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Cause-specific mortality differences across socioeconomic position of municipalities in Japan, 1973–1977 and 1993–1998: increased importance of injury and suicide in inequality for ages under 75

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Background Socioeconomic inequality in health has been a major concern in public health. This study examined socioeconomic inequality in regional mortality and the impact on inequality by cause of deaths in 1973–1977 and 1993–1998 using municipal statistics in Japan.

Methods The municipalities across the country (N = 3244 in 1973–1977 and 3334 in 1993–1998) were classified into quintiles according to the index of socioeconomic position (SEP) obtained by principal component analysis of municipal indicators related to income and education. Mortality gradient by SEP for selected major causes of death in the population aged 0–74 years was examined using standardized mortality ratio by quintile and rate ratio of mortality across quintiles. As a measure of cause-specific impact on inequality, the number of excess deaths from each cause in the lower four SEP quintiles compared with the highest quintile was calculated.

Results Mortality gradient by SEP and excess deaths in the lower SEP quintiles due to injury and suicide markedly increased from 1973–1977 to 1993–1998 for both males and females. In contrast, stroke, especially cerebral haemorrhage, showed a decrease in mortality gradient and excess deaths. For females in 1993–1998, a negative gradient of mortality by SEP was found, and cancer contributed the higher all-cause mortality in the higher SEP quintile.

Conclusions The relative importance of socioeconomic inequality in regional mortality of stroke decreased, while that of injury and suicide increased. The prevention of injury and suicide, in addition to stroke, in socioeconomically disadvantaged regions, and cancer in urban areas with higher SEP should be given priority.

Keywords Socioeconomic factors, small-area study, cause-specific mortality, health inequality, Japan

Regional variation in health levels has been demonstrated between and within countries.[1–4] The variation is closely linked to the socioeconomic conditions of the residential area, and people living in socioeconomically disadvantaged areas commonly show a poorer health status.[5] This study addressed the variation of mortality among regions according to their socioeconomic position (SEP); that is, socioeconomic inequality in regional mortality.

In Japan, previous studies have revealed substantial regional variation in health levels among administrative units, and the variation was strongly related to area socioeconomic indicators.[6,7] The following study in Japan showed higher

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all-cause mortality in areas of lower SEP, and males showed a stronger association between mortality and SEP than females.[8] In addition, the trends demonstrated a change in the impact of socioeconomic factors, with a significant decrease in excess mortality in municipalities with lower income and educational level over time.[8]

It was confirmed by previous studies that the association between mortality and socioeconomic conditions differ according to the cause of death in Western countries.[9–11] In Japan, a few studies have demonstrated differences in the association between cause-specific mortality and area socioeconomic indicators.[12–14] These studies examined the mortality variation only within one prefecture and little is known about the situations across the country and the trends in socioeconomic inequality in regional mortality by cause of death in Japan.

In order to reduce socioeconomic inequality in mortality, the relative importance of cause of death in socioeconomic inequality was quantified, and heart diseases showed the largest contribution in Western countries.[15,16] While the prioritized cause of death may vary among countries and change over time, the cause-specific impact has not been quantified in the Japanese population.

The purpose of this study was to elucidate the socioeconomic inequality in regional mortality by cause of death, and to compare the cause-specific impact on inequality in the past few decades in Japan. For this purpose, we examined the relation between mortality from selected major causes and area SEP in 1973–1977 and 1993–1998, using municipal statistics across the country.

Methods

Study units and observation periods

According to the Local Autonomy Law, local public entities in Japan are divided into two categories. The first category consists of municipalities: cities, towns, and villages. The second category consists of prefectures. All districts in the country belong to one of the municipalities and at the same time fall within the boundaries of one of the prefectures. The Tokyo prefecture (Tokyo Metropolis) includes 23 special wards ('ku') in addition to cities, towns, and villages. Twelve large cities (cities designated by ordinance) such as Osaka and Nagoya consist of wards ('ku'). In total, there were 3372 municipalities in 1995 (23 Tokyo special ward cities, 127 wards of 12 cities designed by ordinance, 651 cities, 1994 towns, and 577 villages) and 3368 municipalities in 1975.[17] These municipalities were used as the study unit in this study. Municipalities are the basic unit for administrative services including public health and preventive health services, and most statistics are collected at the municipal level.

The observation periods were 1973–1977 and 1993–1998. In 1995, 5488 people died in the Hanshin-Awaji earthquake in January, and 5447 among them comprised 11.6% of the total annual deaths in Hyogo prefecture.[18] To exclude the influence of this disaster, data for deaths in 1995 were excluded.

The data from municipalities that were annexed or divided during the observation periods could not be used. Finally, the total number of municipalities for whom data on mortality and socioeconomic indicators were available was 3244 in 1973–1977 and 3334 in 1993–1998, reflecting 96.3% and 98.9%, respectively, of the total municipalities.

Cause-specific death

Deaths in the population aged under 75 years were studied, since this study focused on premature mortality.[8] The leading eight causes of death in 1995 were selected as the study subjects.[19] Among them, senility (the seventh leading cause) was excluded because the number of deaths from senility in the population aged under 75 is small (273 in 1995).[20] Table 1

Table 1 Disease categories of selected causes of death in Japan

ICD (year)	ICD–8 (1973–77)	ICD–9 (1993–94)	ICD–10 (1996–98)
Cancer (all sites)	140–209	140–208	C00–C97
Stomach cancer	151	151	C16
Colorectal cancer	153, 154	153, 154	C18–C21
Liver cancer	155, 197.7, 197.8	155, 199.1C	C22
Lung cancer	162	162	C33–C34
Breast cancer	174	174	C50
Uterine cancer	180–182	179–182	C53–C55
Heart disease	393–398, 410–429	393–398, 410–429	I01–I02.0, I05–I09, I20–I25, I27, I30–I52
Coronary heart disease	410–414	410–414	I20–I25
Stroke	430–438	430–438	I60–I69
Cerebral haemorrhage	431	431–432	I61, I69.1
Cerebral infarction	432–434, 438.a	433,434,437.7A, 437.7B	I63, I69.3
Pneumonia	480–486	480–486	J12–J18
Liver disease	570–573	570–573	K70–K77
Injury	E810–E949	E810–E949	V01–X59
Suicide	E950–E959	E950–E959	X60–X84

ICD: International Classification of Diseases and Injuries.

shows the selected causes of death with the subgroups of cancer, heart disease, and stroke, and the corresponding codes of the International Classification of Diseases and Injuries (ICD).

Numbers of deaths from selected causes by municipality, sex, 5-year age group, and observation period were compiled using individual death registers with the permission of the Management and Co-ordination Agency. Table 2 shows the average annual number of deaths and age-adjusted mortality rate calculated using the 1985 Japanese model population[21] for males and females in the two observation periods. The proportion of deaths from these causes among the total number of deaths was 75.7% in 1973–1977 and 82.8% in 1993–1998 for males, and 74.3% in 1973–1977 and 80.4% in 1993–1998 for females.

Socioeconomic indicators

As municipal socioeconomic indicators, education level and per capita income were used. Education level reflected the sex-specific and age-adjusted education level, using the percentage of those who had graduated from college or at a higher level among the population aged ⩾20 years, which was based on the population census,[22] and was standardized by the nationwide population of sex- and age-specific groups as for age-adjusted mortality rate. Income data were drawn from Indicators of Citizens' Income, which was based on the data of the Ministry of Public Management, Home Affairs, Posts and Telecommunications (formerly the Ministry of Home Affairs).[22,23] Per capita income was calculated by aggregating the annual taxable income per household by municipality, and dividing it by the total municipal population.

A factor score of the factor obtained by principal component analysis with the three indicators was assigned to each municipality as the SEP index. Principal component analysis was conducted separately for 1973–1977 and 1993–1998. The data for education in 1980 and 1990 were used for 1973–1977 and 1993–1998, respectively, and the data for education in 1980 and 1995 was used for 1973–1977 and 1993–1998, respectively, because of limited data availability. SPSS 11.0 for Windows was used for principal component analysis.

A summary of the indicators and the results of principal component analysis are shown in Table 3. All indicators consistently showed high factor loading, and the obtained factor explained a large part of the variation: the percentage of variance explained was 80.4% for 1973–1977 and 87.6% for 1993–1998. The range of the SEP index was −1.89 to 7.03 for 1973–1977 and −1.90 to 7.03 for 1993–1998, with mean of 0.0 and standard deviation of 1.0. These indices for the two periods were strongly correlated with each other (r = 0.943).

Relation between mortality and SEP

According to the SEP index, municipalities were classified into quintiles; the highest SEP quintile was designated Q1 and the lowest Q5. Then, two measures of the socioeconomic inequality in regional mortality were used: mortality gradient by SEP and excess deaths in the lower SEP municipalities.

Mortality gradient by SEP was assessed using standardized mortality ratio (SMR) by SEP quintile and rate ratio (RR) across the quintiles. SMR was calculated using the aggregated population by sex and 5-year age group by SEP quintile and sex- and age-specific mortality of the highest SEP quintile (Q1) as the standard mortality. RR according to quintiles was estimated by Bayesian hierarchical Poisson regression.[8,24] The details of this analysis are previously reported.[8] Briefly, RR was

Table 2 Annual number of deaths (N) and age-adjusted mortality rate from selected causes in Japanese aged under 75 years, 1973–77 and 1993–98

	Males				Females			
	1973–77		1993–98		1973–77		1993–98	
Cause of death	N	Mortality	N	Mortality	N	Mortality	N	Mortality
All causes	238,956	577.0	257,555	384.6	157,898	332.7	134,471	178.7
Cancer (all sites)	58,183	146.9	101,692	147.8	43,063	92.6	55,917	73.5
Stomach cancer	22,619	57.8	19,787	28.8	13,768	29.6	8,725	11.6
Colorectal cancer	4,292	10.6	11,287	16.4	3,776	8.2	7,179	9.3
Liver cancer	654	1.7	17,108	24.5	242	0.5	4,891	6.0
Lung cancer	7,954	20.6	20,096	29.2	2,881	6.3	6,190	7.8
Breast cancer	–	–	–	–	2,729	5.9	6,376	9.1
Uterine cancer	–	–	–	–	4,636	10.1	3,049	4.1
Heart disease	27,702	69.7	34,391	50.9	19,032	41.1	16,828	21.1
Coronary heart disease	14,177	36.3	16,970	24.8	7,996	17.4	7,032	9.4
Stroke	49,394	127.9	25,426	37.4	34,351	74.9	15,736	19.8
Cerebral haemorrhage	23,415	60.1	10,328	15.0	15,580	34.0	5,177	6.6
Cerebral infarction	6,765	17.8	10,003	14.6	4,871	10.6	4,976	5.9
Pneumonia	7,229	17.5	10,614	15.7	4,955	10.1	4,692	5.8
Liver disease	9,750	23.9	9,657	14.2	3,630	7.8	3,073	4.0
Injury	18,904	39.9	17,465	27.8	5,768	11.4	5,973	8.8
Suicide	9,765	20.6	14,157	22.5	6,448	13.0	5,833	8.8

Mortality is the age-adjusted mortality rate (per 100,000) calculated using the 1985 Japanese model population.

Table 3 Characteristics of socioeconomic indicators among municipalities in Japan and results of principle component analysis (factor loading), for 1973–77 and 1993–98.

	1973–77			1993–98		
Socioeconomic indicator	Mean	(S.D.)	Factor loading	Mean	(S.D.)	Factor loading
Education level[a] (Males) (%)	11.2	(6.1)	0.957	16.7	(7.4)	0.973
Education level[a] (Females) (%)	7.5	(3.3)	0.937	14.3	(5.4)	0.939
Per capita income[b] (1000 yen)	524.1	(156.5)	0.786	1185.6	(312.5)	0.879

[a] Age-adjusted education level, using the percentage of those who graduated from college or a higher level among the population aged 20 years and over: data from 1980 and 1990 were used for 1973–77 and 1993–98, respectively.

[b] Aggregated taxable income divided by total population: data from 1980 and 1995 were used for 1973–77 and 1993–98, respectively.

estimated from the model with municipal observed deaths and expected deaths calculated using the mortality rate of the highest SEP quintile (Q1) as the standard, and two hierarchical regional levels (level 1 = municipality and level 2 = secondary medical care zone). This hierarchical model adjusted the fluctuation in municipal mortality due to the heterogeneity of population size among municipalities, ranging from a few hundred to a few hundred thousand. Dummy variables for SEP quintiles were given to each municipality (Q1 = 0.0, Q2 = 0.25, Q3 = 0.5, Q4 = 0.75, and Q5 = 1.0), and RR across SEP quintiles was estimated. The software MLwiN 1.10 was used for this analysis.

To assess the cause-specific impact on socioeconomic inequality in regional mortality, the number of excess deaths in the lower four SEP quintiles (Q2–Q5) was calculated. Excess deaths reflected the difference between the observed deaths and the expected deaths, which were estimated using the age-specific mortality rates of the highest SEP quintile (Q1) as the standard. Then, the rate of cause-specific excess deaths was calculated by dividing the number of excess deaths from each cause by the total observed deaths from all causes in the lower four SEP quintiles separately in 1973–1977 and 1993–1998.

Results

The number of deaths and age-adjusted mortality rates by cause of death in 1973–1977 and 1993–1998 are shown in Table 2. Stomach cancer, and stroke, especially cerebral haemorrhage, showed a marked decline in mortality. In contrast, an increase in age-adjusted mortality rate was found for colorectal cancer, liver cancer, lung cancer, breast cancer, and male suicide.

Table 4 shows SMR by SEP quintile and RR across quintiles for males in 1973–1977 and 1993–1998. For all causes, a substantial mortality gradient with RR of 1.10 was found in 1973–1977. During this period, a significant relation between higher mortality and lower SEP was shown for stroke, pneumonia, injury, and suicide, and the steepest gradient was found for injury, followed by suicide and cerebral haemorrhage. In contrast, a higher SEP quintile showed lower mortality from cancer at all sites, stomach, colorectal, liver, and lung cancer in 1973–1977. Over time, a marked increase in RR was found for injury and suicide, while a decrease in RR was found for cerebral haemorrhage and pneumonia. The direction of RR for lung cancer reversed between 1973–1977 and 1993–1998.

Table 5 shows SMR by SEP quintile and RR across quintiles for females in 1973–1977 and 1993–1998. In 1973–1977, liver cancer, stroke including cerebral haemorrhage and cerebral infarction, pneumonia, injury, and suicide showed a significant relation between higher mortality and lower SEP. In 1993–1998, significantly higher mortality in higher SEP quintiles was found for all causes as well as cancer at all sites and all types of cancer. A significant relation between higher mortality and lower SEP was found for stroke, injury, and suicide. Over time, stroke showed a decrease in RR, while injury and suicide showed an increase in RR.

The annual number of excess deaths estimated in SEP disadvantaged municipalities by cause of death is shown in Table 6. For males in 1973–1977, excess deaths (13 937) in the lower SEP quintiles compared with the highest SEP quintile reflected 12.4% of total observed deaths from all causes in these quintiles. Among them, the largest part was excess deaths from stroke (5354: 4.8%), followed by deaths from injury (2952: 2.6%). Over time, excess deaths from all causes decreased to 4712 (4.2%). In 1993–1998, stroke, especially cerebral haemorrhage, showed a marked decrease in excess deaths, and the largest number of excess deaths was found for injury, followed by suicide. Cancer at all sites showed a negative value, reflecting that the highest SEP quintile showed the higher mortality compared with the lower quintiles.

For females in 1973–1977, the number of excess deaths was 5535 (4.9% of total deaths), of which the largest proportion was deaths from stroke: 3067 (4.1%). In 1993–1998, the number of excess deaths from all causes was negative: the highest SEP quintile had higher mortality compared with the lower SEP quintiles. The decline in excess deaths in the lower SEP quintiles and negative excess deaths in 1993–1998 were attributable to the decrease in excess deaths from stroke (3067 to 324), as well as an increase of negative impact of cancer (−663 to −2131).

Discussion

Methodological issues

This study applied two measurements to assess the relation between SEP and cause-specific mortality. The mortality gradient including RR across SEP quintiles did not directly reflect the impact on mortality variation since it did not take account of absolute number of deaths. On the other hand, excess deaths in the lower SEP quintiles compared with the highest SEP quintile and the rate of cause-specific excess deaths out of the total number of all-cause observed deaths make it possible to compare the relative importance of socioeconomic inequality in regional mortality among causes of death and over time. The rate of cause-specific excess deaths out of the total

Table 4 Standardized mortality ratio (SMR) by quintile of socioeconomic position (Q1 to Q5) and rate ratio (RR) across quintiles in Japan, 1973–77 and 1993–98: males aged under 75 years

	1973–77						1993–98					
	SMR						SMR					
Cause or death	Q1 (highest)	Q2	Q3	Q4	Q5 (lowest)	RR (95%CI)	Q1 (highest)	Q2	Q3	Q4	Q5 (lowest)	RR (95%CI)
All causes	1.00	1.11	1.13	1.16	1.21	1.10 (1.08, 1.11) ***	1.00	1.03	1.06	1.04	1.08	1.07 (1.05, 1.09) ***
Cancer (all sites)	1.00	1.00	0.99	0.98	1.00	0.96 (0.94, 0.99) **	1.00	0.98	0.98	0.93	0.95	0.95 (0.93, 0.97) ***
Stomach cancer	1.00	1.06	1.03	1.03	1.02	1.00 (0.96, 1.03)	1.00	1.03	1.01	0.96	0.98	0.99 (0.95, 1.02)
Colorectal cancer	1.00	0.90	0.87	0.83	0.82	0.80 (0.75, 0.84) ***	1.00	0.91	0.90	0.81	0.85	0.80 (0.77, 0.83) ***
Liver cancer	1.00	1.00	0.90	0.88	0.73	0.80 (0.68, 0.93) **	1.00	0.96	0.85	0.71	0.63	0.77 (0.72, 0.82) ***
Lung cancer	1.00	0.93	0.92	0.90	0.93	0.92 (0.88, 0.97) ***	1.00	1.01	1.03	1.00	1.04	1.06 (1.02, 1.09) ***
Heart disease	1.00	1.07	1.06	1.07	1.05	1.03 (1.00, 1.06)	1.00	1.00	1.04	1.00	1.05	1.05 (1.01, 1.08) **
Coronary heart disease	1.00	1.00	0.99	1.01	0.94	0.94 (0.91, 0.98) **	1.00	0.89	0.90	0.85	0.88	0.96 (0.90, 1.03)
Stroke	1.00	1.20	1.23	1.30	1.43	1.16 (1.13, 1.19) ***	1.00	1.04	1.14	1.18	1.20	1.18 (1.14, 1.22) ***
Cerebral haemorrhage	1.00	1.22	1.29	1.40	1.53	1.29 (1.25, 1.35) ***	1.00	1.01	1.11	1.20	1.20	1.21 (1.15, 1.27) ***
Cerebral infarction	1.00	1.18	1.16	1.25	1.48	1.16 (1.08, 1.24) ***	1.00	1.09	1.19	1.18	1.23	1.19 (1.14, 1.25) ***
Pneumonia	1.00	1.11	1.12	1.19	1.29	1.20 (1.14, 1.26) ***	1.00	1.01	1.05	1.04	1.07	1.09 (1.05, 1.15) ***
Liver disease	1.00	0.95	0.90	0.84	0.81	0.88 (0.83, 0.93) ***	1.00	0.93	0.92	0.83	0.81	0.94 (0.88, 1.00) *
Injury	1.00	1.35	1.48	1.61	1.63	1.43 (1.38, 1.49) ***	1.00	1.37	1.53	1.73	1.90	1.75 (1.69, 1.82) ***
Suicide	1.00	1.14	1.18	1.28	1.42	1.36 (1.30, 1.41) ***	1.00	1.12	1.28	1.40	1.61	1.49 (1.43, 1.55) ***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

SMR was calculated using age-specific mortality rates of Q1 as standard.

RR was calculated using Bayesian hierarchical Poisson regression with ordinal variables of SEP (Q1= 0.0, Q2 = 0.25, Q3 = 0.5, Q4 = 0.75, and Q5 = 1.0).

Table 5 Standardized mortality ratio (SMR) by quintile of socioeconomic position (Q1 to Q5) and rate ratio (RR) across quintiles in Japan, 1973–77 and 1993–98: females aged under 75 years

	1973–77						1993–98					
	SMR						SMR					
Cause of death	Q1 (highest)	Q2	Q3	Q4	Q5 (lowest)	RR (95%CI)	Q1 (highest)	Q2	Q3	Q4	Q5 (lowest)	RR (95%CI)
All causes	1.00	1.07	1.07	1.08	1.11	1.07 (1.05, 1.09) ***	1.00	0.98	0.98	0.94	0.94	0.96 (0.94, 0.98) ***
Cancer (all sites)	1.00	0.99	0.95	0.94	0.96	0.94 (0.92, 0.97) ***	1.00	0.94	0.93	0.86	0.85	0.87 (0.85, 0.89) ***
Stomach cancer	1.00	1.04	1.00	0.98	0.98	0.98 (0.94 , 1.01)	1.00	1.00	0.97	0.91	0.87	0.90 (0.86, 0.95) ***
Colorectal cancer	1.00	0.96	0.93	0.92	0.93	0.91 (0.86, 0.96) **	1.00	0.91	0.89	0.81	0.84	0.81 (0.78, 0.85) ***
Liver cancer	1.00	1.21	1.07	1.22	1.32	1.25 (1.03, 1.51) *	1.00	0.89	0.81	0.69	0.64	0.73 (0.68, 0.80) ***
Lung cancer	1.00	0.88	0.85	0.83	0.81	0.82 (0.77, 0.87) ***	1.00	0.91	0.91	0.82	0.80	0.83 (0.79, 0.88) ***
Breast cancer	1.00	0.81	0.76	0.68	0.64	0.64 (0.60, 0.69) ***	1.00	0.85	0.81	0.71	0.68	0.69 (0.65 , 0.73) ***
Uterine cancer	1.00	0.97	0.90	0.85	0.87	0.85 (0.80, 0.90) ***	1.00	0.92	0.88	0.75	0.74	0.76 (0.71, 0.81) ***
Heart disease	1.00	1.04	1.03	1.01	1.00	1.00 (0.97, 1.03)	1.00	1.00	1.00	0.92	0.93	0.96 (0.92, 0.99) *
Coronary heart disease	1.00	1.00	1.01	0.99	0.94	0.95 (0.91, 1.00)	1.00	0.90	0.89	0.82	0.79	0.94 (0.88, 0.99) *
Stroke	1.00	1.17	1.17	1.25	1.32	1.16 (1.13, 1.20) ***	1.00	1.02	1.05	1.05	1.12	1.09 (1.05, 1.13) ***
Cerebral haemorrhage	1.00	1.18	1.23	1.34	1.40	1.27 (1.22, 1.32) ***	1.00	1.00	1.05	1.11	1.18	1.17 (1.10, 1.24) ***
Cerebral infarction	1.00	1.20	1.18	1.22	1.35	1.17 (1.09, 1.26) ***	1.00	1.06	1.10	1.06	1.16	1.11 (1.05, 1.17) ***
Pneumonia	1.00	1.09	1.11	1.20	1.26	1.24 (1.17, 1.31) ***	1.00	0.96	0.95	0.97	0.97	1.02 (0.96, 1.08)
Liver disease	1.00	1.05	1.03	0.95	0.97	0.99 (0.93, 1.06)	1.00	0.95	0.85	0.73	0.73	0.79 (0.73, 0.86) ***
Injury	1.00	1.18	1.27	1.29	1.21	1.19 (1.13, 1.25) ***	1.00	1.32	1.30	1.43	1.44	1.38 (1.29, 1.48) ***
Suicide	1.00	1.05	1.04	1.11	1.17	1.21 (1.15, 1.28) ***	1.00	1.05	1.14	1.23	1.36	1.34 (1.28, 1.41) ***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

SMR was calculated using age-specific mortality rates of Q1 as standard.

RR was calculated using Bayesian hierarchical Poisson regression with ordinal variables of SEP (Q1=0, Q2=0.25, Q3=0.5, Q4=0.75, and Q5=1.0).

Table 6 Annual excess deaths in under 75 year population in lower four quintiles of socioeconomic position (SEP) compared to the highest SEP quintile, 1973–77 and 1993–98

	Males				Females			
	1973–77		1993–98		1973–77		1993–98	
Cause of death	N	(%)	N	(%)	N	(%)	N	(%)
All causes	13,937	(12.38)	4,712	(4.34)	5,535	(7.46)	−1,719	(−3.09)
Cancer (all sites)	−177	(−0.16)	−1,377	(−1.27)	−663	(−0.89)	−2,131	(−3.83)
Stomach cancer	400	(0.36)	47	(0.04)	69	(0.09)	−150	(−0.27)
Colorectal cancer	−268	(−0.24)	−571	(−0.53)	−103	(−0.14)	−396	(−0.71)
Liver cancer	−26	(−0.02)	−1,201	(−1.11)	19	(0.03)	−479	(−0.86)
Lung cancer	−285	(−0.25)	145	(0.13)	−213	(−0.29)	−331	(−0.59)
Breast cancer	–	–	–	–	−342	(−0.46)	−567	(−1.02)
Uterine cancer	–	–	–	–	−187	(−0.25)	−186	(−0.33)
Heart disease	804	(0.71)	311	(0.29)	252	(0.34)	−187	(−0.34)
Coronary heart disease	−61	(−0.05)	–877	(−0.81)	−30	(−0.04)	−438	(−0.79)
Stroke	5,354	(4.76)	1,154	(1.06)	3,067	(4.13)	324	(0.58)
Cerebral haemorrhage	2,946	(2.62)	389	(0.36)	1,668	(2.25)	124	(0.22)
Cerebral infarction	669	(0.59)	631	(0.58)	464	(0.63)	188	(0.34)
Pneumonia	463	(0.41)	158	(0.15)	294	(0.40)	−81	(−0.15)
Liver disease	−456	(−0.41)	−423	(−0.39)	21	(0.03)	−207	(−0.37)
Injury	2,952	(2.62)	2,964	(2.73)	491	(0.66)	732	(1.32)
Suicide	742	(0.66)	1,259	(1.16)	198	(0.27)	298	(0.54)

Number of excess deaths in municipalities in lower four quintiles was the difference between observed deaths and expected deaths calculated using age-specific mortality rates in the highest quintile. The percentage of excess deaths was calculated by dividing the number of cause-specific excess deaths by the total number of all-cause observed deaths in the lower four quintiles.

number of all-cause 'excess deaths', instead of 'observed deaths', might be easier to understand.[15] However, the total number of all-cause excess deaths was not suitable as the denominator in the rate when the lower SEP quintiles showed lower all-cause mortality than the highest quintile: e.g. in females of 1993–1998 in this study; and thus, we used the total number of all-cause observed deaths as the denominator.

There are several possible limitations in this study. The first is related to the heterogeneity in population size among municipalities. Bayesian hierarchical method was adopted to correct the mortality fluctuation attributable to the heterogeneity of population size.[8] Since SEP indices were strongly correlated with each other over time, the relative SEP among municipalities had not changed, and it thus seems that the heterogeneity of population size among quintiles would not influence the interpretation of the time trend in the relation between SEP and mortality.

A second limitation might be related to the selection of socioeconomic indicators. Previous studies demonstrated that the choice of socioeconomic indicator/index was a critical matter in the investigation of socioeconomic inequality,[25,26] and the relation between cause-specific mortality and area socioeconomic conditions showed some difference depending on the measures.[27] In Japan there is no established SEP index like the deprivation index in other industrialized countries[25,28] and our companion study, using unemployment rate and living space as well as income and education, failed to obtain a single index representing SEP in Japan.[8] Since income- and education-related indicators are consistently used as components of deprivation and SEP index,[28] we used these two indicators as measures of area socioeconomic conditions.

Previous studies at the prefectural level in Japan demonstrated a close relation between higher socioeconomic conditions and indicators related to urbanization such as higher population density and lower proportion of primary industrial workers.[29,30] The SEP index in this study was strongly correlated with population size and population density: Spearmen's correlation coefficient was 0.521 in 1973–1977 and 0.574 in 1993–1998 for population size, and 0.523 in 1973–1977 and 0.617 in 1993–1998 for population density. Therefore, we discussed the findings in this study considering that SEP index includes an aspect of urban/rural difference.

Third, the change in the death registration system in 1995 could have led to an artificial fluctuation in the numbers of cause-specific deaths, especially in heart disease and stroke: mortality from coronary heart disease and stroke increased and mortality from heart failure decreased.[31,32] Also, in urban areas such as Tokyo and Osaka prefectures, coronary heart disease is less likely to be assigned as an 'ill-defined code', in particular heart failure.[33] These facts might bias the relation between SEP and mortality from these diseases.

Last, this study applied an ecological study design. Although ecological studies face several problems including the ecological fallacy,[34] recent studies, in particular multilevel studies, demonstrated that regional or neighbourhood context independently influenced health status, in addition to

individual characteristics.[27] The limited data availability for mortality and socioeconomic status at the individual level in Japan encourages municipal-level analysis, which is the smallest unit enabling researchers to link mortality data and SEP and to examine time trends in the relation between mortality and SEP.

Socioeconomic inequality in cause-specific mortality

In 1973–1977, stroke showed the largest excess deaths as well as a steep gradient of mortality. However, both mortality gradient and excess deaths, especially those for cerebral haemorrhage, markedly decreased over time. The results of this study indicate that the decreased impact of cerebral haemorrhage was caused by a decline in both mortality and mortality gradient by SEP. The decline of stroke mortality was attributable to not only preventive programmes such as hypertension control, but also economic growth and improvement in living standards, and lifestyle change, especially in rural areas.[35,36] The marked decline of stroke mortality in rural areas is likely to have contributed to the decreased socioeconomic inequality in regional mortality.

On the other hand, in 1993–1998, injury showed the steepest mortality gradient and the largest excess deaths for both males and females. Death from traffic accidents comprised a large proportion of injury deaths: 32.6% in 2000.[37] A study examining the association between mortality from traffic accidents and individual and neighbourhood socioeconomic conditions showed a higher risk of dying in socioeconomically disadvantaged areas.[38,39] In addition, rural environments and lifestyles such as road characteristics, average driving mileage, driving behaviour, and alcohol intoxication influence the risk of motor vehicle accidents.[29]

Suicide showed an increase in mortality gradient and excess deaths for both males and females over time. Previous studies indicated that socioeconomically disadvantaged conditions such as higher unemployment and divorce rate were strongly related to increased mortality from suicide.[40,41] In Japan, suicide mortality has increased since the late 1990s,[19] and the economic recession is suspected to have contributed to the increased suicide rate.[42,43]

Coronary heart disease has been shown to be the greatest cause of death contributing to health inequality in area- and individual-based studies in Western countries.[15,16] The present study showed a smaller impact of heart disease and a negative impact of coronary heart disease on the socioeconomic inequality in regional mortality. This small contribution was due to not only lower mortality from heart disease in Japan compared with Western countries,[44] but also a non-significant positive relation between SEP and mortality from this disease. The weak relation between individual socioeconomic status and risk factors for coronary heart disease such as smoking in the Japanese population[45,46] is a plausible explanation for the weak relation between SEP and mortality.

The negative relation between SEP and all-cause mortality for females was strongly contributed to by cancer mortality, and the negative relation with SEP and the negative impact on inequality in cancer was strengthened both for males and females. In other countries, the pattern of the relation between cancer mortality and SEP differed according to sites, and breast cancer showed higher mortality in areas with higher SEP,[10] as well in individuals with higher socioeconomic status.[47] The relation between higher mortality and higher SEP is rationalized by the fact that most cancers in recent decades are caused by health risk behaviours,[48] and suggests that people living in higher SEP regions and urban areas are more likely to have these behaviours.

Implications and future

During the past few decades, Japan has experienced a marked increase in life expectancy.[19] The present study implies that the increase in life expectancy was accompanied by a decrease in socioeconomic inequality in regional mortality, and that the decline in mortality and the mortality gradient by SEP for stroke largely contributed to this phenomenon.

In contrast, injury and suicide showed an increased impact. Health policies targeting prevention of injury and suicide in socioeconomically disadvantaged areas, in addition to traditional strategies against stroke, will contribute to a decline of socioeconomic inequality in premature mortality. At present, there is little focus on injury prevention in the public health field in Japan: e.g. 'Health Japan 21', a national health promotion campaign, does not include any kind of objectives or targets for injury prevention.[49] Public health practitioners should pay attention to prevention of injury since it showed the largest impact on socioeconomic inequality in regional mortality. Also, awareness that suicide is a public health issue has been rising,[50] and community-based health promotion programmes in rural areas are expected to be effective in suicide prevention in Japan.[51]

Urban areas in Japan have shown a deterioration in relative health status:[52] e.g. life expectancy in the Tokyo Metropolis was longest before 1965 among 47 prefectures, while it ranked 15th for males and 37th for females in 2000.[53] The results of this study imply that the deterioration of relative health level in the urban population compared with the rural population is attributable to decreased advantage of stroke mortality and increased disadvantage of cancer mortality in urban areas. Especially for females, all selected types of cancer showed higher mortality in higher SEP municipalities; thus, cancer prevention in higher SEP areas reflecting urban areas should be encouraged.

Health inequality is a large concern in the public health agenda, in particular focusing on socioeconomic determinants of health.[54,55] A recent series of studies in social epidemiology has revealed that health inequality is caused by various socioeconomic and environmental factors such as individual socioeconomic status, social support network including social capital, and early life course.[56,57] The longest national life expectancy in Japan was achieved by not only improvement in the standard of living due to economic growth, but also advantages in terms of equality of socioeconomic conditions.[4,58] A previous study demonstrated that the national financial adjustment policy has helped to reduce disparity in health levels across Japan over the past few decades.[59] Recently, the relative income hypothesis, in which income inequality has a greater impact on individual health than absolute income, has been proposed.[60,61] The weakened association between mortality and the SEP index and the increased negative relation for several causes of death in this

study suggest that relative inequality will be addressed in Japan as well as other industrialized countries.

The findings of this study should be cautiously interpreted at the individual level, with consideration of methodological issues, especially the ecological fallacy.[34,62] The decreased socioeconomic inequality in regional mortality does not indicate decreased inequality among individuals, and the higher mortality in higher SEP municipalities for females does not indicate a lower health status in higher socioeconomic females. Although there is insufficient evidence of a relation between health and socioeconomic status at the individual level in Japan, a few recent studies demonstrated a relation between lower individual socioeconomic status and poorer self-rated health and health risk behaviours in the Japanese population.[63,64] To clarify the contexts underlying the findings of this study and to propose effective health policies, further studies examining the influence of individual socioeconomic status in combination with regional SEP on health in Japan are required.

Conclusions

The present study revealed different relations between cause-specific mortality and SEP of municipalities. Stroke remained a major cause with a large impact, while the mortality gradient and the impact of injury and stroke on socioeconomic inequality in regional mortality have increased. Recent figures showed higher mortality from several causes, especially cancer, in higher SEP municipalities. The prevention of injury and suicide as well as stroke in socioeconomically disadvantaged regions and cancer in urban areas with higher SEP should be given priority.

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KEY MESSAGES

- The relation between cause-specific mortality of ages under 75 and area socioeconomic position (SEP) at the municipal level across Japan in 1973–1977 and 1993–1998 was examined.
- Mortality gradient by SEP and excess deaths in lower SEP quintiles for stroke markedly decreased over time, while those for injury and suicide increased.
- In 1993–1998, females showed a relation between higher SEP and higher all-cause mortality, and cancer mortality largely contributed to this relation.
- The prevention of injury and suicide as well as stroke in socioeconomically disadvantaged regions and cancer in advantaged regions should be enhanced.

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