83)	1.15 (1.02-1.30)
		60+	1.98 (1.56-2.53)	1.88 (1.48-2.40)	1.71 (1.34-2.18)	1.25 (0.97-1.61)
Fair/poor self-rated health	Male	20-59	1.56 (1.35-1.79)	1.45 (1.26-1.66)	1.20 (1.05-1.37)	1.09 (0.95-1.25)
		60+	1.76 (1.51-2.05)	2.02 (1.72-2.37)	1.12 (0.97-1.30)	1.12 (0.96-1.31)
	Female	20-59	1.48 (1.30-1.69)	1.30 (1.14-1.48)	1.00 (0.88-1.13)	0.84 (0.74-0.96)
		60+	1.34 (1.18-1.52)	1.33 (1.17-1.52)	0.99 (0.87-1.12)	0.93 (0.82-1.07)

*: Adjusted for age

Table 4 shows the results of logistic regression analysis according to the ordinal variables of income indicators. The results of this analysis were similar to those shown in Table 3. The association of two health variables with household income was more pronounced than that with household expenditure, except for the smoking status in men aged 60+ years. The total and equivalent incomes showed similar positive associations, whereas the equivalent expenditure did not show a significant positive association with the smoking status or self-rated health status for a certain sex and some sex and age groups.

The concentration index of current smoking and fair/poor self-rated health according to different income indicators are shown in Table 5. A negative index indicates that current smoking or fair/poor self-rated health was likely to be concentrated in lower income categories. For male smokers, the absolute concentration indices were low, indicating modest inequality among male smokers. High absolute concentration indices were found among female smokers, particularly for the total income, followed by the equivalent income. For the self-rated health status, the concentration indices of the total and equivalent incomes were similar and markedly higher than those of the total and equivalent expenditure. For women, the total and equivalent expenditures showed inverse associations (positive concentration index) with health variables in some cases.

Table 4. Odds ratios* (95% confidence intervals) of smoking and fair/poor self-rated health according to ordinal variables of four income indicators.

Health variable	Sex	Age (year)	Household income		Household expenditure	
			Total	Equivalent	Total	Equivalent
Smoking	Male	20-59	1.44 (1.30-1.60)	1.49 (1.35-1.66)	1.02 (0.92-1.12)	1.05 (0.95-1.16)
		60+	1.25 (1.07-1.47)	1.34 (1.15-1.56)	1.36 (1.17-1.58)	1.42 (1.22-1.66)
	Female	20-59	3.82 (3.32-4.39)	2.96 (2.58-3.40)	1.72 (1.51-1.97)	0.99 (0.86-1.13)
		60+	2.63 (1.97-3.51)	2.31 (1.74-3.07)	2.01 (1.52-2.67)	1.33 (1.01-1.77)
Fair/poor self-rated health	Male	20-59	1.72 (1.47-2.02)	1.53 (1.30-1.79)	1.24 (1.07-1.45)	1.09 (0.93-1.27)
		60+	2.00 (1.68-2.38)	2.35 (1.98-2.80)	1.17 (0.99-1.39)	1.18 (1.00-1.40)
	Female	20-59	1.53 (1.32-1.77)	1.38 (1.19-1.60)	0.99 (0.85-1.14)	0.82 (0.71-0.95)
		60+	1.36 (1.17-1.57)	1.41 (1.22-1.64)	1.01 (0.87-1.17)	0.95 (0.82-1.11)

*: Adjusted for age

Table 5. Concentration index of smoking and fair/poor self-rated health according to four income indicators.

Health variable	Sex	Age (year)	Household income		Household expenditure	
			Total	Equivalent	Total	Equivalent
Smoking	Male	20-59	-0.030	-0.033	-0.006	-0.011
		60+	-0.013	-0.017	-0.021	-0.022
	Female	20-59	-0.181	-0.150	-0.083	-0.006
		60+	-0.136	-0.108	-0.084	-0.003
Fair/poor self-rated health	Male	20-59	-0.069	-0.047	-0.019	0.004
		60+	-0.094	-0.117	-0.033	-0.040
	Female	20-59	-0.052	-0.034	0.009	0.044
		60+	-0.031	-0.048	-0.003	-0.015

DISCUSSION

In this study, we compared the degree of associations of different income indicators with smoking status and self-rated health status in the Japanese population. Although there were slightly different patterns according to sex, age group, and health variables, the indicators of household income, either crude or equivalent, generally showed stronger associations than those of household expenditure. The equivalent household expenditure showed the weakest associations with the smoking and self-rated health statuses. The same findings were obtained regardless of the method of statistical analysis.

In addition to educational and occupational information, income is commonly used as a measurement of individual socioeconomic position in health inequality studies.[8-10] However, there are a few disadvantages in using income information. First, personal income is a delicate issue; thus, people may be reluctant to provide their actual income information.[7,8,37] Second, additional information on household members is required to obtain equivalent income for comparability across households. Compared with income, household expenditure is easier to acquire and provides a better representation of current living standards and material wealth than household income.[23] Therefore, household expenditure has been used in a number of national surveys, including the basic survey used in this study,[33] in addition to individual epidemiologic studies.[24-26]

The results of this study indicated that household income, either total or equivalized by the composition of household members, is more sensitive to health inequality than household expenditure. Regarding household expenditure, the total expenditure showed weak but significant associations with both smoking and self-rated health statuses, whereas the equivalent expenditure did not show clear associations. Thus, when household expenditure is used as income information, the total, not equivalent, expenditure appears to be suitable. The use of less sensitive indicators such as equivalent expenditure will underestimate health inequality.

The reason why the association of health variables with household income was stronger than that with household expenditure was not determined in this study. It is possible that household income reflects other socioeconomic factors, including educational attainment, occupational status, and socioeconomic position, throughout the course of a person's life more closely than household expenditure. The more pronounced health status differences according to household income are probably due to the effect of other socioeconomic factors as reflected by household income.

The strengths of this study include the use of both household income and expenditure of a large study sample from across the country. In addition, we applied two different health variables and different established methods of statistical analyses to identify health inequality.[8,20,34] Similar patterns of differences according to income information were found regardless of the method used for statistical analysis.

This study has several limitations. First, income information was self-reported. Information about household income was obtained by interview using detailed items; thus, it might be more reliable than expenditure information. This fact may partly explain the stronger association between income and health variables.

Second, only two health variables were used, namely, smoking and self-rated health statuses, which are the most common variables strongly associated with socioeconomic indicators.[13-15,19-22,31,32] It is possible that other health variables show degrees of association with income indicators different from those in this study.

Third, it is not clear whether the results of this study can be generalized to other populations, particularly those in other countries. Although health inequality has been demonstrated in most countries, the pattern of inequality differs between countries.[34,38-41] Differences in the meaning of income and expenditure, and the structure and size of the household between countries possibly result in variations in income-related health inequality.

Finally, important confounding factors might not be considered; thus, we were not able to identify independent effects of income. Indicators of education and occupation are generally associated with smoking and self-rated health statuses.[13,14,22,31,39,40] Social conditions such as marital status, living arrangement, and social support might be critical for both smoking and self-rated health statuses.[20,21,42,43] On the basis of our present findings, the independent and interactive associations of income and other socioeconomic indicators with health variables need to be examined in future studies.

In conclusion, results of this study suggest that income-related differences in smoking and self-rated health statuses can be detected using household income, either the total or equivalent, more sensitively than using household expenditure. The notably good health status of the Japanese population may be attributable to a small degree of socioeconomic disparities.[44,45] Nevertheless, recent studies demonstrated substantial differences in health status according to the individual socioeconomic position in Japan.[13-16,19-22,31,32,46,47] The findings of this study will contribute to future analysis and debate on health inequality among the Japanese population.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

In-depth descriptive analysis of trends in prevalence of long-term care in Japan

Yoshiharu Fukuda,[1,2] Hiroyuki Nakao,[1] Yuichiro Yahata[1] and Hirohisa Imai[1]

[1]*Department of Epidemiology, National Institute of Public Health, Wako, Saitama and* [2]*Department of Community Health and Medicine, Yamaguchi University School of Medicine, Ube, Yamaguchi, Japan*

Background: Long-term care (LTC) insurance was introduced in Japan in 2000. Herein, we describe the trends in demand for LTC, using age-standardized and level-specific rates of entitlement and utilization of LTC at national and prefectural levels.

Methods: We analyzed LTC data from 2002–2005 to examine: (i) the influence of population aging, calculating crude and age-standardized entitlement and utilization rates; (ii) the relation between baseline entitlement rate and increase in the rate over this 3-year period; and (iii) differences in increases in entitlement rate between low and high care levels.

Results: The entitlement and utilization rates increased even after adjustment for age; approximately two-thirds of the increase was not due to population aging. Variations in the entitlement rates among prefectures did not decrease (coefficient of variance was 0.12 in 2002 and 0.11 in 2005), and there was no significant correlation between baseline entitlement rates and the later increases among prefectures ($r = -0.20$, $P = 0.19$). The increase in entitlement rate was larger for low than for high care levels (31% vs 6%), and those for low and high care levels were weakly correlated.

Conclusion: This study suggested that a large part of the increase in LTC demand could not be explained by population aging, and the increase did not result from equalization of LTC services across the country. In addition, it seems that the demands of low and high care levels depend on different factors. The increase in LTC demand should be monitored carefully to identify underlying factors and to ensure sustainability of the system.

Keywords: aged, descriptive epidemiology, health policy, long-term care.

Introduction

Japan has the highest rate of population aging worldwide, with the percentage of elderly people (≥65 years) being 19.5% in 2004 and expected to reach 35.7% by 2050.[1] Long-term care (LTC) insurance was introduced in 2000 for the elderly requiring nursing care in Japan. This system, which includes certification procedures, criteria of certification, benefit services and fee schedules, is universal across the country, with people aged 40 years and over having compulsory insurance. People aged 65 years or over who require sustained nursing care, and those aged 40–64 years with 15 specified diseases, are eligible for LTC under this scheme.[1]

The number of those certified as requiring care services and receiving insurance benefits has increased steadily in Japan since the introduction of LTC insurance. According to the Ministry of Health, Labor and Welfare, the number of certified people increased from 1.49 million in April 2000 to 2.97 million in April 2004.[2] The increases in LTC demand will result in an increased cost to society, and it is therefore necessary to carefully explore the factors associated with the increased demands.

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Correspondence: Yoshiharu Fukuda, MD, PhD, Department of Community Health and Medicine, Yamaguchi University School of Medicine, 1-1-1 Minami-kogushi, Ube, Yamaguchi, 755-8505, Japan. Email: fukuday@yamaguchi-u.ac.jp

The needs and utilization of health and welfare services are dependent on various factors, such as demographic features, sociocultural context and other factors.[3–7] At the individual level, socioeconomic factors, such as income and family context, are critical factors associated with needs and utilization of medical and nursing care.[8–12] Despite the large number of studies on the factors associated with increased health-care needs and health expenditure, little is known about the factors associated with increases in LTC demand.

The present study was performed to examine the following three hypotheses for the increase in LTC demand in Japan:

1 Population aging: the increase in LTC demand may be due to the increase in number of elderly people and population aging.
2 Equalization of services: the services of LTC insurance may have had an inhomogeneous distribution, especially among different regions. Thus, the increase in LTC demand may be a process of the equalization and diffusion of LTC services.
3 Decrease in health level: the health level of the elderly population may have deteriorated, and the number of elderly patients with disabilities and need for nursing care may have increased.

To determine whether these hypotheses can explain the observed increases in LTC demand, we performed a detailed analysis of the data of LTC insurance, including the rates of people certified as requiring LTC (entitlement rate) and of people using LTC insurance benefits (utilization rate). In this study, we examined the influence of population aging by comparing crude and age-standardized rates, the relations between baseline rates and the observed increases, and difference in the rate increase between low and high care levels.

Methods

Data sources

The LTC insurance data from 2001–2005 were taken from the database of the Ministry of Health, Labor and Welfare.[13] The prefecture-specific data regarding the numbers of certified people and of those receiving LTC insurance services divided by sex and age group (5-year intervals) and care level were reported monthly beginning in May 2002. Prior to May 2002, only national data by age group and care level were available.

National population data were based on the estimated population obtained from the Statistics Bureau, the Ministry of Internal Affairs and Communications.[14,15] The prefecture-specific populations in March 2002 and 2005 were based on the residential registration records, and data by sex and age group (5-year intervals) were obtained from the Ministry of Internal Affairs and Communications.[14,15] Age standardization of entitlement and utilization rates was conducted using the national population of 2002.

Although the LTC insurance data included those for people aged 64 years and under, certified people and those receiving LTC insurance services in this age group comprised only approximately 5% of the total number.[13] Therefore, this study was restricted to the data for people aged 65 years and over.

Influence of population aging determined by comparison between crude and age-adjusted rates

To classify the increase in number of certified people into two portions that were attributed to population aging and that were not attributed to population aging, we calculated the expected number of certified people using the following formula:

$$\sum(\text{entitlement rate of age-category } i \text{ in } 2002) \times (\text{population of age-category } i \text{ in year } x).$$

The difference between the expected number in year x and the number of certified people in 2002 was assumed to be the proportion of the increase due to population aging. Conversely, the difference between the expected number and actual number of certified people in year x was assumed to be the proportion of the increase not due to population aging.

Relation between baseline rate and rate increase

To determine the influence of the equalization of services on the increase in LTC demand, we examined: (i) coefficient of variance (CV = standard deviation/mean) of the entitlement rates in 2002 and 2005; and (ii) the relationship between the prefecture-specific entitlement rate in 2002 (baseline rate) and the increase in entitlement rate from 2002 to 2005. The former analysis was performed to determine the change in variation: equalization of the LTC services might lead to a decline in CV. The latter analysis was based on the hypothesis that prefectures with a lower baseline rate showed the greater increase, as regional differences in the rate were lessening due to equalization of services.

Difference in rate increase between low and high care levels

We compared the increase in entitlement rate among care levels. LTC insurance specifies six care levels, comprised of "support" (least severe disability) and "levels I–V" in order of increasing disability.

First, the dimensions of the entitlement rates by care levels were examined by principle component analysis (PCA). PCA with varimax rotation was conducted for prefecture-specific rates by care levels in 2002 and 2005,

Table 1 Results of principle component analysis for entitlement rates by care levels for 2002 and 2005

Care level	2002		2005	
	Component 1	Component 2	Component 1	Component 2
Support (least severe)	−0.02	0.97	−0.16	0.90
Level I	0.32	0.92	0.37	0.85
Level II	0.87	0.32	0.80	0.48
Level III	0.90	0.12	0.88	0.24
Level IV	0.89	0.16	0.94	0.00
Level V (most severe)	0.74	−0.03	0.75	−0.10

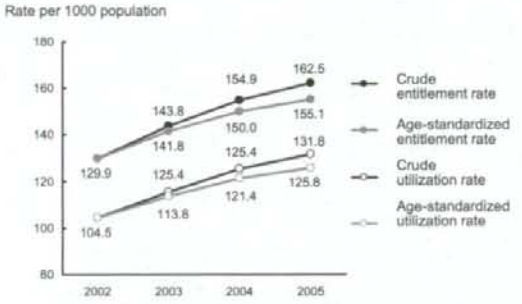

Figure 1 Trends in crude and age-adjusted entitlement and utilization rates of long-term care in Japan from 2002 to 2005. Age standardization was conducted using the 2002 population, and thus the crude and age-standardized rates in 2002 were equal.

and the results are shown in Table 1. Two components were obtained for both years: low care level and high care level. Based on the results of PCA, we calculated two aggregated rates of "support to level I" and "levels II–V".

The increases in aggregated rates from 2002 to 2005 were then estimated, and the Spearman's correlation coefficient between these increases was calculated. The increases in age-standardized entitlement rates of low and high care levels from 2002 to 2005 were compared using rate differences and rate ratios with paired Student's *t*-tests. Statistical analyses were performed using SPSS ver. 15.0J (SPSS Software, Chicago, IL, USA).

Results

The trends in crude and age-standardized entitlement and utilization rates are shown in Figure 1. Both age-standardized entitlement and utilization rates increased steadily from 2002 to 2005, as did the crude rates. Table 2 shows care level-specific data for 2002 and 2005.

Figure 2 shows the trend in number of certified people from 2002 to 2005, in which the increase was

Table 2 Numbers and age-standardized rates of those certified as requiring long-term care (entitlement) and receiving insurance benefits (utilization) by care levels among the aged over 65 years in 2002 and 2005 in Japan

	2002		2005	
	Number (thousand)	†Rate (/1000)	Number (thousand)	Rate† (/1000)
Entitlement				
All levels	3070	129.9	4112	155.1
Support	420	18.2	684	26.1
Level I	909	39.4	1324	50.4
Level II	566	24.5	605	23.0
Level III	394	17.1	528	20.0
Level IV	397	17.2	502	19.0
Level V	384	16.7	468	17.7
Utilization				
All levels	2469	104.5	3338	125.8
Support	280	12.1	548	17.4
Level I	705	30.6	1059	40.2
Level II	472	20.4	523	19.9
Level III	342	14.8	466	17.7
Level IV	347	15.0	445	16.8
Level V	322	14.0	388	14.7

†Age-standardization of the rates was conducted using the national population of 2002.

classified into the proportions that were and were not due to population aging. The proportion due to population aging was 39.9% of the total increase from 2002 to 2005.

As an indicator of the variance, the CV of the entitlement rates among 47 prefectures changed from 0.12 in 2002 to 0.11 in 2005. The relationship between the entitlement rate in 2002 and its increase from 2002 to 2005 in 47 prefectures is shown in Figure 3. Prefecture A (Okinawa) had the highest rate in 2002, which then declined over the subsequent 3 years. The Spearman's correlation coefficient between two variables was −0.196 ($P = 0.19$).

Figure 4 summarizes the age-standardized entitlement rates by care level in 47 prefectures in 2002 and

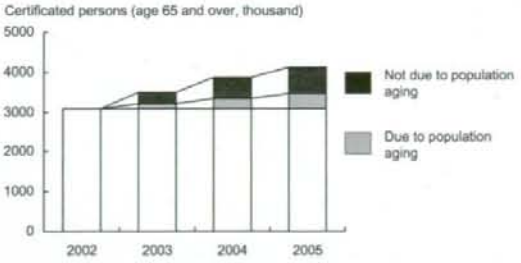

Figure 2 Trends in number of certified people, and classification into proportions that were and were not due to population aging from 2002 to 2005. The portion due to population aging was estimated using age-specific entitlement rates from 2002 and the population from 2003 to 2005.

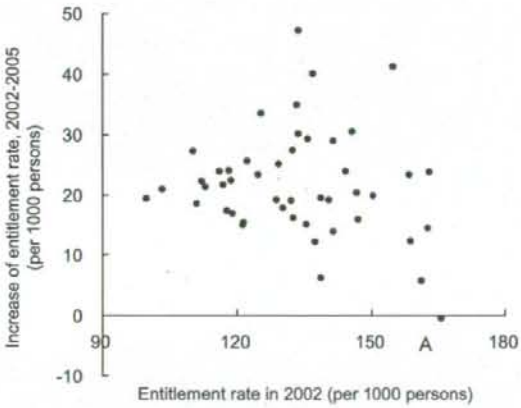

Figure 3 Relationship between entitlement rate in 2002 and rate increase from 2002 to 2005 in 47 prefectures in Japan.

2005, showing the average and spread. With the exception of level II, all levels showed statistically significant increases. Table 3 shows the age-standardized entitlement rates in 2002 and 2005 in 47 prefectures and their rate differences and rate ratios according to care level (low and high levels). The rate difference and rate ratio for low care levels (support and level I) were significantly larger than those for high care levels (level II–V).

The relations between rate increases in low and high care levels are shown in Figure 5. The variables showed a significant correlation (Spearman's coefficient = 0.34, $P = 0.02$). Prefecture A (Okinawa) showed little increase in low or high level entitlement rates, while B (Nagasaki) and C (Akita) showed large increases in both levels. If these three cases are excluded, the correlation among 44 prefectures was weak and not significant (Spearman's coefficient = 0.20, $P = 0.20$).

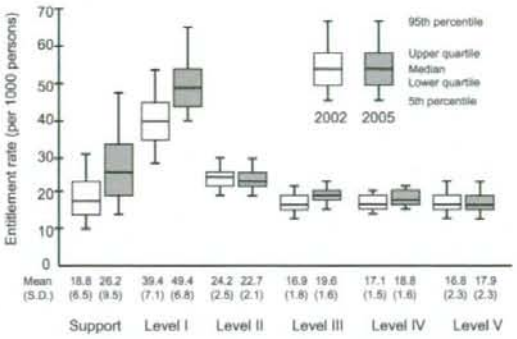

Figure 4 Changes in age-standardized entitlement rates by care level in 47 prefectures from 2002 to 2005.

Discussion

The increase in number of elderly people requiring LTC and the associated costs of these services are imposing an increasing burden on Japanese society. The Ministry of Health, Labor and Welfare estimated that the number of elderly people requiring LTC will increase from 1.5 million in 2000 to 5.2 million by 2025.[16] This increase in LTC demand will jeopardize not only LTC insurance but also Japanese society itself.

However, if the increase in number of elderly people requiring LTC services is the result of population aging, society should bear these costs. On the other hand, increases due to other factors, including socioeconomic context, may be preventable by various means. There has been a marked increase in medical care expenditure in Japan since the introduction of the medical care service system for the elderly in the 1970s.[17] This expanding health expenditure has had a deleterious effect on Japanese society. Detailed discussion from this viewpoint will aid in policy decisions and may slow or reverse the increase in LTC demand.

The present study was performed to examine three possible explanations for the increase in number of people certified to receive care under the LTC insurance program. However, our findings refuted the validity of these postulated explanations.

First, although the influence of population aging on the increase in LTC demand was substantial, it could not be sufficiently explained by this mechanism: approximately two-thirds of the increase could not be explained by the effect of population aging.

Second, the increase in LTC demand was unlikely to be due to equalization of geographical variations. One prefecture, Okinawa (A in Fig. 3), showed a decline in entitlement rate in the context of the highest rate at baseline. However, for the country as a whole, the baseline rate (in 2002) was not related to further increases

Table 3 Comparisons of rate difference and rate ratio of age-standardized entitlement rate in 2002 and 2005 in 47 prefectures

Indicator	Care level		*P*-value
	Low (support and level I)	High (level II–V)	
Rate of 2002 (/1000)	58.2 ± 13.0	75.1 ± 6.8	
Rate of 2005 (/1000)	75.6 ± 14.6	79.3 ± 6.6	
†Rate difference (/1000)	17.4 ± 6.7	4.2 ± 3.4	<0.001
‡Rate ratio	1.31 ± 0.12	1.06 ± 0.05	<0.001

Figures represent means ± SD. Age-standardization was conducted using the national population in 2002. *P*-values were estimated by paired Student's *t*-test. †Rate difference = (rate of 2005) − (rate of 2002). ‡Rate ratio = (rate of 2005)/(rate of 2002).

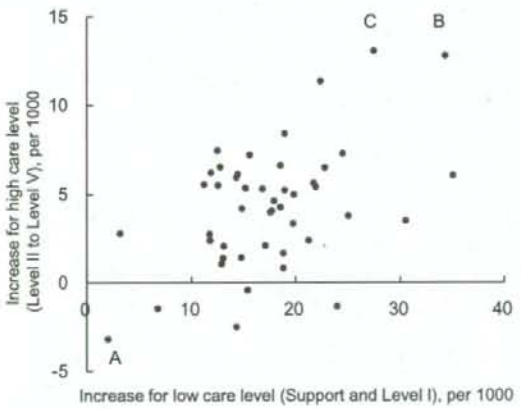

Figure 5 Relationship between increases in age-standardized entitlement rates of low care level ("support and level I") and high care level ("level II–V") from 2002 to 2005. The Spearman's correlation coefficient is 0.34 ($P = 0.02$) for all cases and 0.20 ($P = 0.20$) when A, B and C are excluded.

(from 2002 to 2005) in the entitlement rate, and the geographical variation did not diminish (CV was 0.12 and 0.11 in 2002 and 2005, respectively).

The third possible explanation for the increase in LTC demand, that it is dependent on a general deterioration in the health of the elderly population, was not supported by the data. If the general deterioration increased LTC demand, entitlement and utilization rates would increase across all care levels or for the high care level to a greater extent than the low care level. Our analysis of national level data showed the opposite findings. In analysis of the prefectural level data, Figure 4 and Table 3 show that the increase in entitlement rate for low care level was larger than that for high care level, and that the increases in low and high care levels did not increase in parallel. However, a few prefectures (e.g. B and C in Fig. 4) showed notable increases in both care levels. Further detailed studies of these cases will elucidate the factors contributing to LTC demand that are unique to selected cases and that are common throughout the country.

Another possible explanation for the increase in LTC demand is the transition from medical care services to LTC services. Governmental policy has been attempting to control national medical expenditure, and increases in national medical expenditure slowed down after the introduction of LTC insurance.[1] Medical expenditure for the elderly decreased from 1999 to 2001, with Okinawa prefecture, which had the highest entitlement rate, showing the most marked decrease in medical expenditure.[18] Further studies are needed to determine the relationship between the decrease in medical expenditure and the increase in LTC demand, and the social advantages of the transition from medical to nursing care.

As one of the limitations of this study, we did not explore the relationships between LTC demand and possible correlates, such as socioeconomic and cultural factors. Several previous studies addressing geographical differences suggested that socioeconomic factors are related not only to health indicators but also to health service utilization.[3-6,19-22] Such approaches will aid in determining possible factors related to the increase in LTC entitlement rate. Interestingly, the results of the present study indicated a larger increase in the age-standardized entitlement rate in the low care level as compared to that in the high care level. This finding implies that there are some specific factors underlying of the increase in low care level (support and level I), including socioeconomic and cultural factors.

The effects of economic factors should also be acknowledged. It has been reported that most institutions and businesses related to LTC face difficulties in their operation.[23] Most such care facilities employ care managers, who should be neutral with regard to care recipients and providers, to facilitate better running, and it appears that these facilities attempt to restrict the recipients of their services.[23,24] As care workers in LTC receive insufficient rewards for their efforts, there is a

high turnover rate with such workers frequently leaving their jobs.[23] Although the relationships between the economic and labor situation and increases in LTC demand are not clear, stable management of LTC, including good running of the relevant facilities and high job satisfaction among care workers, is required for sustainability of the LTC system.

In conclusion, we examined the influence of population aging, equalization of services and decreases in health level as possible explanations for the recent increases in LTC demand in Japan. The results refuted the possibility that these factors were responsible for the observed changes, and thus the increases in LTC demand during the study period could not be explained. The results of this study in which we applied simple epidemiological methods to routinely collected data regarding long-term care may have implications for future health policy.

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Original Article

Multilevel analysis of solar radiation and cancer mortality using ecological data in Japan

Yoshiharu Fukuda[1,*], Tomoki Nakaya[2], Hiroyuki Nakao[3], Yuichiro Yahata[3], Hirohisa Imai[3]

[1] *Department of Community Health and Medicine, Yamaguchi University School of Medicine, Ube, Yamaguchi, Japan;*
[2] *Department of Geography, Ritsumeikan University, Kyoto, Japan;*
[3] *Department of Epidemiology, National Institute of Public Health, Wako, Saitama, Japan.*

Summary **A preventive effect of solar radiation on cancer has been suspected. This study aimed to compare the statistical relationship between solar radiation and cancer mortality according to hierarchical models and adjustment for confounding factors, and then to demonstrate the relationship with main site-specific cancer mortalities in Japan. We examined the relationship between all-site and main site-specific cancer mortalities and global solar radiation using Poisson regression with municipal data around 2000. The models included single-level (municipality) and multilevel (municipality and prefecture) with/without potential confounding factors (lifestyle and socioeconomic variables). For all-site cancer, single-level analysis showed a significant, strong negative association with solar radiation. However, multilevel analysis showed a moderate or no association. In multilevel analysis with potential confounding factors, solar radiation was significantly negatively associated with most site-specific cancers, but not with gallbladder and liver cancer in men and stomach and breast cancer in women. Our findings support the preventive effective of solar radiation on several types of cancer. However, to show a concrete relationship, a statistical model with an appropriate hierarchy and adjustment for potential confounding factors is required.**

Keywords: Malignant neoplasm, Solar radiation, Vitamin D, Multilevel analysis, Ecological study

1. Introduction

The influence of solar radiation on cancer has recently received attention (*1*). Some epidemiological studies have suggested a preventive effect of solar radiation on several types of cancer, such as colonic (*2-4*), breast (*5,6*), lung (*7,8*), pancreatic (*9,10*), prostatic (*11*), and ovarian cancer (*12*). In addition to epidemiological studies in western countries, a few studies in Asian countries including Japan (*13-15*) support the protective effect of solar radiation against cancer.

Investigation of the relation between solar radiation and cancer mortality predominantly depends on ecological studies, since individual-level exposure to solar radiation is difficult to measure (*16,17*). Ecological studies, however, have several critical weaknesses in providing causal evidence, including confounding and ecological fallacy (*18*). Waltz and Chodick suggested that the association of solar radiation with cancer mortality resulted from confounding effects caused by ecological study design (*19*). In Japan, prefectural-level analysis has a small unit size (n = 47), and thus, possible confounders might not be sufficiently considered. Municipal-level analysis with a large number of units (about 2,000) can deal with several possible confounders, although some kinds of important data such as life-style related variables are not available. There has been little discussion to compare results among different study designs and to elucidate which study design is suitable to detect the true relationship between solar radiation and cancer mortality.

Multilevel analysis has been used for various public

*Correspondence to: Dr. Yoshiharu Fukuda, Department of Community Health and Medicine, Yamaguchi University School of Medicine, 1-1-1 Minamikoguchi, Ube, Yamaguchi 755-8505, Japan;
e-mail: fukuday@yamguchi-u.ac.jp

health and epidemiological studies (*20,21*). It detects the influence of hierarchical levels (*e.g.*, individual and neighborhood levels) and their interaction. Multilevel analysis can also be applied to not only individual data but also ecological data (*20,22,23*). However, it is not clear whether multi-level analysis demonstrates different and more valid evidence than single-level analysis.

This study compared the results of different types of ecological studies, including single-level and multilevel models with and without adjustment for possible confounding variables, on the relationship between solar radiation and cancer mortality in Japan. In addition, its relationship with major sites of cancer was examined using multilevel ecological analysis.

2. Methods

2.1. *Data*

The unit of analysis was basically municipalities: cities, towns, villages, and wards ("ku") of several designated cities. In 2002, there were 3,000 municipalities in Japan. The local governments of Japan have two hierarchical systems: prefectures and municipalities. There are 47 prefectures, which consist of a few tens of municipalities.

Mortality was based on deaths from 1998 to 2002 (*24*). The expected number of deaths in municipalities was estimated using the sex-age (five-year interval)-specific population and the national mortality rate in 2002. We estimated empirical Bayes estimates of local standardized mortality ratio (EBSMR) from all-site cancer of municipalities using maximum likelihood method of Poisson-Gamma model with the secondary medical care zones as groups of municipalities to estimate empirical prior distribution (*22,23,25*). The estimation of EBSMR was conducted by a window based program developed by Nakaya (*26*).

The data on solar radiation for this study were constructed as population-weighted mean annual global solar radiation of municipalities (MJ/m^2). According to the Standard Grid Square (*27*), the population as of 2000 based on the national population census and climate summary statistics including annual mean solar radiation during the period of 1971-2000 were compiled as grid square statistics based on a small square unit defined as 30" latitude × 45" longitude (approximately 1 square kilometer). Overlaying these gridded data with a municipality zoning layer, we calculated the population-weighted average value of global solar radiation for each municipality in a GIS environment. The original gridded data of 30-year mean climate summaries are provided as Mesh Climatic Data 2000 (*28*) in which the amount of global solar radiation was computed by the gridded duration of sunshine, which was interpolated by applying a multiple regression technique to the records of meteorological stations with elevation and urban indices. It should also be noted that adjustment for the effect of elevation, that is, shadowing of land features, was made for computing the gridded data of global solar radiation.

We used socioeconomic and lifestyle data as potential confounding factors. Since municipality-level data of dietary and nutritional intake were not available, we used prefecture-level data of these variables (*29*). Using principle component analysis with eighteen items of dietary consumption (*e.g.*, rice, potato, beans, fruit and green vegetables, and egg) (*30*), we drew five components and thus we used the factor scores of these components. An additional lifestyle variable was smoking rate, which was obtained from the Comprehensive Survey of the Living Conditions of People on Health and Welfare ("Kokuminseikatu Kiso Chosa") in 2004 conducted by the Japanese Ministry of Health, Labour and Welfare (*31*). The socioeconomic variables consisted of per capita income, unemployment rate, and population density, which were municipality-level data. Previous studies have demonstrated a strong relationship between these factors and all-cause and main leading causes of death in Japan (*22,23*).

2.2. *Analysis*

The relationship between mortality and solar radiation was evaluated by Poisson regression analysis, which is described in previous studies (*22,23*). We used the following six models: Model 1 was single-level (municipality) analysis without adjustment; Model 2 was single-level analysis with adjustment for socioeconomic variables; Model 3 was single-level analysis with adjustment for socioeconomic and municipal variables; Model 4 was multilevel (municipality and prefecture) analysis without adjustment; Model 5 was multilevel analysis with adjustment for socioeconomic variables; and Model 6 was multilevel analysis with adjustment for prefectural and municipal data.

The equation for Poisson regression was as follows; O_{ij} is the observed death number, E_{ij} expected death number, x_{nj} a variable of a potential confounder of j prefecture, x_{nij} that of i municipality in j prefecture, and u is a random effect among prefectures.

Single-level:

$$\log(O_{ij}) = \log(E_{ij}) + \beta_0 + \beta_{1r}x_{1j} + \ldots + \beta_{nr}x_j + \beta_{1r}x_{1ij} + \ldots + \beta_{nr}x_{nij}$$

Multilevel:

$$\log(O_{ij}) = \log(E_{ij}) + \beta_0 + u_j + \beta_{1r}x_{1j} + \ldots + \beta_{nr}x_{ij} + \beta_{1r}x_{1ij} + \ldots + \beta_{nr}x_{nij}$$

We used SPSS 15.0J (Chicago, SPSS Inc.) for principle component analysis and MLwiN 2.0 (London,