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TITLE

Socioeconomic characteristics associated with increased suicide risk across 1887 municipalities in Japan, 2009-2017.

Authors

Eiji Yoshioka[1], MD, PhD, e-mail: e-yoshi@asahikawa-med.ac.jp

Sharon J.B. Hanley, MA (Hons), PhD[2], e-mail: sjbh1810@med.hokudai.ac.jp

Yukihiro Sato, DDS, PhD[1], e-mail: yukihiro-sato@asahikawa-med.ac.jp

Yasuaki Saijo, MD, PhD[1], email: y-saijo@asahikawa-med.ac.jp

[1] Department of Social medicine, Asahikawa Medical University

[2] Center for Environmental and Health Sciences, Hokkaido University

Corresponding author

Eiji Yoshioka, MD, PhD, e-mail: e-yoshi@asahikawa-med.ac.jp

Department of Social Science, Asahikawa Medical University, Midorigaoka-higashi 2-1-1-1, Asahikawa, Hokkaido 078-8510, Japan.

TEL: +81-166-68-2401; **FAX:** +81-166-68-2409.

Abstract

Objective: Previous studies have indicated that spatial variation in suicide mortality is associated with area-specific socioeconomic characteristics, such as socioeconomic deprivation and social fragmentation. However, most of these studies have been conducted in the West and findings from Asian countries are limited. This study aims to investigate associations between socioeconomic characteristics and suicide mortality rates across 1887 municipalities in Japan between 2009 and 2017. We also assessed these associations by gender and age group.

Methods: Suicide data were obtained from suicide statistics of the Ministry of Health, Labour and Welfare in Japan and included information on the number of suicides by gender, age, and municipality location. Social fragmentation, socioeconomic deprivation, and urbanity were used as socioeconomic characteristics in this study and were created from survey data obtained from the 2010 census. Bayesian hierarchical models were used to examine associations between socioeconomic characteristics and suicide risk.

Results: Among the Japanese population, increased rate ratios of suicide were significantly associated with higher levels of socioeconomic deprivation and lower levels of urbanity but not with social fragmentation. Gender-/age-specific analyses revealed that the associations between area-specific socioeconomic characteristics and area suicide risk varied considerably by gender and age. For both males and females aged 0-39 years, socioeconomic deprivation was not significantly associated with area-specific suicide risk, but social fragmentation was significantly associated.

Conclusion: Our results show that there are clear geographic and socioeconomic inequalities associated with the risk of suicide in Japan, which vary by gender and age. Suicide prevention in Japan should particularly focus on areas with high levels of deprivation or low levels of urbanity. Furthermore, young Japanese people residing in the most fragmented municipalities were also at high risk of suicide, and appropriate measures need to be taken.

Key words

Suicide; Socioeconomic deprivation; Social fragmentation; Spatial analysis; Bayesian hierarchical models.

Strengths and limitations of this study

- In this study, spatial analysis is conducted using data on the number of suicides in municipalities, which are relatively small geographic units.
- The results of spatial analysis for small geographic units can be unstable and unreliable, and this study used A Bayesian hierarchical Poisson regression model to address this problem.
- This study considers social fragmentation, socioeconomic deprivation, and urbanity as area-specific socioeconomic characteristics.
- Since this is an ecological study, the associations identified cannot be directly inferred at the individual level.

Introduction

Suicide is a leading cause of premature mortality worldwide. In addition, there are notable geographic variations in the incidence of suicide globally. According to one WHO report,[1] national suicide rates range from 0.4 to 44.2 per 100,000 people. Within the same country, suicide incidence also varies between regions and distinct features exist with regards to geographic distribution.[2–4]

Previous studies have indicated that spatial variation in suicide mortality is associated with area-specific socioeconomic characteristics.[2,5,6] One such characteristic is socioeconomic deprivation, which refers to geographical concentrations of material hardship.[7–9] It is also considered to be multidimensional, composed of poverty, housing, employment, education, racial composition, and occupational domains.[10] Systematic reviews, largely based on studies conducted in the West, indicate that areas characterized by high levels of socioeconomic deprivation tend to have increased suicide rates.[5,6] In addition, social fragmentation is another factor possibly associated with area-specific suicide risk.[11,12] This refers to low levels of community integration linked to above-average numbers of non-family households (for example, one-person households), high residential turnover and concentrations of particular household tenure, such as short-stay private rented households.[9,12,13] Recently, there is growing evidence that areas characterized by high levels of social fragmentation have increased suicide rates.[3,9,11,14]

So far, studies investigating the association between area-specific suicide rates and socioeconomic

characteristics have been mainly conducted in European countries, the United States, and Australia.[5,6] In comparison, reports from Asian countries are limited. Regarding socioeconomic factors associated with area-specific suicide risk, it has been pointed out that findings from Asian countries may be different from those of Western countries.[15] The results from the UK tended to show that area-specific suicide risk was more strongly associated with social fragmentation than socioeconomic deprivation.[11,12,14,16,17] In contrast, studies from Taiwan and Hong Kong have shown that indicators of socioeconomic deprivation appear to affect area-specific suicide risk as strong or stronger than those of social fragmentation.[3,15,18] Although it is not clear why the findings of Asian countries are different from those of the UK, Lin et al. suggested that one of the reasons may be the differences in social protection measures between the UK and Asian countries.[15] That is, social protection measures might be relatively more comprehensive in the UK than in Asian countries and offset some of the suicide risk in deprived areas. Japan can provide a unique setting to investigate the spatial patterning and determinants of suicide since Japan has developed a more comprehensive social security system compared to most other Asian countries.[19] Identifying socioeconomic characteristics that are strongly associated with area-specific suicide risk in Japan may provide important insights into the differences between the UK and Asia.

In addition, studies have indicated that associations between suicide rate and area-specific characteristics might vary by gender/age group.[6,14,20] One review article from European countries showed that a positive association between area-level deprivation and suicidal behaviour was consistent

across different countries, all age groups, and both genders, but was particularly the case for men.[6] However, there are still limited findings as to whether the differential associations by demographic group observed in Western countries could also be found in non-Western settings. Furthermore, previous studies have shown no consistent pattern of gender-/age-difference in the association of suicide with social fragmentation.[3,14,20]

This study aimed to investigate the association between a variety of socioeconomic characteristics, including socioeconomic deprivation and social fragmentation, and suicide mortality across 1887 municipalities in Japan between 2009 and 2017. We also assessed these associations by gender and age group.

Methods

Suicide and population data

Suicide data between 2009 and 2017 were obtained from the suicide statistics of the Ministry of Health, Labour and Welfare in Japan,[21] and included information on the number of suicides by gender, age, and municipality location. Each suicide is assigned to a municipality based on residential address before death. In this study, the units of analyses were municipalities. The category of municipality in Japan consists of "special wards of the Tokyo Metropolis," "cities," "towns," and "villages." In addition, 20 large cities (cities designated by ordinance) consist of several wards. These wards were also used as municipalities in

this study. Because three of the cities designated by ordinance (Kumamoto, Okayama, Sagamihara) were subdivided into wards after January 2009, these cities were aggregated in this study. Therefore, although there were 1896 municipalities in Japan in 2017, suicide data were grouped into 1887 aggregated municipalities. Population data for each of the municipalities in Japan by year were obtained from demographic surveys based on the nation's domiciliary registration system.[22]

Area-specific socioeconomic characteristics

Previous studies in the United Kingdom, Finland, the Netherlands, and Sweden calculated the indices of social fragmentation and socioeconomic deprivation by using data from the census.[12,14,23–25] Our study also carunculated the indices of social fragmentation and socioeconomic deprivation for each municipality in Japan based on the computational procedures of these previous studies, using data from the 2010 Census.[26] The social fragmentation index, reflecting low levels of community integration, was based on single-person households (% of single-person households), unmarried adults (% of unmarried adults), population mobility (% of those who moved to the address in the last five years). The socioeconomic deprivation index was calculated by unemployment rate (% of people aged 15+ who were neither in paid employment nor in school or higher education), educational level (% of those aged 35-64 with less than college education), and not-owner-occupied households (% of households where the occupants did not own their house). To construct both indices, each input variable was z-scored and

summed, with higher scores referring to higher levels of social fragmentation and socioeconomic deprivation. These area-specific socioeconomic characteristics were selected based on findings from previous studies.[5,10,12,14] Large proportions of single-person households, unmarried adults and population mobility were significantly associated with an increased risk of area-specific suicide mortality.[14] And they are among the variables included in Congdon's index of social fragmentation.[12] Large proportions of unemployment and not-owner-occupied households were significantly associated with an increased risk of suicide,[5,14] and they are among the variables included in the Townsend's deprivation index.[14] A low level of educational attainment was significantly associated with an increased risk of suicide,[5] and educational attainment is considered to be one of the domains of area-specific deprivation.[10] And thus, in this study, we used single-person households, unmarried adults and population mobility as indicators of social fragmentation, and unemployment rate, educational attainment and not-owner-occupied households as indicators of socioeconomic deprivation. In addition to social fragmentation and socioeconomic deprivation, population density was used as an indicator of urbanity.[27] Population density (people per square kilometre [km^2]) for each area was calculated by using the 2010 census population data. We divided the indicators of social fragmentation, socioeconomic deprivation and urbanity into quartiles. None of these area-specific characteristics was gender-/age-specific.

Statistical analysis

For each municipality, we calculated 'raw' (unsmoothed) standardized mortality ratios (SMRs: the ratio of the observed to the expected number of suicides) for inhabitants during the period 2009–2017. Expected suicides were calculated by multiplying the national gender-and age-specific suicide rates (in 10-year age-bands) by the corresponding gender-and age-specific population in each municipality. SMRs for males and females under the age of 40 years, 40–59 years and 60 years or above were also calculated separately. Geographic variations in suicide rates were presented using differences over the middle 90% of SMRs (i.e., the ratios between values at 95% and 5%), as extreme values at both ends of the distribution are likely to be unreliable estimates.

Bayesian hierarchical models were used to estimate the 'smoothed' SMR for each municipality. These were based on Poisson regression models with random effects allowing for both non-structural variability (heterogeneity across all areas in the study region) and structural variability (autocorrelation between neighboring areas).[28–30] In the models used, an intrinsic conditional autoregressive prior distribution was assigned to the random effect for structural variability, while the random effect for non-structural variability was represented using independent normal distributions. The default prior distributions were specified for the model parameters.[31] Sensitivity tests with altered hyperparameters did not change the results, confirming the robustness of the results. Sets of municipalities that share a border were defined as neighboring areas. Concerning island areas, sets of municipalities that have a regular sea route were defined as neighboring areas, therefore all municipalities had some neighboring areas. Associations with area-

specific socioeconomic characteristics were examined before and after controlling for all other variables in multivariable models. 'Residual' SMRs after controlling for the effects of all investigated socioeconomic variables were estimated and mapped, to investigate the spatial patterning of residual variation which could not be accounted for by studied variables. The models were estimated with integrated nested Laplace approximation [32,33]. Statistical analyses of the models were carried out using the R-INLA library (18.07.12) in R-3.5.3. All other statistical analyses were performed using Stata statistical software, version 15.1, for Macintosh (StataCorp, College Station, TX, USA).

SMRs were mapped using seven categories that are symmetrical on the logarithmic scale (< 0.50, 0.50 – < 0.67, 0.67 – < 0.90, 0.90 – < 1.10, 1.10 – < 1.50, 1.50 – < 2.00, and ≥ 2.00). Red, blue and pale yellow with varying degrees of lightness were used to present those higher (red) and lower (blue) than the middle category (pale yellow), respectively. All maps were produced using QGIS Version 2.18.15 for Macintosh.

Patient and public involvement

No patient involved.

Results

Table 1 summarizes the number of suicides, population and area-specific socioeconomic characteristics of the 1887 municipalities in Japan used in this study. There were 240,673 suicides in Japan between 2009

and 2017. Of these, 2,699 (1.1%) suicides were excluded from the analysis because address or age data were unavailable, and thus 237,974 suicides (males: 164,432 [69.1%]) were used in the study. Across municipalities, the number of suicide deaths ranged from 0 to 1440. The number of suicides was zero in 15 of the 1887 municipalities. For males aged 0-39 years, 158 municipalities (8.4%) had zero suicides. Corresponding figures were 80 (4.2%) for males aged 40-59 years, 57 (3.0%) for males aged 60+ years, 439 (23.3%) for females aged 0-39 years, 271 (14.4%) for females aged 40-59 years, and 120 (6.4%) for females aged 60+ years.

Table 1. Summary statistics of the number of suicides in 2009-2017, as well as population and area-specific socioeconomic characteristics from the 2010 census, across 1887 municipalities in Japan.

	Mean	SD	Min	25%	Median	75%	Max
Number of suicides in 2009-2017	126.1	176.8	0	5	60	468	1440
Populaiton size	67862.9	99233.4	201	9842	30534	82866	671138
Single-person households (%)	27.0%	8.9%	8.8%	20.8%	25.8%	31.2%	65%
Unmarried adult population (%)	39.4%	3.3%	28.5%	37.3%	39.0%	40.8%	55%
Population mobidity (%)	18.2%	5.8%	5.4%	13.7%	17.9%	22.0%	44.1%
Unemployment rate (%)	6.3%	2.1%	0%	5.1%	6.2%	7.3%	27%
Non-owner occupied households. (%)	26.2%	13.4%	2.3%	16.0%	24.6%	34.4%	83%
Population with less than college degree (%)	85.4%	6.8%	53.8%	82.1%	86.7%	90.3%	95%
Population density (people/km^2)	1516.9	3138.6	1.6	69.8	248.2	1107.2	21398.3

Table 2 shows estimates of suicide rate ratios among the total Japanese population according to levels of each of the area-specific socioeconomic characteristics before and after adjustment. Compared to the Quartile 1 group, there were no statistical differences in the associations between social fragmentation and area-specific suicide risk in the other groups. Regarding socioeconomic deprivation, the rate ratios of suicide were significantly higher in Quartile 2, Quartile 3, and Quartile 4 compared to Quartile 1. And as the level of deprivation increased, so did the suicide risk. With regard to the level of urbanity, the rate ratios of suicide were significantly lower in Quartile 2, Quartile 3, and Quartile 4 compared to Quartile 1. And as the level of urbanity increased, the suicide risk became smaller. For neither fragmentation, deprivation, nor urbanization did the rate ratios of suicide change much before or after the adjustment.

Table 2. Rate ratios (and 95% credible intervals) of suicide among the Japanese population according to quartile levels of each of the area-specific characteristics.

	Quartile 1	Quartile 2		Quartile 3		Quartile 4	
Social fragmentation							
Unadjusted	Ref.	0.98	(0.95, 1.01)	0.98	(0.95, 1.00)	1.02	(0.99, 1.05)
Adjusted[#]	Ref.	0.98	(0.95, 1.00)	0.97	(0.95, 1.00)	1.00	(0.97, 1.04)
Socioeconomic deprivation							
Unadjusted	Ref.	1.04*	(1.01, 1.06)	1.07*	(1.05, 1.10)	1.12*	(1.09, 1.15)
Adjusted[#]	Ref.	1.05*	(1.03, 1.07)	1.09*	(1.06, 1.12)	1.13*	(1.10, 1.17)
Urbanity							
Unadjusted	Ref.	0.93*	(0.90, 0.96)	0.85*	(0.83, 0.88)	0.80*	(0.77, 0.83)
Adjusted[#]	Ref.	0.93*	(0.90, 0.95)	0.84*	(0.82, 0.87)	0.79*	(0.77, 0.82)

*: p-value < 0.05. #: adjustments for the other two area-specific characteristics.

Quartile 1 refers to the lowest levels of fragmentation, deprivation and urbanity, and Quartile 4 refers to the highest levels.

Figure 1 shows the maps of smoothed SMRs (sSMRs) and residual SMRs (rSMRs) after taking into account all studied area-specific characteristics for suicide among the total Japanese population. Compared with the map of sSMRs, the spatial concentration of high and low risk areas was attenuated or disappeared in the map of rSMRs. This suggests that the spatial patterning of suicide can be explained to some extent by the area-specific characteristics investigated in the current study. The 90% range of sSMRs was 0.81 to 1.31 (a 1.6-fold difference), while the corresponding rSMRs values were 0.86 to 1.21 (a 1.4-fold difference).

Table 3 shows gender-/age-specific estimates of suicide rate ratios according to levels of each of the area-specificsocioeconomic characteristics after adjusting for all other variables. Regarding social fragmentation, the rate ratios of suicide were significantly larger in Quartile 4 compared to Quartile 1 for males aged 0-39 years and females aged 0-39 and 40-59 years. However, the rate ratios were significantly smaller in Quartile 2, Quartile 3, and Quartile 4 for males aged 60 years and older, and in Quartile 3 and Quartile 4 for females aged 60 years and older, compared to Quartile 1. Concerning socioeconomic deprivation, the rate ratios were significantly larger in Quartile 2, Quartile 3, and Quartile 4 than in Quartile 1 for males aged 40-59 and 60+ years and females aged 40-59 and 60+ years. And for males aged 40-59 and 60+ years and females aged 40-59 years, the rate ratios of suicide tended to increase as the level of deprivation increased. And the values of the rate ratios were greater for men than for women, suggesting that the associations between deprivation and suicide are stronger for men. Regarding urbanity, the rate ratios were significantly smaller in Quartile 2, Quartile 3, and Quartile 4 compared to Quartile 1 among

males aged 0-39, 40-59 and 60+ years and females aged 60+ years. And for these gender-age groups, the rate ratios of suicide tended to decrease as the level of urbanity increased. Among women aged 40-59 years, the rate ratio of suicide was significantly smaller only in Quartile 2 compared to Quartile 1. The values of the rate ratios were smaller for men than for women, suggesting that the associations between urbanity and suicide are stronger for men.

Table 3. Rate ratios (and 95% credible intervals) of suicide in males and females aged 0-39, 40-59 and 60+ years according to quartile levels of each of the area characteristics after adjusting for other characteristics.

	Quartile 1	Quartile 2		Quartile 3		Quartile 4	
Males aged 0-39							
Social fragmentation	Ref.	1.01	(0.96, 1.06)	1.01	(0.96, 1.06)	1.07*	(1.01, 1.13)
Socioeconomic deprivation	Ref.	1.02	(0.98, 1.06)	1.04	(1.00, 1.08)	1.02	(0.98, 1.07)
Urbanity	Ref.	0.92*	(0.86, 0.98)	0.85*	(0.80, 0.91)	0.79*	(0.74, 0.84)
Males aged 40-59							
Fragmentation	Ref.	1.01	(0.97, 1.05)	1.01	(0.97, 1.05)	1.04	(0.99, 1.08)
Deprivation	Ref.	1.07*	(1.04, 1.10)	1.13*	(1.09, 1.17)	1.22*	(1.18, 1.26)
Urbanity	Ref.	0.93*	(0.89, 0.98)	0.83*	(0.79, 0.87)	0.72*	(0.69, 0.76)
Males aged 60+							
Fragmentation	Ref.	0.94*	(0.90, 0.98)	0.94*	(0.90, 0.98)	0.95*	(0.90, 1.00)
Deprivation	Ref.	1.07*	(1.03, 1.11)	1.14*	(1.09, 1.18)	1.26*	(1.21, 1.31)
Urbanity	Ref.	0.93*	(0.88, 0.97)	0.8*	(0.76, 0.84)	0.75*	(0.71, 0.79)
Females aged 0-39							
Fragmentation	Ref.	0.99	(0.91, 1.07)	1.05	(0.97, 1.14)	1.15*	(1.06, 1.25)
Deprivation	Ref.	1.03	(0.97, 1.09)	1.05	(0.99, 1.12)	1.06	(1.00, 1.14)
Urbanity	Ref.	1.00	(0.90, 1.13)	1.01	(0.91, 1.13)	1.09	(0.98, 1.22)
Females aged 40-59							

Fragmentation	Ref.	1.03	(0.96, 1.10)	1.07	(1.00, 1.14)	1.13*	(1.05, 1.21)
Deprivation	Ref.	1.06*	(1.01, 1.11)	1.08*	(1.03, 1.14)	1.15*	(1.09, 1.21)
Urbanity	Ref.	0.91*	(0.84, 1.00)	0.93	(0.86, 1.01)	0.96	(0.88, 1.05)
Females aged 60+							
Fragmentation	Ref.	0.96	(0.91, 1.01)	0.91*	(0.86, 0.96)	0.88*	(0.83, 0.93)
Deprivation	Ref.	1.08*	(1.04, 1.13)	1.08*	(1.03, 1.13)	1.07*	(1.01, 1.12)
Urbanity	Ref.	0.94*	(0.88, 0.99)	0.87*	(0.82, 0.92)	0.85*	(0.80, 0.91)

*: p-value < 0.05.

Quartile 1 refers to the lowest levels of fragmentation, deprivation and urbanity, and Quartile 4 refers to the highest levels.

Discussion

Main findings

In this study, we examined the associations between suicide rates and area-specific socioeconomic characteristics across 1877 municipalities in Japan during the period 2009-2017. This study considered social fragmentation, socioeconomic deprivation, and urbanity as area-specific socioeconomic characteristics. Among the total Japanese population, municipalities with higher levels of socioeconomic deprivation were associated with greater suicide risk, and those with higher levels of urbanity were associated with smaller suicide risk. As for social fragmentation, however, there was no association with area-specific suicide risk. Gender-/age-specific analyses revealed that the associations between area-specific socioeconomic characteristics and area suicide risk varied considerably by gender and age in Japan. Municipalities in the highest quartile level for social fragmentation were associated with significantly larger suicide risk than those in the lowest quartile among males aged 0-39 and females aged 0-39 and 40-59. Higher levels of socioeconomic deprivation were associated with greater suicide risk among males aged 40-59 and 60+, and among females aged 40-59, with the association appearing to be stronger for males than for females. Higher levels of urbanity were associated with smaller suicide risk among males of all the age groups and among females aged 60+ years, with the association appearing to be stronger for males than for females.

Socioeconomic correlates of overall suicides

The findings from the UK indicated that the associations of area-specific suicide risk were stronger with social fragmentation rather than socioeconomic deprivation.[11,14] There are several possible reasons why the results of the Japanese population in our study differed from the findings of the UK in that social fragmentation was not associated with suicide risk while socioeconomic deprivation was associated with the risk. Firstly, this result may be influenced by the fact that Japan started suicide prevention measures at the national level much later than the UK. The UK government launched the Health of the Nation strategy in 1992, which included suicide reduction as a key target area.[34] On the other hand, in Japan, the Basic Law for Suicide Countermeasures was finally enacted in 2009, and since then, suicide countermeasures at the national level have started in earnest.[35] Secondly, differences in social and cultural circumstances between Japan and the UK may have influenced the results. The society of Japan is considered to be more cohesive than that of many Western countries, including the UK.[36,37] The cohesiveness of society may have considerably reduce the effect of social fragmentation on area-specific suicide risk in Japan.

The studies in Taiwan and Hong Kong showed that both social fragmentation and socioeconomic deprivation were associated with area-specific suicide risk, but deprivation tended to be more strongly associated with suicide risk compared to fragmentation.[3,15,20] It is possible that Taiwan and Hong Kong, like Japan, are also more cohesive societies than the UK, which has resulted in a stronger impact of deprivation, as found in the current study. And the findings in Taiwan and Hong Kong were somewhat

different from our results of the Japanese population. In Japan, no significant association was found between fragmentation and suicide, but in these two countries, a significant association was indicated. The difference in the results may be due to the different indicators used. That is, unlike our study, the studies of Taiwan and Hong Kong did not use composite measures of fragmentation or deprivation, and rather used indicators directly from the census and other sources, such as unemployment rate, unmarried adults and educational attainment, without compositing them.

Socioeconomic correlates of gender-age-specific suicides

A review article in Europe indicated that the associations between area-level socioeconomic disadvantage and suicidal behaviours were more pronounced among men,[6] and the results of our study in Japan were similar, with a stronger association in males. However, our study did not find the significant association for males aged 0-39. As for the associations of suicide with social fragmentation, previous studies showed no consistent pattern with respect to gender or age.[3,14,15,20] Our results indicated that, only among males aged 0-39 and females aged 0-39 and 40-59 years, suicide risk was significant larger for municipalities in the highest quartile category of social fragmentation. Future researches will need to clarify why area-specific suicide risk among young Japanese population is not associated with socioeconomic deprivation, but social fragmentation. Concerning males and females aged 60+ years, suicide risk appeared to be lower in municipalities with higher level of social fragmentation.

These results were difficult to interpret appropriately. We think that these unexpected results are due to the failure of this study to consider some important factors in the area risk of suicide among old people, such as social capital and neighbourhood specific features. Previous studies in Taipei have shown that election participation, a proxy indicator of linking social capital, was associated with reduced suicide rates in females aged 65 + years after adjusting for a variety of areasocioeconomic characteristics.[15] An ecological study in Hong Kong indicated that neighborhood specific features, such as recreational services, daily necessity resources, and community centers, were significantly associated with suicides in older adults.[38]

As for the associations of suicide with urbanity, previous studies showed no consistent pattern with respect to gender or age.[3,4,14,24] In our study, higher levels of urbanity assessed by population density were associated with a decreased risk of suicide in males but not necessarily in females. Previous review article on suicide in rural areas has reported that geographic and interpersonal isolation, agricultural or otherwise hazardous vocational demands, environmental and governmental policies, availability of means, lack of access to care and rural ideologies appear to contribute to suicide risk among people residing in rural areas.[39] Therefore, since Japanese men can be vulnerable to rural characteristics such as those mentioned above, suicide prevention in Japan measures should take this into account.

Limitations

Our study had several methodological issues which must be acknowledged. First, since this is an ecological study, the associations identified cannot be directly inferred at the individual level. Furthermore, as indicators of area-specific characteristics in this study were used to describe the overall social and economic environment of each area, these exposure measures are not gender-/age-specific. And thus, this may limit the interpretability of findings from subgroup analyses. Second, the indices of fragmentation and deprivation used in our study were calculated based on those used in the previous studies of European countries.[12,14,23–25] However, it is possible that the indices did not sufficiently reflect the circumstances in Japan. Therefore, it will be necessary to investigate in the future what indicators can adequately assess social fragmentation and socioeconomic deprivation in Japan. Third, area socioeconomic characteristics investigated in the study did not include other variables of potential importance such as alcohol consumption and the prevalence of mental disorders, for which data were unavailable. Forth, different municipalities might have experienced different secular trends in suicide during the 9-year study period. Fifth, we used municipalities as the unit of analysis. Although municipalities are not large geographical units, they vary greatly in both geographical and population size in Japan. Finally, congruent with most previous studies,[3,14] we assumed that people are only exposed to their actual place of residence. As suicide risk develops over a lifetime, future studies should be longitudinal and include people's residential history over their life course.

Conclusion

Our results, along with findings from other countries and regions, show that there were marked geographic and socioeconomic inequalities in suicide, which varied considerably by gender and age. These suggest that appropriate attention should be paid to social policies addressing social fragmentation, socioeconomic deprivation and urbanity underlying the spatial variations in suicide in countries. Concerning Asian countries and regions, including Japan, it seems that suicide prevention needs to focus on areas with high level of socioeconomic deprivation rather than social fragmentation. However, among the younger Japanese population, suicide risk is larger in municipalities with high level of social fragmentation, and appropriate measures for this need to be taken. And to construct effective place-based interventions more research is needed into underlying mechanisms in order to identify specific area characteristics that exacerbate or protect against suicide risk.

Ethical Approval Statement

Not applicable

Contributors

EY contributed conception and design of the study, acquisition and analysis of data, and analysis and interpretation of data, and drafted the article and approved the final version to be published. SH contributed analysis and interpretation of data and drafted the article and approved the final version to be

published. YS contributed analysis and interpretation of data, and revised the article critically for important intellectual content and approved the final version to be published. YS contributed analysis and interpretation of data, and revised the article critically for important intellectual content and approved the final version to be published.

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Competing interests

We declare that we have no conflicts of interest in relation to this study.

Patient consent for publication

Not required.

Data availability

All data used in this manuscript are publicly available. Suicide data are available from the website of suicide statistics (https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/0000140901.html). Data about population estimate are available from the website of Statistics Japan (https://www.e-stat.go.jp/stat-search/files?page=1&toukei=00200241&tstat=000001039591). Data about Census in 2010 are available from the website of Statistics Japan (https://www.e-stat.go.jp/stat-search/files?page=1&toukei=00200521&tstat=000001039448).

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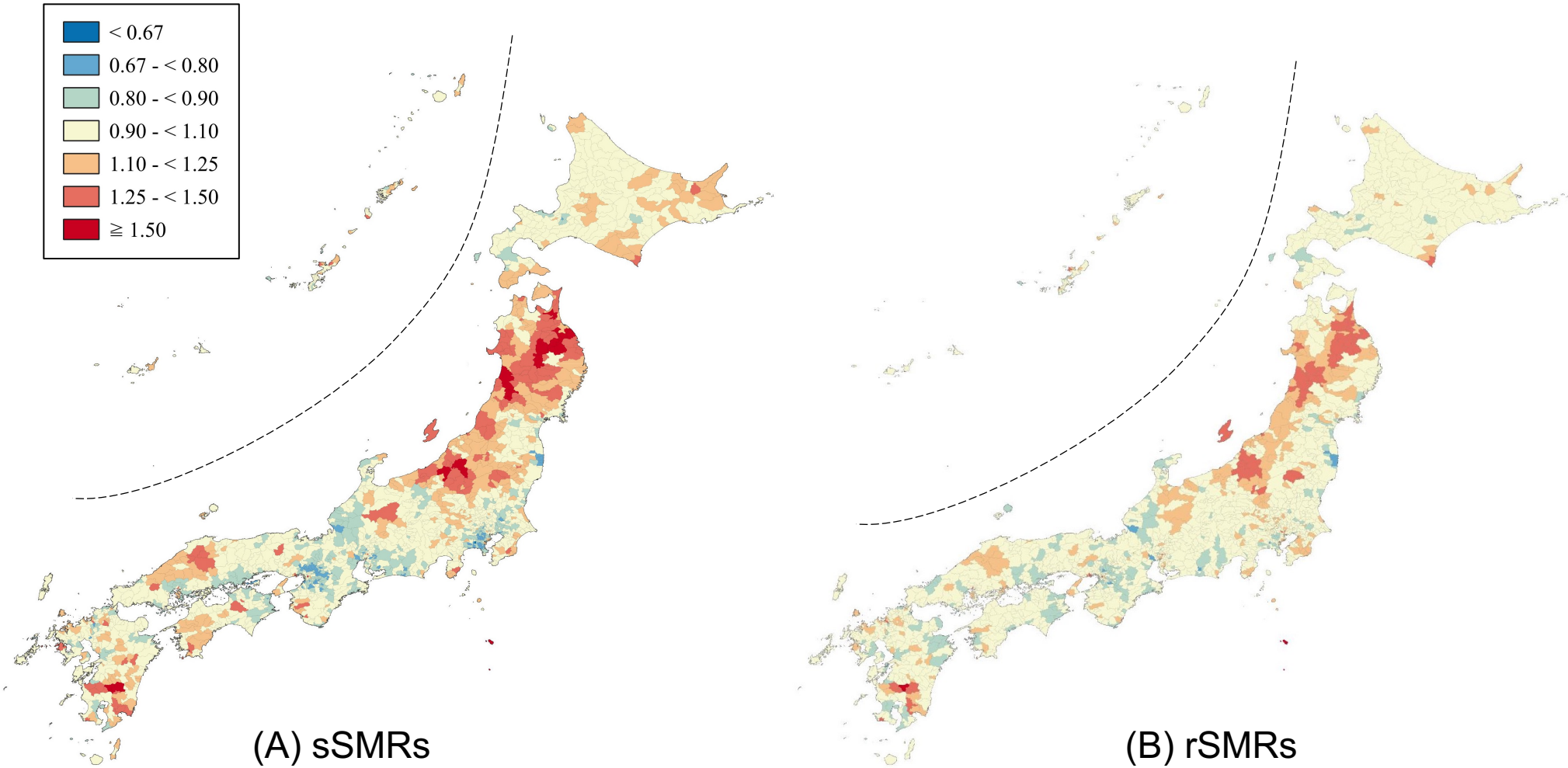

Fig. 1. Maps of (A) smoothed standardized mortality ratios (sSMRs), and (B) residual standardized mortality ratios (rSMRs) after adjusting for social fragmentation, socio-economic deprivation, and urbanity, for suicide among total Japanese population across 1887 municipalities, 2009–2017.

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-10
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-10
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6-7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	6-7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-8*
Bias	9	Describe any efforts to address potential sources of bias	8-10
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-10
		(*b*) Describe any methods used to examine subgroups and interactions	8-10
		(*c*) Explain how missing data were addressed	8-10
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	8-10
		(*e*) Describe any sensitivity analyses	8-10

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10-11
		(b) Give reasons for non-participation at each stage	10-11
		(c) Consider use of a flow diagram	10-11
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11
		(b) Indicate number of participants with missing data for each variable of interest	10-11
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	*10-11*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-12
		(*b*) Report category boundaries when continuous variables were categorized	11-12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Associations between social fragmentation, socio-economic deprivation and suicide risk across 1887 municipalities in Japan, 2009 to 2017: a spatial analysis using the Bayesian hierarchical model.

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TITLE

Associations between social fragmentation, socio-economic deprivation and suicide risk across 1887 municipalities in Japan, 2009 to 2017: a spatial analysis using the Bayesian hierarchical model.

Authors

Eiji Yoshioka[1], MD, PhD, e-mail: e-yoshi@asahikawa-med.ac.jp

Sharon J.B. Hanley, MA (Hons), PhD[2], e-mail: sjbh1810@med.hokudai.ac.jp

Yukihiro Sato, DDS, PhD[1], e-mail: yukihiro-sato@asahikawa-med.ac.jp

Yasuaki Saijo, MD, PhD[1], email: y-saijo@asahikawa-med.ac.jp

[1] Department of Social Medicine, Asahikawa Medical University

[2] Center for Environmental and Health Sciences, Hokkaido University

Corresponding author

Eiji Yoshioka, MD, PhD, e-mail: e-yoshi@asahikawa-med.ac.jp

Department of Social Science, Asahikawa Medical University, Midorigaoka-higashi 2-1-1-1, Asahikawa, Hokkaido 078-8510, Japan.

TEL: +81-166-68-2401; **FAX:** +81-166-68-2409.

Abstract

Objective: Previous studies have indicated that spatial variation in suicide mortality is associated with area-specific socioeconomic characteristics, such as socioeconomic deprivation and social fragmentation. However, most of these studies have been conducted in the West and findings from Asian countries are limited. This study aims to investigate associations between socioeconomic characteristics and suicide mortality rates across 1887 municipalities in Japan between 2009 and 2017. We also assessed these associations by gender and age group.

Methods: Suicide data were obtained from the suicide statistics of the Ministry of Health, Labour and Welfare in Japan and included information on the number of suicides by gender, age, and municipality location. Social fragmentation, socioeconomic deprivation, and urbanicity were used as socioeconomic characteristics in this study and were created from survey data obtained from the 2010 census. Bayesian hierarchical models were used to examine associations between socioeconomic characteristics and suicide risk.

Results:

Suicide rates were significantly higher in municipalities with higher levels of deprivation, with a rate ratio of 1.13 (95% CI: 1.10-1.17) in the highest quartile compared with the lowest. Higher levels of urbanicity had significantly lower suicide rates, with a rate ratio of 0.79 (95% CI: 0.77-0.82) in the highest quartile compared with the lowest. However, associations between exposures and suicide varied considerably by

gender and age. Among both men and women aged 0-39 years, fragmentation was significantly associated with suicide, with rate ratios of 1.07 and 1.15 for men and women, respectively, in the highest quartile compared to the lowest.

Conclusion: Suicide prevention in Japan should particularly focus on areas with high levels of deprivation or low levels of urbanicity. Furthermore, young Japanese people residing in the most fragmented municipalities were also at high risk of suicide, and appropriate measures need to be taken.

Key words

Suicide; Socioeconomic deprivation; Social fragmentation; Spatial analysis; Bayesian hierarchical models.

Strengths and limitations of this study

- In this study, spatial analysis is conducted using data on the number of suicides in municipalities, which are relatively small geographic units.
- The results of spatial analysis for small geographic units can be unstable and unreliable, and this study used a Bayesian Hierarchical Poisson Regression Model to address this problem.
- This study considers social fragmentation, socioeconomic deprivation, and urbanicity as area-specific socioeconomic characteristics.
- Since this is an ecological study, associations identified cannot be directly inferred at the individual

level.

Introduction

Suicide is a leading cause of premature mortality worldwide. In addition, there are notable geographic variations in the incidence of suicide globally. According to one WHO report,[1] national global suicide rates range from 0.4 to 44.2 per 100,000 people. Within the same country, suicide incidence also varies between regions and distinct features exist with regards to geographic distribution.[2–4]

Previous studies have indicated that spatial variation in suicide mortality is associated with area-specific socioeconomic characteristics.[2,5,6] One such characteristic is socioeconomic deprivation, which refers to geographical concentrations of material hardship.[7–9] It is also considered to be multidimensional, composed of poverty, housing, employment, education, racial composition, and occupational domains.[10] Systematic reviews, largely based on studies conducted in the West, indicate that areas characterized by high levels of socioeconomic deprivation tend to have increased suicide rates.[5,6] In addition, social fragmentation is another factor possibly associated with area-specific suicide risk.[11,12] This is derived from Durkheim's theory of social integration,[13] and refers to low levels of community integration linked to above-average numbers of non-family households (for example, one-person households), high residential turnover and concentrations of particular household tenure, such as short-stay private rented households.[9,12,14] Recently, there is growing evidence that areas characterized by high levels of social

fragmentation have increased suicide rates.[3,9,11,15]

So far, studies investigating the association between area-specific suicide rates and socioeconomic characteristics have been mainly conducted in European countries, the United States, and Australia.[5,6] In comparison, reports from Asian countries are limited. Regarding socioeconomic factors associated with area-specific suicide risk, it has been pointed out that findings from Asian countries may be different from those of Western countries.[16] The results from the UK tended to show that area-specific suicide risk was more strongly associated with social fragmentation than socioeconomic deprivation.[11,12,15,17,18] In contrast, studies from Taiwan and Hong Kong have shown that indicators of socioeconomic deprivation appear to affect area-specific suicide risk as strong or stronger than those of social fragmentation.[3,16,19] For South Korea, two spatial analyses reported a positive association between area suicide rates and socioeconomic deprivation, but these studies did not examine the association between social fragmentation and suicide.[20,21] It has been previously reported that there were significant associations between area suicide rates and social environment characteristics such as socio-economic status and isolation.[22] Although it is not clear why the findings of Asian countries are different from those of the UK, Lin et al. suggested that one of the reasons may be the differences in social protection measures between the UK and Asian countries.[16] That is, social protection measures might be relatively more comprehensive in the UK than in Asian countries and offset some of the suicide risk in deprived areas. Japan can provide a unique setting to investigate the spatial patterning and determinants of suicide since Japan has developed a more

comprehensive social security system compared to most other Asian countries.[23] Identifying socioeconomic characteristics that are strongly associated with area-specific suicide risk in Japan may provide important insights into the differences between Western countries and Asia.

In addition, studies have indicated that associations between suicide rate and area-specific characteristics might vary by gender/age group.[6,15,24] One review article from Europe showed that a positive association between area-level deprivation and suicidal behaviour was consistent across different countries, all age groups, and both genders, but was particularly the case for men.[6] Also in South Korea, results of one spatial analysis revealed a clear positive association between suicide rates and area deprivation among men, but this association was less clear for women.[20] However, there are still limited findings as to whether the differential associations by demographic group observed in Western countries could also be found in non-Western settings. Furthermore, previous studies have shown no consistent pattern of gender-/age-difference in the association of suicide with social fragmentation.[3,15,24]

Our previous study investigated the geographic distribution of suicide risk by gender and age group using data on the number of suicides for municipalities in Japan from 2009 to 2017. We found that the geographic distribution of suicide mortality in Japan varied considerably by gender and age.[25] In the current study, we conducted analyses to investigate the association between a variety of socioeconomic characteristics, including socioeconomic deprivation and social fragmentation, and suicide mortality across

1887 municipalities in Japan between 2009 and 2017. We also assessed these associations by gender and age group.

Methods

Suicide and population data

Suicide data between 2009 and 2017 were obtained from the suicide statistics of the Ministry of Health, Labour and Welfare in Japan,[26] and included information on the number of suicides by gender, age, and municipality location. Each suicide is assigned to a municipality based on residential address before death. In this study, units of analyses were municipalities. The category of municipality in Japan consists of special wards of the Tokyo Metropolis; cities; towns; and villages. In addition, 20 large cities (cities designated by ordinance) consist of several wards. These wards were also classifies as municipalities in this study. Because three of the cities designated by ordinance (Kumamoto, Okayama, Sagamihara) were subdivided into wards after January 2009, these cities were aggregated in this study. Therefore, although there were 1896 municipalities in Japan in 2017, suicide data were grouped into 1887 aggregated municipalities. Population data for each of the municipalities in Japan by year were obtained from demographic surveys based on the nation's domiciliary registration system.[27]

Area-specific socioeconomic characteristics

Previous studies in the United Kingdom, Finland, the Netherlands, and Sweden calculated the indices of social fragmentation and socioeconomic deprivation by using data from the census.[12,15,28–30] Our study also calculated the indices of social fragmentation and socioeconomic deprivation for each municipality in Japan based on the computational procedures of these previous studies, using data from the 2010 Census.[31] The social fragmentation index, reflecting low levels of community integration, was based on single-person households (% of single-person households), unmarried adults (% of unmarried adults), and population mobility (% of those who moved to the address in the last five years). The socioeconomic deprivation index was calculated by unemployment rate (% of people aged 15+ who were neither in paid employment nor in school or higher education), educational level (% of those aged 35-64 with less than college education), and non-owner-occupied households (% of households where the occupants did not own their house). To construct both indices, each input variable was z-scored and summed, with higher scores referring to higher levels of social fragmentation and socioeconomic deprivation. These area-specific socioeconomic characteristics were selected based on findings from previous studies.[5,10,12,15] Large proportions of single-person households, unmarried adults and population mobility were significantly associated with an increased risk of area-specific suicide mortality.[15] And they are among the variables included in Congdon's index of social fragmentation.[12] Large proportions of unemployment and non-owner-occupied households were significantly associated with an increased risk of suicide,[5,15] and they are among the variables included in the Townsend's

deprivation index.[15] A low level of educational attainment was significantly associated with an increased risk of suicide,[5] and educational attainment is considered to be one of the domains of area-specific deprivation.[10] And thus, in this study, we used single-person households, unmarried adults and population mobility as indicators of social fragmentation, and unemployment rate, educational attainment and not-owner-occupied households as indicators of socioeconomic deprivation. In addition to social fragmentation and socioeconomic deprivation, population density was used as an indicator of urbanicity.[32] Population density (people per square kilometre [km^2]) for each area was calculated using the 2010 census population data. For the indicators of social fragmentation, socioeconomic deprivation and urbanicity, we used the quartiles as exposure variables in the primary analyses and continuous quantities in the secondary analyses. The continuous quantities of fragmentation and deprivation were z-scored, and population density was transformed to a logarithm and then z-scored. None of these area-specific characteristics was gender-/age-specific.

Statistical analysis

For each municipality, we calculated 'raw' (unsmoothed) standardized mortality ratios (SMRs: the ratio of the observed to the expected number of suicides) for inhabitants during the period 2009–2017. Expected suicides were calculated by multiplying the national gender-and age-specific suicide rates (in 10-year age-bands) by the corresponding gender-and age-specific population in each municipality. SMRs for males and

females under the age of 40 years, 40–59 years and 60 years or above were also calculated separately. Geographic variations in suicide rates were presented using differences over the middle 90% of SMRs (i.e., the ratios between values at 95% and 5%), as extreme values at both ends of the distribution are likely to be unreliable estimates.

Bayesian Hierarchical Models were used to estimate the 'smoothed' SMR for each municipality. These were based on Poisson Regression Models with random effects allowing for both non-structural variability (heterogeneity across all areas in the study region) and structural variability (autocorrelation between neighboring areas).[33–35] In the models used, an intrinsic conditional autoregressive prior distribution was assigned to the random effect for structural variability, while the random effect for non-structural variability was represented using independent normal distributions. The default prior distributions were specified for the model hyperparameters.[36] By default, prior distributions for the log transformation of both the unstructured effect precision and the structure effect precision are given in logGamma(1, 0.0005), which is a minimally informative prior. We changed the prior distribution for the precisions to logGamma(1, 0.01) or logGamma(2, 0.1) and conducted sensitivity analyses, but the results remained much the same, confirming the robustness of our results. Sets of municipalities that share a border were defined as neighboring areas. Concerning island areas, sets of municipalities that have a regular sea route were defined as neighboring areas, therefore all municipalities had some neighboring areas. Associations with area-specific socioeconomic characteristics were examined before and after controlling for all other variables in

multivariable models. 'Residual' SMRs after controlling for the effects of all investigated socioeconomic variables were estimated and mapped, to investigate the spatial patterning of residual variation which could not be accounted for by studied variables. The models were estimated with integrated nested Laplace approximation [37,38]. Statistical analyses of the models were carried out using the R-INLA library (18.07.12) in R-3.5.3. All other statistical analyses were performed using Stata statistical software, version 15.1, for Macintosh (StataCorp, College Station, TX, USA).

When testing for evidence of interactions between each area's socioeconomic characteristics and gender or age group, the complex correlations between different gender/age groups (i.e. an area's rate is not only correlated with values in its neighbours within the same gender/age group but also those in other gender/age groups) could not be readily specified in the R-INLA library. Therefore, referring to the approach taken by the previous study of Chang et al. negative binomial regression models were used to test interactions between area characteristics and gender or age group, ignoring any spatial autocorrelations.[3] Continuous quantities of the area characteristics were used in the analyses of the interactions.

SMRs were mapped using seven categories that are symmetrical on the logarithmic scale (< 0.50, 0.50 – < 0.67, 0.67 – < 0.90, 0.90 – < 1.10, 1.10 – < 1.50, 1.50 – < 2.00, and ≥ 2.00). Red, blue and pale yellow with varying degrees of lightness were used to present those higher (red) and lower (blue) than the middle category (pale yellow), respectively. All maps were produced using QGIS Version 2.18.15 for Macintosh.

Patient and public involvement

No patient or public groups were involved.

Results

Table 1 summarizes the number of suicides, population and area-specific socioeconomic characteristics of the 1887 municipalities in Japan used in this study. There were 240,673 suicides in Japan between 2009 and 2017. Of these, 2,699 (1.1%) suicides were excluded from the analysis because address or age data were unavailable, and thus 237,974 suicides (males: 164,432 [69.1%]) were included in the study. Across municipalities, total number of suicide deaths ranged from 0 to 1440. Total number of suicides was zero in 15 of the 1887 municipalities. For males aged 0-39 years, 158 municipalities (8.4%) had zero suicides. Corresponding figures were 80 (4.2%) for males aged 40-59 years, 57 (3.0%) for males aged 60+ years, 439 (23.3%) for females aged 0-39 years, 271 (14.4%) for females aged 40-59 years, and 120 (6.4%) for females aged 60+ years.

Table 1. Summary statistics of the number of suicides in 2009-2017, as well as population and area-specific socioeconomic characteristics from the 2010 census, across 1887 municipalities in Japan.

	Mean	SD	Min	25%	Median	75%	Max
Number of suicides in 2009-2017	126.1	176.8	0	5	60	468	1440
Population size	67862.9	99233.4	201	9842	30534	82866	871138
Single-person households (%)	27.0%	8.9%	8.8%	20.8%	25.8%	31.2%	65%
Unmarried adult population (%)	39.4%	3.3%	28.5%	37.3%	39.0%	40.8%	55%
Population mobility (%)	18.2%	5.8%	5.4%	13.7%	17.9%	22.0%	41%
Unemployment rate (%)	6.3%	2.1%	0%	5.1%	6.2%	7.3%	27%
Non-owner-occupied households. (%)	26.2%	13.4%	2.3%	16.0%	24.6%	34.4%	83%
Percentage population with less than a college degree	85.4%	6.8%	53.8%	82.1%	86.7%	90.3%	95%
Population density (people/km^2)	1516.9	3138.6	1.6	69.8	248.2	1107.2	21398.3

Table 2 shows estimates of suicide rate ratios among the overall Japanese population according to levels of each of the area-specific socioeconomic characteristics before and after adjustment. Compared to the Quartile 1 group, there were no statistical differences in the associations between social fragmentation and area-specific suicide risk in the other groups. Regarding socioeconomic deprivation, the rate ratios of suicide were significantly higher in Quartile 2, Quartile 3, and Quartile 4 compared to Quartile 1. And as the level of deprivation increased, so did the suicide risk. With regard to the level of urbanicity, the rate ratios of suicide were significantly lower in Quartile 2, Quartile 3, and Quartile 4 compared to Quartile 1. And as the level of urbanicity increased, the suicide risk became smaller. For neither fragmentation, deprivation, nor urbanization did the rate ratios of suicide change much before or after the adjustment. Appendix Table 1 presents the results of the analysis of the associations with suicide rates when area socio-economic characteristics are continuous quantities. Concerning deprivation and urbanicity, the results for continuous quantities and quartiles were similar. For fragmentation, the results of the analysis of continuous quantity showed that suicide rates were significantly higher in more fragmented municipalities, although rate ratios were not large.

Table 2. Rate ratios (and 95% credible intervals) of suicide among the Japanese population according to quartile levels of each of the area-specific characteristics.

	Quartile 1	Quartile 2		Quartile 3		Quartile 4	
Social fragmentation							
Unadjusted	Ref.	0.98	(0.95, 1.01)	0.98	(0.95, 1.00)	1.02	(0.99, 1.05)
Adjusted[#]	Ref.	0.98	(0.95, 1.00)	0.97	(0.95, 1.00)	1.00	(0.97, 1.04)
Socioeconomic deprivation							
Unadjusted	Ref.	1.04*	(1.01, 1.06)	1.07*	(1.05, 1.10)	1.12*	(1.09, 1.15)
Adjusted[#]	Ref.	1.05*	(1.03, 1.07)	1.09*	(1.06, 1.12)	1.13*	(1.10, 1.17)
Urbanicity							
Unadjusted	Ref.	0.93*	(0.90, 0.96)	0.85*	(0.83, 0.88)	0.80*	(0.77, 0.83)
Adjusted[#]	Ref.	0.93*	(0.90, 0.95)	0.84*	(0.82, 0.87)	0.79*	(0.77, 0.82)

*: p-value < 0.05. [#]: adjustments for the other two area-specific characteristics.

Quartile 1 refers to the lowest levels of fragmentation, deprivation and urbanicity, and Quartile 4 refers to the highest levels.

Figure 1 shows the maps of smoothed SMRs (sSMRs) and residual SMRs (rSMRs) after taking into account all studied area-specific characteristics for suicide among the overall Japanese population. Compared with the map of sSMRs, the spatial concentration of high and low risk areas was attenuated or disappeared in the map of rSMRs. This suggests that the spatial patterning of suicide can be explained to some extent by the area-specific characteristics investigated in the current study. The 90% range of sSMRs was 0.81 to 1.31 (a 1.6-fold difference), while the corresponding rSMRs values were 0.86 to 1.21 (a 1.4-fold difference).

Table 3 shows gender-/age-specific estimates of suicide rate ratios according to levels of each of the area-specific socioeconomic characteristics after adjusting for all other variables. Regarding social fragmentation, the rate ratios of suicide were significantly larger in Quartile 4 compared to Quartile 1 for males aged 0-39 years and females aged 0-39 and 40-59 years. However, the rate ratios were significantly smaller in Quartile 2, Quartile 3, and Quartile 4 for males aged 60 years and older, and in Quartile 3 and Quartile 4 for females aged 60 years and older, compared to Quartile 1. Concerning socioeconomic deprivation, the rate ratios were significantly larger in Quartile 2, Quartile 3, and Quartile 4 than in Quartile 1 for males aged 40-59 and 60+ years and females aged 40-59 and 60+ years. For males aged 40-59 and 60+ years and females aged 40-59 years, the rate ratios of suicide tended to increase as the level of deprivation increased. And the values of the rate ratios were greater for men than for women, suggesting that the associations between deprivation and suicide are stronger for men. Regarding urbanicity, the rate

ratios were significantly smaller in Quartile 2, Quartile 3, and Quartile 4 compared to Quartile 1 among males aged 0-39, 40-59 and 60+ years and females aged 60+ years. And for these gender-age groups, the rate ratios of suicide tended to decrease as the level of urbanicity increased. Among women aged 40-59 years, the rate ratio of suicide was significantly smaller only in Quartile 2 compared to Quartile 1. The values of the rate ratios were smaller for men than for women, suggesting that the association between urbanicity and suicide is stronger for men. Appendix Table 2 presents the results of the analysis of the associations with suicide rates where area socio-economic characteristics are continuous quantities, by gender and age group. Comparing the results of this analysis with those for quartiles, the results were roughly similar, although there were some differences. Appendix Table 3 presents the results of an analysis examining interactions between gender or age and socio-economic characteristics. The results indicated that all the interaction terms were statistically significant. That is, there were stronger associations between a higher level of fragmentation and higher suicide rates for women than for men, and for young people than for older people. In contrast, a weaker association with deprivation was observed among women and young people. The associations between a higher level of urbanicity and lower suicide rates were stronger for men and older people.

Table 3. Rate ratios (and 95% credible intervals) of suicide in males and females aged 0-39, 40-59 and 60+ years according to quartile levels of each of the area characteristics after adjusting for other characteristics.

	Quartile 1	Quartile 2		Quartile 3		Quartile 4	
Males aged 0-39							
Social fragmentation	Ref.	1.01	(0.96, 1.06)	1.01	(0.96, 1.06)	1.07*	(1.01, 1.13)
Socioeconomic deprivation	Ref.	1.02	(0.98, 1.06)	1.04	(1.00, 1.08)	1.02	(0.98, 1.07)
Urbanicity	Ref.	0.92*	(0.86, 0.98)	0.85*	(0.80, 0.91)	0.79*	(0.74, 0.84)
Males aged 40-59							
Fragmentation	Ref.	1.01	(0.97, 1.05)	1.01	(0.97, 1.05)	1.04	(0.99, 1.08)
Deprivation	Ref.	1.07*	(1.04, 1.10)	1.13*	(1.09, 1.17)	1.22*	(1.18, 1.26)
Urbanicity	Ref.	0.93*	(0.89, 0.98)	0.83*	(0.79, 0.87)	0.72*	(0.69, 0.76)
Males aged 60+							
Fragmentation	Ref.	0.94*	(0.90, 0.98)	0.94*	(0.90, 0.98)	0.95*	(0.91, 1.00)
Deprivation	Ref.	1.07*	(1.03, 1.11)	1.14*	(1.09, 1.18)	1.26*	(1.21, 1.31)
Urbanicity	Ref.	0.93*	(0.88, 0.97)	0.8*	(0.76, 0.84)	0.75*	(0.71, 0.79)
Females aged 0-39							
Fragmentation	Ref.	0.99	(0.91, 1.07)	1.05	(0.97, 1.14)	1.15*	(1.06, 1.25)
Deprivation	Ref.	1.03	(0.97, 1.09)	1.05	(0.99, 1.12)	1.06	(1.00, 1.14)
Urbanicity	Ref.	1.00	(0.90, 1.13)	1.01	(0.91, 1.13)	1.09	(0.98, 1.22)
Females aged 40-59							

Fragmentation	Ref.	1.03	(0.96, 1.10)	1.07	(1.00, 1.14)	1.13*	(1.[illegible] 1.21)
Deprivation	Ref.	1.06*	(1.01, 1.11)	1.08*	(1.03, 1.14)	1.15*	(1.[illegible] 1.21)
Urbanicity	Ref.	0.91*	(0.84, 1.00)	0.93	(0.86, 1.01)	0.96	(0.[illegible] 1.05)
Females aged 60+							
Fragmentation	Ref.	0.96	(0.91, 1.01)	0.91*	(0.86, 0.96)	0.88*	(0.[illegible] 0.93)
Deprivation	Ref.	1.08*	(1.04, 1.13)	1.08*	(1.03, 1.13)	1.07*	(1.[illegible] 1.12)
Urbanicity	Ref.	0.94*	(0.88, 0.99)	0.87*	(0.82, 0.92)	0.85*	(0.[illegible] 0.91)

*: p-value < 0.05.

Quartile 1 refers to the lowest levels of fragmentation, deprivation and urbanicity, and Quartile 4 refers to the highest levels.

Discussion

Main findings

In our previous study, we examined the geographical distribution of and rural-urban differences in suicide mortality in Japan from 2009 to 2017.[25] Results showed that, overall, suicide rates in Japan tended to be higher in rural municipalities than in urban ones, but the geographical distribution of and rural-urban differences in suicide mortality varied considerably by gender and age. In the current study, we used a spatial analysis approach to investigate associations between suicide rates and area-specific socioeconomic characteristics across 1877 municipalities in Japan during the period 2009-2017. This study considered social fragmentation, socioeconomic deprivation, and urbanicity as area-specific socioeconomic characteristics. Among the overall Japanese population, municipalities with higher levels of socioeconomic deprivation were associated with greater suicide risk, and those with higher levels of urbanicity were associated with smaller suicide risk. As for social fragmentation, however, there was no association with area-specific suicide risk. Gender-/age-specific analyses revealed that the associations between area-specific socioeconomic characteristics and area suicide risk varied considerably by gender and age in Japan. Municipalities in the highest quartile level for social fragmentation were associated with significantly larger suicide risk than those in the lowest quartile among males aged 0-39 and females aged 0-39 and 40-59. Higher levels of socioeconomic deprivation were associated with greater suicide risk among males aged 40-59 and 60+ years, and among females aged 40-59 years, with the association appearing to be stronger

for males than for females. Higher levels of urbanicity were associated with smaller suicide risk among males of all the age groups and among females aged 60+ years, with the association appearing to be stronger for males than for females.

Socioeconomic correlates of overall suicides

Findings from the UK indicated that associations of area-specific suicide risk were stronger with social fragmentation rather than socioeconomic deprivation.[11,15] There are several possible reasons why the results of our study differed from the findings of the UK in that social fragmentation was not associated with suicide risk, while socioeconomic deprivation was associated with risk. Firstly, this result may be influenced by the fact that Japan started suicide prevention measures at the national level much later than the UK. The UK government launched the Health of the Nation strategy in 1992, which included suicide reduction as a key target area.[39] On the other hand, in Japan, the Basic Law for Suicide Countermeasures was finally enacted in 2009, and from then, suicide countermeasures at the national level started in earnest.[40] Secondly, differences in social and cultural circumstances between Japan and the UK may have influenced the results. Japanese society is considered to be more cohesive than that of many Western countries, including the UK.[41,42] The cohesiveness of society may have mitigated the effect of social fragmentation on area-specific suicide risk in Japan.

Studies in Taiwan and Hong Kong have shown that both social fragmentation and socioeconomic

deprivation were associated with area-specific suicide risk, but deprivation tended to be more strongly associated with suicide risk compared to fragmentation.[3,16,24] It is possible that Taiwan and Hong Kong, like Japan, are also more cohesive societies than the UK, which has resulted in deprivation having a stronger impact, as found in the current study. However, the findings in Taiwan and Hong Kong were somewhat different from the current study. In Japan, no significant association was found between fragmentation and suicide, but in the former two countries, a significant association was indicated. The difference in the results may be due to the different indicators used. That is, unlike our study, the studies of Taiwan and Hong Kong did not use composite measures of fragmentation or deprivation, and rather used indicators directly from the census and other sources, such as unemployment rates, unmarried adults and educational attainment, without compositing them.

Socioeconomic correlates of gender-age-specific suicides

A review article in Europe indicated that the associations between area-level socioeconomic disadvantage and suicidal behaviours were more pronounced among men,[6] and the results of our Japanese study were similar, with a stronger association found in males. However, our study did not find any significant association for males aged 0-39 years. As for the associations of suicide with social fragmentation, previous studies showed no consistent pattern with respect to gender or age.[3,15,16,24] Our results indicated that, only among males aged 0-39 and females aged 0-39 and 40-59 years, suicide risk

was significant larger for municipalities in the highest quartile category of social fragmentation. Jang et al. reported that in South Korea, the associations between indices of isolation (% divorce and % detached houses) and suicide rates were stronger for men than for women and for younger age groups than older.[22] Future research is needed to clarify why area-specific suicide risk among young Japanese population is not associated with socioeconomic deprivation, but social fragmentation. Concerning males and females aged 60+ years, suicide risk appeared to be lower in municipalities with higher level of social fragmentation. These results were difficult to interpret appropriately. We think that these unexpected results are due to the failure of this study to consider some important factors in the area risk of suicide among elderly people, such as social capital and neighbourhood specific features. Previous studies in Taipei have shown that election participation, a proxy indicator of linking social capital, was associated with reduced suicide rates in females aged 65 + years after adjusting for a variety of area socioeconomic characteristics.[16] An ecological study in Hong Kong indicated that neighborhood specific features, such as recreational services, daily necessity resources, and community centers, were significantly associated with suicide rates in older adults.[43]

As for the associations of suicide with urbanicity, previous studies have shown no consistent pattern with respect to gender or age.[3,4,15,29] In our study, higher levels of urbanicity assessed by population density were associated with a decreased risk of suicide in males but not necessarily in females. One previous review article on suicide in rural areas reported that geographic and interpersonal isolation, agricultural or

otherwise hazardous vocational demands, environmental and governmental policies, availability of means, lack of access to care and rural ideologies appeared to contribute to suicide risk among people residing in rural areas.[44] Therefore, since Japanese men can be vulnerable to rural characteristics such as those mentioned above, suicide prevention measures in Japan should take this into account.

Limitations

Our study had several methodological issues which must be acknowledged. First, since this is an ecological study, the associations identified cannot be directly inferred at the individual level. Furthermore, as indicators of area-specific characteristics in this study were used to describe the overall social and economic environment of each area, these exposure measures are not gender-/age-specific. And thus, this may limit the interpretability of findings from subgroup analyses. Second, the indices of fragmentation and deprivation used in our study were calculated based on those used in the previous European studies.[12,15,28–30] However, it is possible that the indices did not sufficiently reflect the circumstances in Japan. The indicators of fragmentation and deprivation in our study were calculated using six variables reported in the national census. In Japan, other than in the census, there is a paucity of data on the socio-economic status of inhabitant in each municipality. For this reason, we had no choice but to select those variables from the census data that we considered appropriate for this study. Therefore, future studies are needed to investigate what indicators can adequately assess social fragmentation and socioeconomic

deprivation in Japan. Third, area socioeconomic characteristics investigated in the study did not include other variables of potential importance such as alcohol consumption and the prevalence of mental disorders, for which data were unavailable.

Considering the geographical distribution of rSMRs, it appears that the socio-economic characteristics taken into account in our study alone do not fully explain the geographical distribution of suicide rates in Japan from 2009 to 2017 and that some other factors may indeed affect it. Future studies will therefore be needed to elucidate such factors. Forth, different municipalities might have experienced different secular trends in suicide during the 9-year study period. During the study period from 2009 to 2017, suicide rates decreased in Japan for all gender and age groups, except for males under 20 years of age (Appendix Table 4). However, the extent of the decrease varies considerably according to gender and age. Therefore, trends in suicide rates in each municipality over the nine-year period may also have varied considerably, but our study did not take this into account in the analysis. Fifth, we used municipalities as the unit of analysis. Although municipalities are not large geographical units, they vary greatly in both geographical and population size in Japan. Finally, congruent with most previous studies,[3,15] we assumed that people are only exposed to their actual place of residence. As suicide risk develops over a lifetime, future studies should be longitudinal and include people's residential history over their life course.

Conclusion

Our results, along with findings from other countries and regions, show that there were marked geographic and socioeconomic inequalities in suicide, which varied considerably by gender and age. This suggests that appropriate attention should be paid to social policies addressing social fragmentation, socioeconomic deprivation and urbanicity underlying the spatial variations in suicide in countries. Concerning Asian countries and regions, including Japan, it seems that suicide prevention needs to focus on areas with high level of socioeconomic deprivation rather than social fragmentation. However, among younger Japanese populations, suicide risk is larger in municipalities with high level of social fragmentation, and appropriate measures for this need to be taken. And to construct effective place-based interventions more research is needed into underlying mechanisms in order to identify specific area characteristics that exacerbate or protect against suicide.

Figure Legend/Caption

Fig. 1. Maps of (A) smoothed standardized mortality ratios (sSMRs), and (B) residual standardized mortality ratios (rSMRs) after adjusting for social fragmentation, socio-economic deprivation, and urbanity, for suicide among total Japanese population across 1887 municipalities, 2009–2017.

Ethical Approval Statement

Not applicable

Contributors

EY contributed to the conception and design of the study, acquisition and analysis of data, and analysis and interpretation of data, and drafted the article and approved the final version to be published. SH contributed to the analysis and interpretation of data and drafted the article and approved the final version to be published. YS contributed to the analysis and interpretation of data, and revised the article critically for important intellectual content and approved the final version to be published. YS contributed to the analysis and interpretation of data, and revised the article critically for important intellectual content and approved the final version to be published.

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Competing interests

None declared.

Patient consent for publication

Not required.

Data availability

All data used in this manuscript are publicly available.

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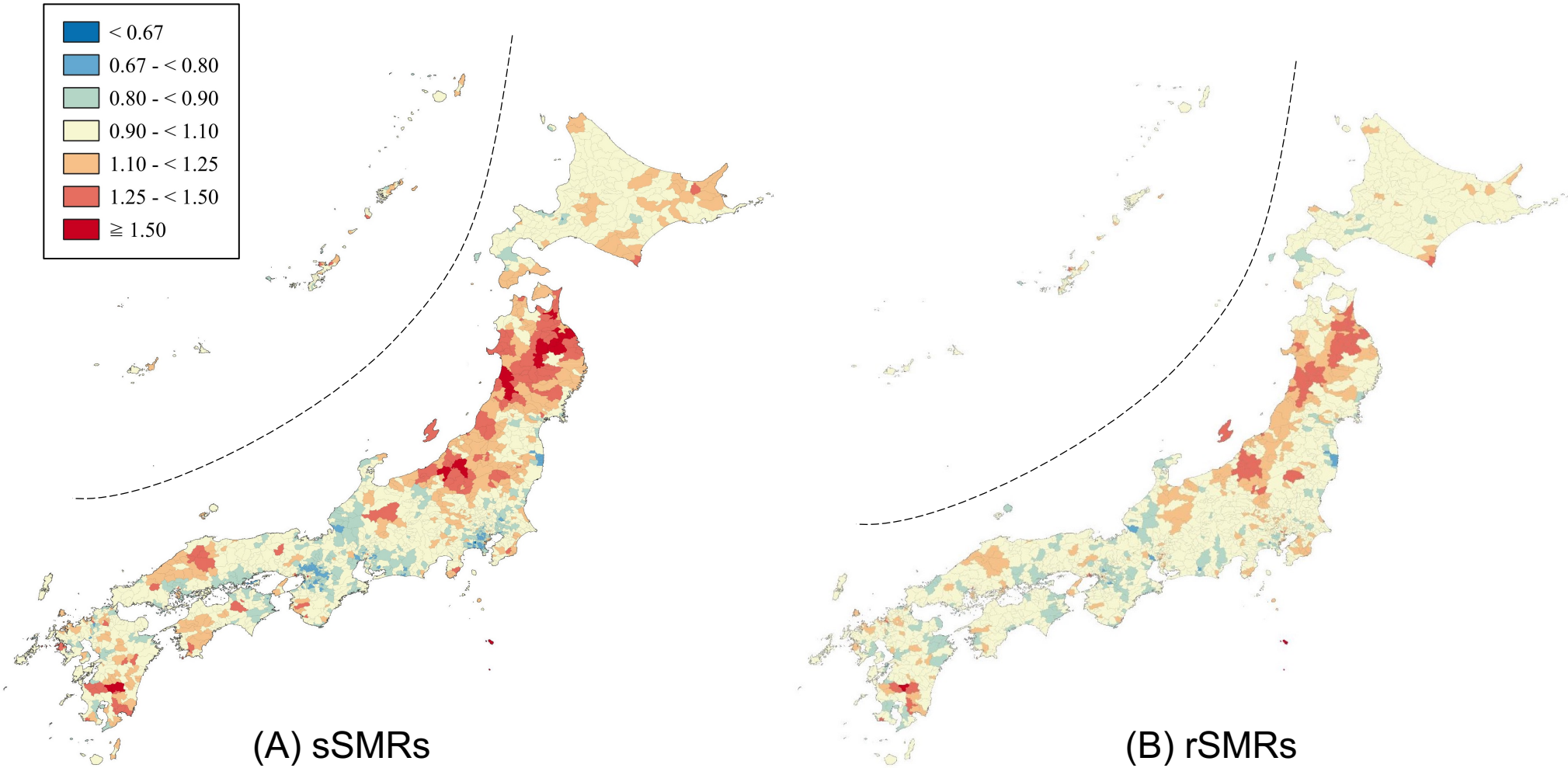

Fig. 1. Maps of (A) smoothed standardized mortality ratios (sSMRs), and (B) residual standardized mortality ratios (rSMRs) after adjusting for social fragmentation, socio-economic deprivation, and urbanity, for suicide among total Japanese population across 1887 municipalities, 2009–2017.

Appendix Table 1. Rate ratios (and 95% credible intervals) of suicide among the Japanese population associated with one standard deviation increase in levels of each of the areas' socioeconomic characteristics.

	Unadjusted		Adjusted for all other variables	
Social fragmentation	1.03	(1.02, 1.04)	1.03	(1.02, 1.04)
Socioeconomic deprivation	1.06	(1.05, 1.07)	1.05	(1.04, 1.06)
Urbanicity	0.92	(0.90, 0.93)	0.90	(0.89, 0.91)

Appendix Table 2. Rate ratios (and 95% credible intervals) of suicide in Japanese men and women aged 0-39, 40-59, 60+ years associated with one standard deviation increase in levels of each areas' socioeconomic characteristics after adjustment for all other variables.

	Males aged 0-39		Females aged 0-39	
Social fragmentation	1.06	(1.04, 1.07)	1.12	(1.10, 1.15)
Socioeconomic deprivation	1.01	(1.00, 1.03)	1.00	(0.97, 1.02)
Urbanicity	0.89	(0.87, 0.91)	1.03	(0.99, 1.06)
	Males aged 40-59		Females aged 40-59	
Social fragmentation	1.03	(1.02, 1.04)	1.06	(1.04, 1.08)
Socioeconomic deprivation	1.09	(1.08, 1.11)	1.06	(1.04, 1.08)
Urbanicity	0.86	(0.84, 0.87)	1.01	(0.99, 1.04)
	Males aged 60 +		Females aged 60+	
Social fragmentation	1.00	(0.98, 1.02)	0.98	(0.96, 1.00)
Socioeconomic deprivation	1.11	(1.09, 1.13)	1.01	(0.99, 1.03)
Urbanicity	0.88	(0.86, 0.90)	0.93	(0.91, 0.96)

Appendix Table 3. Results' summary of the negative binomial regression analysis considering interaction terms between socioeconomic characteristics (fragmentation, deprivation, and urbanicity) and gender or age.

	Model without interaction terms			Model with interaction term between gender and fragmentation			Model with interaction term between age and fragmentation			Model with interaction term between gender and deprivation			Model with interaction term between age and deprivation			Model with interaction term between gender and urbanity			Model with interaction term between age and urbanity		
	IRR	95%CI	p value	IRR	95%CI	p value	IRR	95%CI	p value	IRR	95%CI	p value	IRR	95%CI	p value	IRR	95%CI	p value	IRR	95%CI	p value
Females (ref. males)	0.98	(0.96, 0.99)	<0.001	0.96	(0.95, 0.97)	<0.001	0.98	(0.96, 0.99)	<0.001	0.98	(0.97, 0.99)	0.001	0.98	(0.96, 0.99)	<0.001	0.91	(0.90, 0.93)	<0.001	0.98	(0.96, 0.99)	<0.001
Age (ref. 0-39y)																					
40-59y	1.01	(1.00, 1.03)	0.119	1.01	(1.00, 1.03)	0.119	1.02	(1.00, 1.04)	0.013	1.01	(1.00, 1.03)	0.128	1.01	(0.99, 1.02)	0.268	1.01	(1.00, 1.03)	0.154	1.04	(1.02, 1.06)	<0.001
60+y	1.01	(1.00, 1.03)	0.075	1.01	(1.00, 1.03)	0.054	1.04	(1.02, 1.05)	<0.001	1.01	(1.00, 1.03)	0.087	1.01	(1.00, 1.03)	0.116	1.02	(1.00, 1.03)	0.044	1.06	(1.04, 1.08)	<0.001
Social fragmenation	1.04	(1.03, 1.05)	<0.001	1.02	(1.01, 1.03)	<0.001	1.07	(1.06, 1.09)	<0.001	1.04	(1.03, 1.05)	<0.001	1.04	(1.03, 1.05)	<0.001	1.04	(1.03, 1.05)	<0.001	1.04	(1.03, 1.05)	<0.001
Interaction with gender				1.05	(1.03, 1.06)	<0.001															
Interaction with age																					
40-59y							0.98	(0.97, 1.00)	0.021												
60+y							0.93	(0.92, 0.95)	<0.001												
Socioeconomic deprivation	1.05	(1.04, 1.06)	<0.001	1.05	(1.05, 1.06)	<0.001	1.05	(1.05, 1.06)	<0.001	1.07	(1.06, 1.07)	<0.001	1.03	(1.01, 1.04)	<0.001						
Interaction with gender										0.96	(0.95, 0.98)	<0.001									
Interaction with age																					
40-59y													1.05	(1.03, 1.07)	<0.001						
60+y													1.02	(1.01, 1.04)	0.002						
Urbanicity	0.90	(0.89, 0.91)	<0.001	0.90	(0.89, 0.91)	<0.001	0.90	(0.89, 0.91)	<0.001	0.90	(0.89, 0.91)	<0.001	0.90	(0.89, 0.91)	<0.001	0.86	(0.85, 0.87)	<0.001	0.94	(0.93, 0.96)	<0.001
Interaction with gender																1.12	(1.10, 1.13)	<0.001			
Interaction with age																					
40-59y																			0.96	(0.94, 0.97)	<0.001
60+y																			0.93	(0.91, 0.94)	<0.001

Appendix Table 4. Number and rates of suicide in 2009 and 2017, changes in the number and rates of suicide between 2009 and 2017 among the Japanese population according to gender and age.

	2009		2017		Change			
	Number	Rate[a]	Number	Rate[a]	Number[b]	%[c]	Rate[a,b]	%[c]
Men								
All ages	22712	36.6	14525	23.3	-8187	-36.0%	-13.3	-36.3%
< 20 years	356	3.0	395	3.5	39	11.0%	0.5	16.3%
20-29 years	2369	32.1	1580	23.8	-789	-33.3%	-8.3	-26.0%
30-39 years	3377	35.5	1968	24.6	-1409	-41.7%	-10.9	-30.7%
40-49 years	3903	47.5	2637	27.0	-1266	-32.4%	-20.6	-43.3%
50-59 years	4960	57.7	2545	32.8	-2415	-48.7%	-24.8	-43.1%
60-69 years	4169	49.7	2269	25.5	-1900	-45.6%	-24.2	-48.7%
70-79 years	2283	40.8	1815	28.7	-468	-20.5%	-12.1	-29.6%
> 80 years	1295	51.7	1316	36.4	21	1.6%	-15.3	-29.5%
Women								
All ages	9257	14.2	6443	9.8	-2814	-30.4%	-4.4	-30.7%
< 20 years	205	1.8	169	1.6	-36	-17.6%	-0.2	-13.1%
20-29 years	1041	14.7	603	9.6	-438	-42.1%	-5.1	-35.0%
30-39 years	1322	14.5	689	8.9	-633	-47.9%	-5.5	-38.1%
40-49 years	1225	15.3	965	10.2	-260	-21.2%	-5.1	-33.6%
50-59 years	1362	15.8	993	12.9	-369	-27.1%	-2.9	-18.3%
60-69 years	1649	18.4	1012	10.9	-637	-38.6%	-7.6	-41.1%
70-79 years	1353	19.5	1080	14.3	-273	-20.2%	-5.2	-26.5%
> 80 years	1100	21.8	932	14.1	-168	-15.3%	-7.7	-35.5%

[a]: Suicides per 100,000 population.

[b]: Differences between the values of 2017 and 2009.

[c]: Percentages of the differences between the 2017 and 2009 values in the 2009 values

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-6
Objectives	3	State specific objectives, including any prespecified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-10
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-10
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6-7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	6-7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-8*
Bias	9	Describe any efforts to address potential sources of bias	8-10
Study size	10	Explain how the study size was arrived at	6-7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	8-10
		(*b*) Describe any methods used to examine subgroups and interactions	8-10
		(*c*) Explain how missing data were addressed	8-10
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	8-10
		(*e*) Describe any sensitivity analyses	8-10

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10-11
		(b) Give reasons for non-participation at each stage	10-11
		(c) Consider use of a flow diagram	10-11
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-11
		(b) Indicate number of participants with missing data for each variable of interest	10-11
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	*10-11*
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-12
		(*b*) Report category boundaries when continuous variables were categorized	11-12
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	12
Discussion			
Key results	18	Summarise key results with reference to study objectives	13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13-15
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-15
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.