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Original Research

Higher mortality in areas of lower socioeconomic position measured by a single index of deprivation in Japan

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KEYWORDS
Socioeconomic factors;
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Summary *Objectives:* To formulate an index representing area deprivation and elucidate the relation between the index and mortality in Japan.
Study design: Ecological study for prefectures ($N = 47$) and municipalities ($N = 3366$) across Japan.
Methods: Based on socioeconomic indicators of seven domains of deprivation (i.e. unemployment, overcrowding, low social class and poverty, low education, no home ownership, low income and vulnerable group), an index was formulated using the z-scoring method. The relation between the index and mortality was examined by correlation analysis, hierarchical Poisson regression and comparison of standardized mortality ratio according to the index.
Results: The deprivation index ranged from −7.48 to 10.98 for prefectures and from −16.97 to 13.82 for municipalities. The index was significantly positively correlated with prefectural mortality, especially in the population aged under 74 years: $r = 0.65$ for men and $r = 0.41$ for women. At the municipal level, hierarchical Poisson regression showed a significant positive coefficient of the index to mortality for both men and women, and excess mortality in the most deprived fifth compared to the least deprived fifth was 26.4% in men and 11.8% in women.
Conclusions: We formulated a deprivation index, which was substantially related to mortality at the prefectural and municipal levels. This study highlights the higher risk of dying among populations in socially disadvantaged areas and encourages the use of indices representing area socioeconomic conditions for further studies of area effects on health.

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Introduction

As well as individual socioeconomic status such as social class, educational attainment and income, area characteristics have been focused on independent and critical determinants of population health.[1–3] Previous studies showed that socially disadvantaged areas had higher mortality, morbidity and prevalence of health risk behaviour.[4–8]

Measurement of area socioeconomic condition, in particular, 'deprivation', is a critical matter in examining the relation between area characteristics and health. Deprivation is generally defined as a state of observable and demonstrable disadvantage related to the local community or the wider society or nation to which an individual, family or group belongs.[9] Deprivation indices have a long history in the UK, where several traditional indices such as Townsend, Jarman and Carstairs have been developed and commonly used.[10] This was followed by a number of studies for the development and use of deprivation indices in many countries including not only European countries but also Australia, Canada, New Zealand, the US, and others.[11–25] These indices were formulated at various administrative levels with multiple indicators mainly from census data, comprising multiple domains such as unemployment, low social class, low educational attainment, household overcrowding, and home ownership. These deprivation indices have been applied in funding formulas, resource allocation and research in a variety of settings such as health and other social services.[16,26]

In Japan also, the relation between health level and area characteristics has been elucidated. Recent systematic studies using municipal data regarding all causes and cause-specific mortality along with several socioeconomic indicators showed significant relationships between regional mortality and socioeconomic characteristics.[27,28]

There have been some efforts to formulate indices of area social characteristics in Japan, mainly representing wealth rather than deprivation, although these indices have not received consensus and are not used in epidemiologic and public health research.[29] Instead of established indices, indices formulated from limited socioeconomic indicators using factorial analysis were used in previous studies, and a substantial relation between these indices and mortality was found.[27,30] However, the dimensions of socioeconomic disadvantage were not integrated into a single index, and the formulated indices appeared to represent not only socioeconomic disadvantage but also other area characteristics such as urban–rural difference.[27,28]

Health inequalities in relation to socioeconomic factors have been of great interest in public health.[31,32] Examining health inequalities in Japan will provide important insights in this field, because the Japanese population shows the healthiest status in the world,[33,34] and it is suggested that relatively smaller socioeconomic disparities partly contributes to this excellent health level.[35,36] The development of an index representing socioeconomic disadvantage would stimulate the study of health inequalities in Japan. The present study formulated an index of area deprivation, which included critical domains of social disadvantage and was available for small area analyses, and examined the relation between the index and mortality at the levels of prefecture and municipality.

Methods

Units of analyses

The study units of this study were prefecture and municipality. Local public entities in Japan are divided into two categories: the first consists of municipalities (i.e. cities, towns and villages), while the second consists of prefectures. All districts in the country belong to one of the municipalities and fall within the boundaries of one of 47 prefectures. 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'). There were a total of 3372 municipalities (23 Tokyo special ward cities, 127 wards of 12 cities designated by ordinance, 651 cities, 1994 towns and 577 villages) in 1995.[37]

Domains of deprivation

Table 1 summarizes the domains of deprivation indices established in other countries.[11–21,25] The domains were classified into unemployment; household overcrowding; low social class and poverty; education; home ownership; income; vulnerable group (e.g. elderly living alone and lone parents); car ownership; barriers to services and transport (e.g. road distance to primary school); communication (e.g. access to telephone and Internet use); health (e.g. mortality and disability prevalence); and crime (e.g. burglary and violence). Among them—placing an emphasis on domains of recently developed indices such as IMD (index of multiple

Table 1 Domains of deprivation indices in previous studies and corresponding indicators in this study

Domain	Townsend[10]	Jarman[10]	Carstairs[10]	IMD SIMD NIMD[11-14]	SEIFA[15]	NZDep[16]	USA[17]	CNI[18]	Spain[19]	Indicators in this study (see Appendix 1)
Unemployment	✓	✓	✓	✓	✓	✓	✓	✓	✓	Unemployment rate
Household overcrowding	✓	✓	✓	✓	✓	✓		✓	✓	Dwelling rooms/area per household
Low social class and poverty			✓	✓	✓		✓	✓	✓	Rate of households on public assistance
Education				✓	✓	✓	✓		✓	Percentage of persons with the highest education
Home ownership	✓	✓		✓		✓	✓			Percentage of owned houses
Income				✓	✓	✓	✓			Per capita income
Vulnerable group		✓			✓	✓		✓		Percentage of aged single households
Car ownership	✓		✓				✓			–
Barriers to services and transport				✓		✓				–
Communication					✓	✓				–
Health				✓						–
Crime				✓						–

See references corresponding to numbers in parentheses.

deprivation), SIMD (Scottish index of multiple deprivation), and NIMD (northern Ireland measures of deprivation) in the UK, SEIFA (socioeconomic indexes for areas) in Australia, and NZDep in New Zealand—the following seven domains were selected as components of the index in this study: unemployment, overcrowding, low social class and poverty, education, home ownership, income, and vulnerable group.

Prefectural level analysis

Formulation of deprivation index

The indicators corresponding to the seven main domains shown in Table 1 were drawn from the database of prefectural socioeconomic indicators, which consisted of governmental surveys around 2000.[38] Selected indicators were: unemployment rate; dwelling rooms per household; number of households with public assistance; percentage of persons with the highest education; percentage of owned houses; per capita income; and percentage of aged single households. The information of the indicators is detailed in Appendix A.

The deprivation index was formulated by two different methods: z-scoring method and factorial analysis. The z-score of each selected socioeconomic indicator was computed: $z = (x - \text{mean})/\text{standard deviation (SD)}$,[39,40] and they were summed to give the deprivation index of z-score (DIz). Second, principle component analysis with varimax rotation was used to formulate an alternative deprivation index.[27] Factors for which the eigenvalue of the correlation matrix was more than 1.0 were selected as significant dimensions, and the factor score of the selected factor was assigned as the deprivation index (DIc).

Relation to mortality

Sex-specific and age-adjusted mortality rates in 2000 were calculated using the sex- and age-specific number of deaths and the 1985 Japanese standard population.[41] Age groups analysed were the total population and the population aged under 75. The correlation between mortality and the index was examined.

Municipal level analysis

Formulation of deprivation index

In the same way as for prefectural analysis, municipal indicators around 1995 were selected from the database of municipal socioeconomic indicators.[42,43] Since the ratio of owned houses was not included in the database, the following six indicators were used: unemployment rate; dwelling area per household; rate of households on public assistance; percentage of persons with the highest education; per capita income; and percentage of aged single households, as shown in Appendix A. Since the data of households on public assistance were not available for some municipalities, the prefectural average, if available, or the national average (z-score = 0) was assigned for these municipalities. Four indicators (unemployment rate, rate of households on public assistance, percentage of persons with the highest education, and percentage of aged single households) were transformed using natural log transformation $y = \ln(x + 1)$ to produce more normal distributions.[40]

Relation to mortality

The mortality database used in the present study was formulated from microfiles of death certification in 1993–1998 in Japan, and composed of observed and expected numbers of deaths among the population aged under 75 by municipality.[27,28] The data of deaths in 1995 were excluded to avoid the influence of the Hanshin–Awaji earthquake. The nationwide age-specific mortality rates and census municipal age-specific population in 1995 were used for calculation of expected number of deaths. The data of mortality and socioeconomic indicators of 3366 municipalities could be linked and used for the following analyses.

Two statistical analyses were used for examining the relation between the deprivation index and mortality. First, comparison of mortality according to deprivation was conducted by calculating standardized mortality ratio (SMR) by quintiles of municipalities according to the deprivation index. SMR was calculated using the aggregated observed and expected numbers of deaths of each quintile, with the mortality of the total population as the reference (= 1.0).

Second, hierarchical Poisson regression analysis was conducted.[27,44] This analysis could correct the fluctuation in mortality due to heterogeneity of population size: there was marked variation in the population size among municipalities, ranging from a few hundred to a few hundred thousand, and municipalities with a small population showed statistical fluctuation in mortality. The secondary medical care zone (SMCZ), which is defined by prefectural governments for medical care planning according to the Medical Service Law, was used as a higher level. There were 344 SMCZs across Japan in 1995, each of which consisted of neighbouring municipalities and covered a population of 300,000 on average. Bayesian standardized mortality ratio (BSMR) of municipalities was estimated using the iterative generalized least squares (IGLS) and the Markov chain Monte Carlo method.[45] The details of hierarchical Poisson regression analysis are described in previous studies.[27,44]

For statistical analyses, SPSS 11.0J was used for correlation analysis and principle component analysis, and MLwiN 1.0 was used for hierarchical Poisson regression analysis.

Results

The age-adjusted mortality rate (per 100,000) of the 47 prefectures ranged from 579.4 to 756.1 for men and 286.9 to 347.7 for women in the total population, and 312.0 to 442.4 for men and 139.0 to 175.2 for women in the population aged under 75. The correlations between mortality and the original indicators in the deprivation index both for prefectural and municipal analyses are summarized in Appendix B.

The deprivation index calculated using the z-scoring method (DIz) by prefecture ranged from −7.48 to 10.98. The highest (most deprived) was Okinawa prefecture, followed by Kochi (7.38) and Kagoshima (7.27). The lowest (least deprived) was Toyama prefecture, followed by Shiga (−6.96) and Fukui (−5.53).

The result of principle component analysis is shown in Table 2. Two factors were obtained as significant dimensions, and they accounted for 80.7% of the total variance in the data. For the first factor, unemployment rate and households on public assistance showed markedly higher factor loading, while the percentage of owned houses and dwelling rooms per household showed strong negative factor loading. For the second factor, per capita income and educational level showed strong negative factor loading. Factor scores of these factors were assigned as composite indices (DIc1 and DIc2, respectively), and then the two composite indices were summed to give the deprivation index from principle component analysis (DIc). DIc by prefecture ranged from −2.04 to 3.31. The highest was Okinawa prefecture, followed by Kochi (2.98) and Kagoshima (2.69). The lowest was Shiga prefecture, followed by Aichi (−1.91) and Toyama (−1.84). The correlation coefficient between DIz and DIc was 0.96.

Table 3 showed the correlation coefficient between prefectural mortality rates and the deprivation index. For mortality of the total population, that of men showed a modest correlation with DIz ($r = 0.48$, $P < 0.001$), while that of women did not show a significant correlation

Table 2 Results of factorial analysis (principle component analysis) with prefectural indicators

Indicator	Factor 1	Factor 2
Unemployment rate	0.831	0.124
Dwelling rooms per household	−0.849	0.371
Rate of households on public assistance	0.843	0.375
Percentage of persons with the highest education	0.327	−0.826
Per capita income	−0.036	−0.936
Percentage of owned houses	−0.829	0.486
Percentage of aged single households	0.471	0.652

Table 3 Correlation coefficients between prefectural mortality and deprivation indices

		z-scoring	Factorial analysis[a]		
		DIz	DIc1	DIc2	DIc
Total population	Men	0.48***	0.28	0.47**	0.57***
	Women	0.10	0.24	−0.17	0.05
Population under 75	Men	0.64***	0.43**	0.52***	0.67***
	Women	0.43**	0.50***	−0.01	0.35*

DIc = DIc1+DIc2
*$P<0.05$.
**$P<0.01$.
***$P<0.001$.
[a]DIc1 and DIc2 are factor scores for factors 1 and 2, respectively (see Table 2).

($r=0.10$, $P=0.48$). For the population aged under 75, DIz showed a stronger correlation with mortality, especially for men: $r=0.64$ ($P<0.001$) for men and $r=0.43$ ($P=0.003$) for women. For indices from principle component analysis, DIc1 showed a significant correlation with mortality of the population aged under 75, while DIc2 showed a significant correlation with male mortality but not with female mortality. DIc was correlated with mortality of the total population and the population aged under 75 for men, and the population aged under 75 for women. The correlation of DIc with mortality rates was similar to that of DIz. The result of the analysis of variance showed that the deprivation index maximally accounted 44.9% and 18.5% of the variance of mortality for under 75 men and women, respectively. Fig. 1 shows the relation between DIz and age-adjusted mortality rates separately for men and women.

At the municipal level, the formulated deprivation index ranged from −16.97 to 13.82, with SD of 3.40. The relation between mortality of the population aged under 75 and the index is shown in Table 4. There was a clear gradient of male SMR according to the quintile of deprivation index. The gradient of female SMR was clear but steeper than that of male SMR. Compared to the least deprived fifth, the most deprived fifth showed 26.4% excess mortality for men and 11.8% excess mortality for women. A similar trend for male mortality to be more strongly associated with the deprivation index was found with hierarchical Poisson regression analysis: the coefficient of the log scale was 0.0248 (rate ratio $=\exp(0.0248)=1.025$) for men and 0.0144 (rate ratio $=\exp(0.0144)=1.015$) for women. These findings mean that an increment in the deprivation index of one unit causes an increase in mortality of 2.5% for men and 1.5% for women.

Figs. 2 and 3 show the relation between municipal BSMR and the index for men and women, respectively. The BSMR ranged 0.62–2.00 for men and 0.76–1.63 for women. The correlation coefficient between municipal BSMR and the deprivation index was 0.504 in men and 0.241 in women. The deprivation index accounted 25.4% and 5.8% of the variance of mortality for men and women, respectively.

When the subjects were restricted to municipalities with a population of more than 50,000 ($N=559$), the SD of the deprivation index was

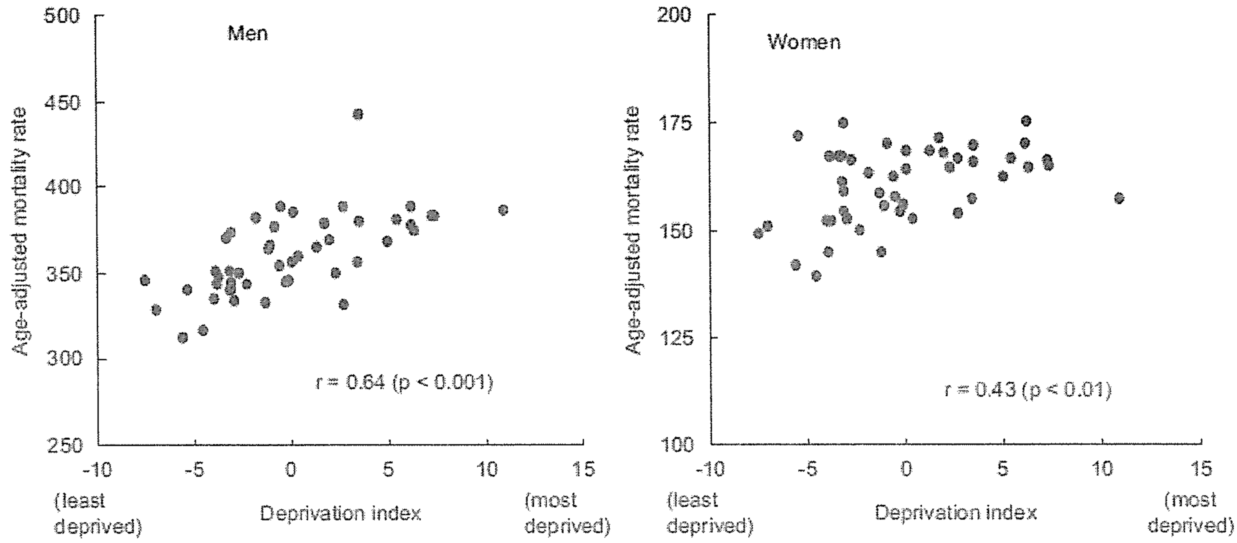

Figure 1 Prefectural deprivation index and sex-specific and age-adjusted mortality (per 100,000) in population aged under 75 ($N = 47$).

Table 4 Relationship between municipal mortality and deprivation index

		Men	Women
Standardized mortality ratio[a]	Q1 (least deprived)	0.922	0.941
	Q2	0.977	0.966
	Q3	1.028	0.985
	Q4	1.078	1.021
	Q5 (most deprived)	1.165	1.052
	(Q5/Q1)	(1.264)	(1.118)
Coefficient (SE)[b]		0.0248 (0.0009)	0.0144 (0.0011)
Rate ratio[c]		1.025	1.015

[a]Reference: whole country (= 1.00).
[b]Coefficient (SE) of log scale in hierarchical Poisson regression analysis.
[c]Exponentiated coefficient: rate ratio for increment in deprivation index of one unit.

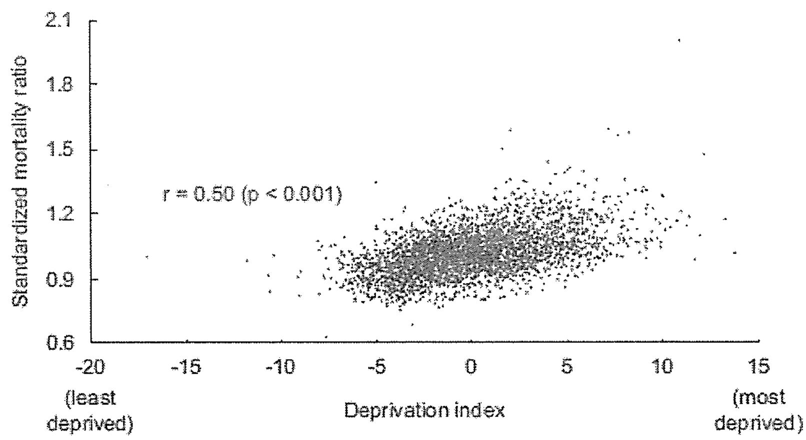

Figure 2 Municipal deprivation index and Bayesian standardized mortality ratio of men aged under 75 ($N = 3366$).

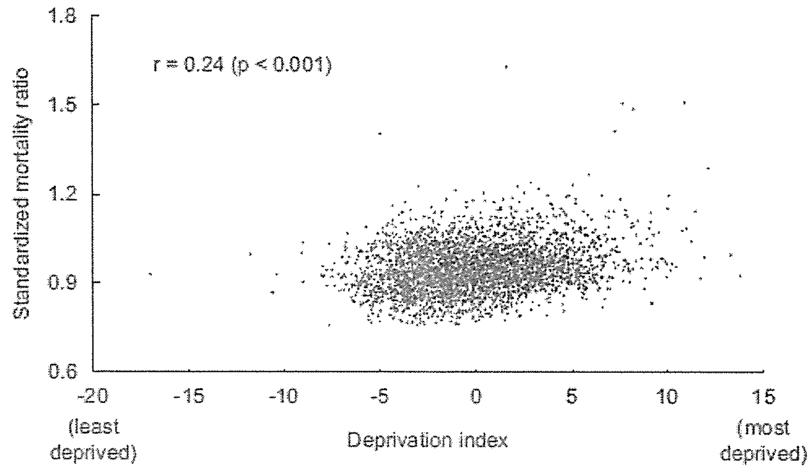

Figure 3 Municipal deprivation index and Bayesian standardized mortality ratio of women aged under 75 ($N = 3366$).

2.93, and the correlation coefficient between BSMR and the deprivation index were 0.692 for men and 0.474 for women.

Discussion

We formulated deprivation indices using multiple socioeconomic indicators at the prefectural and municipal levels in Japan, and examined the relation between the indices and mortality. The formulated deprivation indices were significantly related to higher mortality at both levels, especially for men and premature mortality.

Selection of indicators and the method of index formulation are critical matters in this study. Indicator selection was based on the main domains of established indices in other countries. The seven domains applied in this study are common for established indices that have been recently used in other industrialized countries.[11–19] The indicators were drawn from reliable and routinely available data sources of the census and census-like surveys, except one sampling survey (the Housing and Land Survey).[38,42,43] Other domains, however, such as car ownership, barriers to services/transport, communication and crime, could be used as additional domains. Moreover, there are various indicators in one domain: e.g. the domain of vulnerable group could include the elderly population, single parents, foreigners and others,[10,15–17] although we selected the indicator related to the elderly population, considering this current priority issue in Japan.

Among the indicators used in this study, the rate of households on public assistance as the domain of low social class and poverty showed the strongest correlation with mortality, as shown in Appendix B. The strong correlation of rate of households on public assistance with other domains suggested that this indicator is a critical domain of area deprivation in Japan. The domains of low education and low income were negatively correlated with some other domains and female mortality. These findings indicate the particular and complicated situation related to area deprivation in Japan. Thus, a more systematic approach is required for the selection of domains and indicators for an agreed-on deprivation index, taking account of possible differences in socioeconomic and cultural conditions between countries.

To formulate a single index, we used two common methods: z-scoring and factorial analysis.[3,8,17,19,20,39,46] Besides, there are more complicated methods for index formulation such as assigning weights to domains and using multiple indicators for each domain.[3,13,15,16,39] Use of different indicators and methods of formulation would yield some differences in the regional distribution of deprivation and in the relation to mortality, although it is difficult to identify which method is theoretically more appropriate. The strong correlation between two indices (DIz and DIc), and consequently similar relation of these indices to mortality suggests the possibility that the method of index formulation is not too critical in our setting.

At a smaller level, as indicators show statistical fluctuation, a combination of multiple indicators for each domain might allow formulation of a more stable index. The restricted analysis for the larger-size municipalities showed the stronger correlation coefficient between BSMR and the deprivation index and the smaller variation of the deprivation. Therefore, analysis for total municipalities appeared to underestimate the relation between area deprivation and mortality because of statistical instability of the deprivation index due to the small population number.

Our results showed the significant relation between area deprivation and higher mortality, and there were sex and age group differences: the relation was more pronounced for men and premature mortality compared to women and total population mortality. A tendency for male mortality to be more strongly related to socioeconomic factors than female mortality has been demonstrated,[47,48] and the stronger relationship between socioeconomic factors and male mortality could be explained by their higher sensitivity to socioeconomic factors and a larger contribution of health-related behaviour.[49,50] The moderate relationship between socioeconomic factors and mortality in the elderly population could be mainly explained by the selective survivor bias, in which vulnerable people are likely to die before becoming elderly and thus elderly people are less vulnerable and healthier survivors.[51–53]

Recent studies demonstrated that area characteristics influence population health and health-related behaviour such as smoking and dietary habit independently of individual characteristics.[6–8] In Japan, previous studies have confirmed that socioeconomic area characteristics are related to mortality and health-risk behaviour,[27,28,50] while the index used in these studies might represent urban–rural difference rather than socioeconomic advantage/disadvantage itself.

As the present study applied an ecological study design, contextual and compositional effects could not be distinguished.[1] In addition to previous ecological studies demonstrating the relation of lower socioeconomic conditions of residential areas and higher mortality,[27,28] individual-based studies indicated higher mortality in individuals with lower socioeconomic status.[54,55] However, these individual-based studies did not consider the area variation. Analysis with socioeconomic indicators at both levels and using such multilevel analysis will identify the precise independent influences at each level. In this context, suitable indices representing area deprivation are needed.

Japan has the longest life expectancy in the world,[33] and it has been pointed out that factors contributing to the achievement of this healthiest status include less socioeconomic disparities, in addition to improved standard of living, universal access to healthcare services, and other factors.[34,35] A previous study demonstrated that the national financial adjustment policy helped to reduce disparity in health levels across Japan over the past few decades.[56] As shown in the present study, however, area socioeconomic disadvantage is significantly related to higher mortality even in this healthiest country, and the impact of area disadvantage, especially on men and premature death, is not too small to be ignored. Policy paying attention to area characteristics will diminish health inequalities and consequently improve population health.

In conclusion, the present study formulated a single index for area measures of socioeconomic deprivation, and the index showed a substantial relation to mortality, especially for men and premature mortality. We found that deprived areas showed higher mortality at both the prefectural and municipal levels. Although further discussion on index formulation is needed, the proposed index based on a common set of socioeconomic indicators will be applicable for research on the effects of area characteristics on health.

Appendix A. Definitions and survey/sources of indicators in deprivation index.[38,42,43]

Indicator	Definition	Survey/source, year (level of analysis)
Unemployment rate	Percentage of persons aged 15 and over who are jobless, engaged in job-seeking activities, and able to be employed	Census, 2000 (prefecture); 1995 (municipality)
Dwelling rooms/area per household[a]	Average number of dwelling rooms per residential dwelling (prefecture); average	Housing and Land Survey, 1998 (prefecture); Census, 1995 (municipality)

	floor space per residential dwelling (m^2) (municipality)	
Proportion of households on public assistance	Number of households assisted by livelihood protection per 1000 households	Statistical Report on Social Welfare Administration Services, 2000 (prefecture); 1995 (municipality)
Percentage of persons with the higher education	Percentage of persons having completed up to college and university in the population aged 20–65 years	Census, 2000 (prefecture); 1990 (municipality)
Per capita income[a]	Total taxable income divided by total population (yen)	Annual Report on Prefectural Account, 1999 (prefecture); Indicators of Citizen's Income, 1995 (municipality)
Percentage of owned houses[a]	Percentage of owned houses to total residential households	Census, 2000 (prefecture); 1995 (municipality)
Percentage of aged single households	Percentage of households of single person aged 65 and over to total households	Census, 2000 (prefecture); 1995 (municipality)

[a]Reversed when deprivation index was formulated.

Appendix B. Matrix of correlation coefficients between mortality and domains used for deprivation index

Mortality/domain[a]	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Male mortality		0.53	0.53	0.17	0.63	0.47	0.07	0.54	0.54
(2) Female mortality	0.54		0.52	0.44	0.41	−0.07	0.36	−0.07	0.17
(3) Unemployment	0.35	0.46		0.67	0.82	−0.10	0.57	0.31	0.43
(4) Household overcrowding	0.20	0.44	0.56		0.46	−0.34	0.89	−0.15	0.14
(5) Low social class and poverty	0.47	0.28	0.28	0.34		0.13	0.45	0.49	0.69
(6) Low education	0.18	−0.20	−0.40	−0.39	0.20		−0.48	0.69	0.28
(7) No home ownership	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.		−0.22	0.16
(8) Low income	0.26	−0.15	−0.21	−0.18	0.41	0.79	n.a.		0.65
(9) Vulnerable group	0.21	−0.06	−0.07	0.16	0.52	0.39	n.a.	0.59	

The upper values in bold are for prefectural analyses, and the lower values are for municipal analyses. n.a.: not available.
[a](1) and (2): Age-adjusted mortality rate or standardized mortality ratio of population aged under 75; (3)–(9): see Appendix A. Some indicators were reversed so that the positive sign represented the deprived.

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