

Socio-economic Characteristics Associated with Increased Suicide Risk Across 1887 Municipalities in Japan, 2009-2017.

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Abstract

Previous studies have indicated that spatial variation in suicide mortality is associated with area-specific socio-economic characteristics, such as socio-economic 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 socio-economic characteristics and suicide mortality rates across 1887 municipalities in Japan between 2009 and 2017. Socio-economic characteristics were extracted from the 2010 census. We used single-person households and unmarried adults as indicators of social fragmentation, unemployment rate and educational attainment as indicators of socio-economic deprivation, and population density as an indicator of rurality. Bayesian hierarchical models were used to examine associations between socio-economic characteristics and suicide risk. Higher levels of both fragmentation and deprivation were significantly associated with higher rates of area-specific suicide risk. The strongest association was seen with educational attainment as an indicator of deprivation. Socio-economic status and suicide risk varied considerably by gender and age. Our results show that there are clear geographic and socio-economic inequalities associated with 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.

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 socio-economic characteristics.^{2,5,6} One such characteristic is socio-economic 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 socio-economic 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, such as a large proportion of single-person households or unmarried adults, have increased suicide rates.^{3,9,11,14}

So far, studies investigating the association between area-specific suicide rates and socio-economic characteristics have been mainly conducted in European countries, the United States, and Australia.^{5,6} In

comparison, reports from Asian countries are limited. Regarding socio-economic 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.^{6,14,18} 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.^{3,14,18}

This study aimed to investigate the association between a variety of socio-economic 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,²⁰ and included information on the number of suicides by gender, age, and municipality location. There are two statistics on suicide in Japan. One is the cause-of-death statistics included in the vital statistics, and the other is the suicide statistics used in this study. ICD-10 codes are used in the cause-of-death statistics but not in the suicide statistics. We used the suicide statistics instead of the cause-of-death statistics in this study, because we could not obtain the cause-of-death statistics including the number of suicides by age for each municipality. In Japan, the cause of death and

manner of death are confirmed by a medical doctor. And if the manner of death is determined to be unnatural (accident, suicide, homicide, or undetermined), it must be reported to the police. The suicide statistics used in this study are based on data on unnatural deaths collected by the police agency. 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, Sagami-hara) 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.²¹

Area-specific socioeconomic characteristics

In Japan, established area-specific measures for assessing socio-economic deprivation and social fragmentation, such as Townsend deprivation scores¹⁴ and Congdon’s index¹² do not exist. For this reason, we investigated associations of area-specific suicide mortality with individual area characteristics in this study. Data on the following 4 socioeconomic characteristics at the municipality level were extracted from the 2010 census²²: (i) single-person households (% of single-person households); (ii) unmarried adults (% of unmarried adults); (iii) unemployment rate (% of people aged 15+ who were neither in paid employment nor in school or higher education); (iv) educational attainment (% of people aged 35-64 years with a college or higher education). These area-specific socioeconomic characteristics were selected based on findings from previous studies.^{5,10,12,14} Previous studies have indicated that large proportions of single-person households and unmarried adults was 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 A high level of unemployment has been significantly associated with an increased risk of suicide,⁵ and unemployment rate is one of 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 education is considered to be one of the domains of area-specific deprivation.¹⁰ And thus, in this study, we used single-person households and unmarried adults as indicators of social fragmentation, and unemployment rate and educational attainment as indicators of socio-economic deprivation. In addition to the four area-specific characteristics above, we calculated population density (people per square kilometre [km²]) for each area, based on the 2010 census population data. Population density was used as an indicator of rurality. We categorized the variables used in this study into quintiles, where Quintile 1 represented the lowest levels of socioeconomic deprivation, social fragmentation, or rurality, and Quintile 5 was that of the highest levels. That is, Quintile 1 referred to municipalities with the lowest levels of single-person households, unmarried adults, or unemployment rate, or those with the highest level of educational attainment or population density. And

Quintile 5 refers to those with highest levels of single-person households, unmarried adults, or unemployment rate, or those with the lowest level of educational attainment or population density. None of these area-specific characteristics were 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).^{23–25} 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.²⁶ 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^{27,28}. 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.

Results

Table 1 summarizes the number of suicides, population and area-specific socio-economic 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. Of male suicides, 27.0%, 36.3%, and 36.2% were 0–39, 40–59, and 60+ years old respectively; the corresponding figures for females were 24.6%, 28.8%, and 46.4%, respectively. Age-specific annual suicide rates for males aged 0–39, 40–64, and 65+ were 18.1, 39.2, and 37.1 per 100,000, respectively; for females they were 7.7, 14.1, and 16.9 per 100,000, respectively. 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. With regard to socio-economic characteristics used in this study, a relatively strong correlation was observed between educational attainment and population density (spearman’s rank correlation coefficient $\rho=0.70$). The correlations between single-person households and unmarried adults ($\rho=0.48$) and between unmarried adults and unemployment rates ($\rho=0.47$) were moderate. All other correlations between the socio-economic characteristics used in this study were weak ($\rho<0.30$).

Table 1

Summary statistics of the number of suicides in 2009–2017, as well as population and area socio-economic 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
Number of population	67862.9	99233.4	201	9842	30534	82866	877138
Single-person households (%)	27.0%	8.9%	8.8%	20.8%	25.8%	31.2%	73.5%
Unmarried adult population (%)	39.4%	3.3%	28.5%	37.3%	39.0%	40.8%	56.5%
Unemployment rate (%)	6.3%	2.1%	0%	5.1%	6.2%	7.3%	22.7%
Population with college or higher education (%)	14.6%	6.8%	2.5%	9.7%	13.3%	17.9%	46.2%
Population density (people/km ²)	1516.9	3138.6	1.6	69.8	248.2	1107.2	21898.3

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. There was a roughly increasing trend in rate ratios of suicide across quintiles of all the variables in the unadjusted models, except for unemployment rate. This increasing trend was still observed after adjusting for other variables, although the rate ratios became slightly smaller. For unemployment rate, rate ratios of Quintile

2, Quintile 3, and Quintile 4 were significantly smaller compared to Quintile 1 in the unadjusted model, but after adjustment these rate ratios were attenuated and no longer significantly associated. Rate ratios for levels of educational attainment were much higher than those of the other variables, which indicated that the association of area-specific suicide risk with educational attainment was strongest among the socio-economic characteristic examined in this study. And the association with population density was the second strongest.

Table 2

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

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Single-person households					
Unadjusted	Ref.	1.01 (0.98, 1.04)	1.01 (0.98, 1.04)	1.02 (0.99, 1.06)	1.06* (1.03, 1.10)
Adjusted for all other variables	Ref.	1.01 (0.98, 1.04)	1.02 (0.99, 1.04)	1.03 (1.00, 1.06)	1.05* (1.02, 1.09)
Unmarried adults					
Unadjusted	Ref.	1.02 (0.99, 1.05)	1.05* (1.02, 1.08)	1.07* (1.04, 1.10)	1.13* (1.10, 1.17)
Adjusted for all other variables	Ref.	1.04* (1.01, 1.07)	1.05* (1.02, 1.08)	1.06* (1.03, 1.09)	1.12* (1.08, 1.16)
Unemployment rate					
Unadjusted	Ref.	0.94* (0.91, 0.97)	0.95* (0.92, 0.98)	0.97* (0.94, 1.00)	1.01 (0.98, 1.05)
Adjusted for all other variables	Ref.	0.99 (0.96, 1.01)	1.00 (0.97, 1.03)	1.00 (0.97, 1.03)	1.01 (0.97, 1.04)
Educational attainment					
Unadjusted	Ref.	1.07* (1.05, 1.10)	1.15* (1.12, 1.18)	1.20* (1.17, 1.23)	1.33* (1.29, 1.38)
Adjusted for all other variables	Ref.	1.07* (1.04, 1.09)	1.11* (1.08, 1.14)	1.13* (1.09, 1.17)	1.24* (1.19, 1.29)
Rurality					
Unadjusted	Ref.	1.03 (1.00, 1.06)	1.11* (1.08, 1.15)	1.19* (1.15, 1.23)	1.27* (1.23, 1.32)
Adjusted for all other variables	Ref.	1.01 (0.98, 1.03)	1.06* (1.03, 1.10)	1.12* (1.08, 1.16)	1.16* (1.11, 1.21)
"Quintile 1" refers to municipalities with the lowest rates and "Quintile 5" refers to ones with the highest rates.					

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 0.87 to 1.18 (a 1.4-fold difference).

Table 3 shows age-specific estimates of suicide rate ratios in males according to levels of each of the area-specific socioeconomic characteristics after adjusting for all other variables. For males aged 0–39 years, there was an increasing trend in rate ratios of suicide across quintiles for single-person households and population density. In this group, the association was strongest for population density. For males aged 40–59 years, there was a roughly increasing trend in rate ratios of suicide across all variables examined. For males aged 60+ years, a roughly increasing trend in rate ratios of suicide across was seen for unmarried adults, educational attainment, and population density. The strongest associations were seen with educational attainment for those aged 40–59 and 60+ years. The second strongest association was seen with population density for those aged 40–59 years and unmarried adults for those aged 60+ years.

Table 3

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

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Males aged 0–39					
Single-person households	Ref.	1.04 (0.99, 1.09)	1.04 (0.99, 1.10)	1.06* (1.00, 1.11)	1.10* (1.04, 1.17)
Unmarried adults	Ref.	1.01 (0.97, 1.06)	1.00 (0.95, 1.05)	1.01 (0.96, 1.07)	1.06 (0.99, 1.12)
Unemployment rate	Ref.	1.00 (0.96, 1.05)	1.05 (1.00, 1.10)	1.02 (0.97, 1.08)	1.04 (0.98, 1.10)
Educational attainment	Ref.	1.00 (0.97, 1.04)	1.00 (0.96, 1.05)	1.00 (0.95, 1.06)	1.05 (0.98, 1.13)
Rurality	Ref.	1.08* (1.04, 1.13)	1.16* (1.11, 1.22)	1.21* (1.13, 1.29)	1.35* (1.23, 1.47)
Males aged 40–59					
Single-person households	Ref.	1.05* (1.01, 1.09)	1.07* (1.03, 1.12)	1.09* (1.04, 1.13)	1.12* (1.07, 1.18)
Unmarried adults	Ref.	1.02 (0.98, 1.06)	1.01 (0.97, 1.05)	1.04 (0.99, 1.08)	1.10* (1.04, 1.16)
Unemployment rate	Ref.	1.04 (1.00, 1.08)	1.07* (1.03, 1.12)	1.06* (1.02, 1.11)	1.09* (1.03, 1.14)
Educational attainment	Ref.	1.10* (1.07, 1.13)	1.19* (1.14, 1.24)	1.25* (1.20, 1.31)	1.32* (1.25, 1.40)
Rurality	Ref.	1.07* (1.03, 1.10)	1.14* (1.10, 1.20)	1.20* (1.14, 1.26)	1.22* (1.14, 1.31)
Males aged 60+					
Single-person households	Ref.	0.99 (0.95, 1.03)	1.00 (0.96, 1.04)	1.00 (0.96, 1.05)	0.98 (0.93, 1.04)
Unmarried adults	Ref.	1.05* (1.01, 1.10)	1.07* (1.03, 1.12)	1.11* (1.06, 1.17)	1.19* (1.13, 1.26)
Unemployment rate	Ref.	0.96 (0.92, 1.01)	0.96 (0.92, 1.01)	0.97 (0.93, 1.02)	1.00 (0.95, 1.06)
Educational attainment	Ref.	1.13* (1.09, 1.17)	1.21* (1.16, 1.27)	1.24* (1.17, 1.30)	1.42* (1.33, 1.51)
Rurality	Ref.	0.96 (0.93, 1.00)	1.03 (0.98, 1.08)	1.10* (1.04, 1.17)	1.10* (1.02, 1.18)

Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
"Quintile 1" refers to municipalities with the lowest rates and "Quintile 5" refers to ones with the highest rates.				

Table 4 shows age-specific estimates of suicide rate ratios for females. For females aged 0–39 years, there was an increasing trend in rate ratios of suicide only for single-person households, while a decreasing trend for educational attainment was observed. For females aged 40–59 years, there was an increasing trend in rate ratios of suicide for single-person households, unemployment rate, and educational attainment. In this group, the association was strongest with educational attainment. For females aged 60+ years, there was an increasing trend in rate ratios of suicide only for educational attainment, while a roughly decreasing trend for single-person households and unemployment rate was observed.

Table 4

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

	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Females aged 0–39					
Single-person households	Ref.	1.03 (0.95, 1.12)	1.06 (0.98, 1.16)	1.12* (1.03, 1.22)	1.24* (1.12, 1.37)
Unmarried adults	Ref.	1.09* (1.02, 1.18)	1.03 (0.95, 1.12)	1.04 (0.95, 1.13)	1.12* (1.02, 1.23)
Unemployment rate	Ref.	1.02 (0.95, 1.10)	1.08* (1.00, 1.17)	1.07 (0.99, 1.17)	1.08 (0.98, 1.18)
Educational attainment	Ref.	0.98 (0.93, 1.03)	0.96 (0.89, 1.03)	0.87* (0.79, 0.95)	0.86* (0.76, 0.97)
Population density	Ref.	0.95 (0.90, 1.01)	1.00 (0.92, 1.08)	1.04 (0.94, 1.15)	1.03 (0.88, 1.20)
Females aged 40–59					
Single-person households	Ref.	1.01 (0.94, 1.08)	1.05 (0.98, 1.13)	1.09* (1.01, 1.17)	1.15* (1.06, 1.25)
Unmarried adults	Ref.	1.04 (0.98, 1.11)	1.06 (0.99, 1.14)	1.02 (0.96, 1.10)	1.12* (1.04, 1.21)
Unemployment rate	Ref.	1.06 (1.00, 1.13)	1.08* (1.02, 1.16)	1.08* (1.01, 1.16)	1.11* (1.03, 1.20)
Educational attainment	Ref.	1.07* (1.03, 1.12)	1.08* (1.01, 1.14)	1.10* (1.02, 1.19)	1.18* (1.07, 1.30)
Population density	Ref.	0.93* (0.89, 0.97)	0.92* (0.87, 0.98)	0.93 (0.86, 1.01)	1.00 (0.89, 1.13)
Females aged 60+					
Single-person households	Ref.	0.96 (0.91, 1.01)	0.92* (0.87, 0.98)	0.92* (0.87, 0.97)	0.93* (0.87, 1.00)
Unmarried adults	Ref.	1.10* (1.04, 1.16)	1.11* (1.05, 1.18)	1.06 (0.99, 1.13)	1.07 (0.99, 1.14)
Unemployment rate	Ref.	0.93* (0.88, 0.98)	0.94 (0.89, 1.00)	0.94 (0.89, 1.00)	0.88* (0.82, 0.94)
Educational attainment	Ref.	1.07* (1.03, 1.12)	1.08* (1.02, 1.14)	1.10* (1.03, 1.18)	1.21* (1.12, 1.31)
Population density	Ref.	0.95 (0.90, 1.00)	0.98 (0.92, 1.04)	1.03 (0.96, 1.11)	1.11* (1.01, 1.21)

Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
"Quintile 1" refers to municipalities with the lowest rates and "Quintile 5" refers to ones with the highest rates.				

Discussion

Main findings

In this study, we examined the associations between suicide rates and area-specific socio-economic characteristics across 1877 municipalities in Japan during the period 2009-2017. We used single-person households and unmarried adults as indicators of social fragmentation, unemployment rate, and educational attainment as indicators of socio-economic deprivation, and population density as an indicator of rurality. All the area-specific variables, except unemployment rate, were associated with increased risk of suicide. Educational attainment was the factor most strongly related to increased risk of suicide, and population density was the second most strongly related factor. However, the associations between these variables and area suicide risk varied by gender and age in Japan. The associations between area suicide risk and educational attainment were strongest for males and females aged 40-59 and 60+ years. The strongest associations were observed with population density for males aged 0-39 years and with single-person households for females aged 0-39 years.

Socioeconomic correlates of overall suicides

Although previous studies, mostly from the UK, have shown that suicide was associated with the area-specific level of both socioeconomic deprivation and social fragmentation, associations were stronger with fragmentation than deprivation.^{11,14} In contrast, although epidemiological studies of suicide in Asia have found that both fragmentation and deprivation are also associated with area-specific suicide risk, deprivation tended to be more strongly associated with suicide risk compared to fragmentation.^{3,15,18} We also found that both indicators of social fragmentation (single-person households and unmarried adults) and deprivation (educational attainment) were significantly associated with an increased risk of suicide in this Japanese study, and that deprivation were more strongly associated with area-specific suicide risk than social fragmentation. There are several possible reasons for the discrepancy between the results of the present study and previous UK studies. Firstly, there are different measures of fragmentation and deprivation in each of the studies. And while indicators for assessing fragmentation and deprivation have been established in the UK,¹⁴ such indicators have not yet been developed in Japan. Due to the lack of indicators for deprivation and fragmentation in Japan, we unavoidably used data from several censuses as alternative indicators in this study. Therefore, this study may not adequately measure the deprivation and fragmentation of each municipality in the country. Secondly, 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.²⁹ 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.³⁰ Thirdly, 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,^{31,32} including the UK, which may result in a mitigating effect of social fragmentation on area-specific suicide risk in the current study. And thus, unlike the results from the UK, the effect of fragmentation on suicide risk may be weaker than that of deprivation in the current study. It is possible that other East Asian countries such as 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.

According to one review that examined the relationship between suicidal behavior and unemployment,³³ findings from individual longitudinal studies pointed to a significantly raised (two- to three-fold) risk of suicide among the unemployed. However, aggregate cross-sectional studies did not present convincing evidence of an association between unemployment and suicide.³³ In this study, as well, there was no association between municipal unemployment rates and area-specific suicide risk. This discrepancy between the findings at the individual level and the aggregate level suggests that the reasons for an association between unemployment and suicide are not simple. The link between unemployment and suicide may be confounded or modified by various factors which include mental illnesses and socio-economic status. Blakely et al. indicated that about half of the association between unemployment and suicide might be attributable to confounding by mental illness.³⁴ In a meta-analysis of over 300 studies investigating the effects of unemployment on mental health, effects were greater in men, blue collar workers, and in countries with a weak level of economic development, unequal income distributions, or weak unemployment protection systems.³⁵ This suggests that the strains associated with unemployment have a worse effect on those who are more socio-economically vulnerable. Huikari and Korhonen indicated that job loss in regions with low unemployment was more strongly associated with suicide than job loss in regions with high unemployment among in males in Finland.³⁶ This suggests that men who lose their jobs in regions where unemployment is uncommon may have a more marked change in social class than those who lose their jobs in regions where unemployment is more prevalent, and that this change in social class may influence suicidal behaviour.

Socioeconomic correlates of gender-age-specific suicides

In Japan, the association between area-specific suicide rates and socioeconomic factors varied considerably by gender and age. Analyses by gender and age group showed strongest associations with educational attainment among people aged 40-59 and 60+ years. However, the associations with educational attainment were not significant for males aged 0-39 years. Moreover, for females aged 0-39 years, an inverse association, with a higher level of educational attainment having a higher area risk of suicide, was even observed. Since educational attainment is an indicator of socio-economic deprivation

or socio-economic status, these results indicate that the effect of deprivation on area suicide risk may be relatively strong in middle age and old age in Japan, but not so much in the younger generation. Furthermore, young Japanese women can be at higher risk of suicide in less deprived municipalities. Behind this seemingly unusual result for young Japanese women may be a gender inequity in the Japanese labor market. The research from cross-sectional data in a variety of industries in Japan showed that women in more advantaged occupational positions were likely to be at a greater risk of poor psychological health due to higher levels of effort–reward imbalance at work, while the prevalence of poor psychological health did not vary by occupational position among men.³⁷ Data from municipalities in the 2010 census in Japan indicated that there was a strong correlation between the proportion of adults with college or higher education and the proportion of those with professional, managerial, or administrative jobs (Spearman's rank correlation coefficient $\rho=0.78$; data are not shown). Thus, in Japan, municipalities with a higher level of educational attainment have more female workers in more advantaged occupational positions. Moreover, in addition to paid work, married female workers in Japan are responsible for the majority of unpaid housework,³⁸ which can also have an impact on the mental health of young Japanese women. Consequently, the increased stress of more workplace responsibility combined with the burden of unpaid work at home, may result in Japanese women with a higher level of educational being at greater risk of suicide.

In this study, higher levels of social fragmentation, assessed by either single-person households or unmarried adults, were associated with an increased area risk of suicide in all gender/age groups except females aged 60+ years. The results suggest that social fragmentation has an impact on area suicide risk in Japan, except for women in older age groups. Concerning females aged 60+ years, the suicide risk tended to be lower in municipalities with a higher proportion of single person households or with a higher rate of unemployment. 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 women in this age group, 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 only in females aged 65 + years after adjusting for a variety of area socioeconomic 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.³⁹

In this study, higher levels of rurality assessed by population density were associated with an increased risk of suicide in males but not necessarily in females. Especially among males aged 0-39 years, population density was the strongest variables associated with an increased risk of suicide. Several previous studies have also indicated that rural or remote residence was associated with the increased risk of suicide in young men.⁴⁰⁻⁴³ It has been indicated that factors such as the migration of healthy workers to cities and the increasing economic disparity between rural and urban areas may lead to an increased risk of suicide among younger generations living in rural areas.^{44,45}

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, as area indicators of social fragmentation and material deprivation have not been developed in Japan yet, several indicators available from the census are used as surrogate indicators of social fragmentation and material deprivation in this study. 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, deprivation and rurality underlying the spatial variations in suicide in countries. Concerning Asian countries and regions, including Japan, it seems that suicide prevention should particularly focus on areas with high levels of deprivation. Furthermore, young Japanese women residing in the least deprived areas were at high risk of suicide and appropriate measures need to be taken. However, 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.

Declarations

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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ADDITIONAL INFORMATION

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

AUTHOR CONTRIBUTIONS STATEMENT

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.

References

1. WHO. Preventing Suicide: A Global Imperative. (2014). Available at: https://www.who.int/mental_health/suicide-prevention/world_report_2014/en/.
2. Middleton, N., Sterne, J. A. C. & Gunnell, D. J. An atlas of suicide mortality: England and Wales, 1988–1994. *Heal. Place* **14**, 492–506 (2008).
3. Chang, S. *et al.* Geography of suicide in Taiwan: Spatial patterning and socioeconomic correlates. *Heal. Place* **17**, 641–50 (2011).
4. Santana, P., Costa, C., Cardoso, G., Loureiro, A. & Ferrão, J. Suicide in Portugal: Spatial determinants in a context of economic crisis. *Heal. Place* **35**, 85–94 (2015).
5. Rehkopf, D. H. & Buka, S. L. The association between suicide and the socio-economic characteristics of geographical areas: A systematic review. *Psychol. Med.* **36**, 145–57 (2006).
6. Cairns, J. M., Graham, E. & Bambra, C. Area-level socioeconomic disadvantage and suicidal behaviour in Europe: A systematic review. *Soc. Sci. Med.* **192**, 102–111 (2017).
7. Townsend, P. Deprivation. *J. Soc. Policy* **16**, 125–146 (1987).

8. Gunnell, D. J., Peters, T. J., Kammerling, R. M. & Brooks, J. Relation between parasuicide, suicide, psychiatric admissions, and socioeconomic deprivation. *BMJ* **311**, 226–230 (1995).
9. Congdon, P. The spatial pattern of suicide in the us in relation to deprivation, fragmentation and rurality. *Urban Stud.* **48**, 2101–22 (2011).
10. Messer, L. & Kaufman, J. Using Census Data to Approximate Neighborhood Effects. in *Methods in Social Epidemiology* (eds. Oakes, J. M. & S.Kaufman, J.) 209–236 (John Wiley and Sons, 2006).
11. Whitley, E., Gunnell, D., Dorling, D. & Smith, G. D. Ecological study of social fragmentation, poverty, and suicide. *BMJ* **319**, 1034–7 (1999).
12. Congdon, P. Suicide and parasuicide in London: A small-area study. *Urban Stud.* **33**, 137–158 (1996).
13. Congdon, P. Assessing the impact of socioeconomic variables on small area variations in suicide outcomes in England. *Int. J. Environ. Res. Public Health* **10**, 158–77 (2013).
14. Middleton, N. *et al.* Suicide risk in small areas in England and Wales, 1991-1993. *Soc. Psychiatry Psychiatr. Epidemiol.* **39**, 45–52 (2004).
15. Lin, C. Y., Hsu, C. Y., Gunnell, D., Chen, Y. Y. & Chang, S. Sen. Spatial patterning, correlates, and inequality in suicide across 432 neighborhoods in Taipei City, Taiwan. *Soc. Sci. Med.* **222**, 20–34 (2019).
16. Evans, J., Middleton, N. & Gunnell, D. Social fragmentation, severe mental illness and suicide. *Soc. Psychiatry Psychiatr. Epidemiol.* **39**, 165–70 (2004).
17. Smith, G. D., Whitley, E., Dorling, D. & Gunnell, D. Area based measures of social and economic circumstances: Cause specific mortality patterns depend on the choice of index. *J. Epidemiol. Community Health* **55**, 149–50 (2001).
18. Hsu, C. Y., Chang, S. Sen, Lee, E. S. T. & Yip, P. S. F. Geography of suicide in Hong Kong: Spatial patterning, and socioeconomic correlates and inequalities. *Soc. Sci. Med.* **130**, 190–203 (2015).
19. Jacobs D. Social Welfare Systems in East Asia: A Comparative Analysis Including Private Welfare. *LSE STICERD Research Paper No. CASE010* (1998). Available at: <https://ssrn.com/abstract=1158901>.
20. Ministry of Health Labor and Welfare. Suicide statistics. (2018). Available at: <https://www.mhlw.go.jp/stf/seisakunitsuite/bunya/0000140901.html>.
21. Ministry of Internal Affairs and Communications. Demographic survey based on the nation's domiciliary registration system. (2018). Available at: <https://www.e-stat.go.jp/stat-search/files?page=1&toukei=00200241&tstat=000001039591>.
22. Ministry of Internal Affairs and Communications. Census in 2010. (2011). Available at: <https://www.e-stat.go.jp/stat-search/files?page=1&toukei=00200521&tstat=000001039448>.
23. Besag, J., York, J. & Mollié, A. Bayesian image restoration, with two applications in spatial statistics. *Ann. Inst. Stat. Math.* **43**, 1–20 (1991).
24. Congdon, P. Bayesian models for spatial incidence: A case study of suicide using the BUGS program. *Heal. Place* **3**, 229–47 (1997).

25. Lawson, A. B. *et al.* Disease mapping models: An empirical evaluation. *Stat. Med.* **14**, 35–59 (2000).
26. Blangiardo, M., Cameletti, M., Baio, G. & Rue, H. Spatial and spatio-temporal models with R-INLA. *Spat. Spatiotemporal. Epidemiol.* **7**, 39–55 (2013).
27. Rue, H., Martino, S. & Chopin, N. Approximate Bayesian inference for latent Gaussian models by using integrated nested Laplace approximations. *J. R. Stat. Soc. Ser. B Stat. Methodol.* **71**, 319–92 (2009).
28. Rue, H. *et al.* Bayesian Computing with INLA: A Review. *Annu. Rev. Stat. Its Appl.* **4**, 395–421 (2017).
29. Gunnell, D. & Frankel, S. Prevention of suicide: Aspirations and evidence. *BMJ* **308**, 1227–33 (1994).
30. Cabinet Office of Japan. White paper on Suicide Prevention in Japan, 2015. (2016). Available at: <http://www8.cao.go.jp/jisatsutaisaku/whitepaper/en/w-2015/summary.html>.
31. Takao, S. Research on social capital and health in Japan. A commentary on Ichida and on Fujisawa. *Soc. Sci. Med.* **69**, 509–11 (2009).
32. Marmot, M. G. & Smith, G. D. Why are the Japanese living longer? *BMJ* **299**, 1547–1551 (1989).
33. Platt, S. & Hawton, K. Suicidal behaviour and the labour market. in *The International Handbook of Suicide and Attempted Suicide* 303–378 (John Wiley & Sons, 2000).
34. Blakely, T. A., Collings, S. C. D. & Atkinson, J. Unemployment and suicide. Evidence for a causal association? *J. Epidemiol. Community Health* **57**, 594–600 (2003).
35. Paul, K. I. & Moser, K. Unemployment impairs mental health: Meta-analyses. *J. Vocat. Behav.* **74**, 264–282 (2009).
36. Huikari, S. & Korhonen, M. The Impact of Unemployment on Well-Being: Evidence from the Regional Level Suicide Data in Finland. *Soc. Indic. Res.* **128**, 1103–1119 (2016).
37. Umeda, M. *et al.* Does an advantageous occupational position make women happier in contemporary Japan? Findings from the Japanese Study of Health, Occupation, and Psychosocial Factors Related Equity (J-HOPE). *SSM - Popul. Heal.* **26**, 8–15 (2015).
38. Tsuya, N. O., Bumpass, L. L. & Choe, M. K. Gender, Employment, and Housework in Japan, South Korea, and the United States. *Review of Population and Social Policy*, **9**, 195–220 (2000).
39. Guo, Y. *et al.* The geography of suicide in older adults in Hong Kong: An ecological study. *Int. J. Geriatr. Psychiatry* **35**, 99–112 (2020).
40. Page, A., Morrell, S., Taylor, R., Dudley, M. & Carter, G. Further increases in rural suicide in young Australian adults: Secular trends, 1979-2003. *Soc. Sci. Med.* **65**, 442–53 (2007).
41. Qin, P. Suicide risk in relation to level of urbanicity - A population-based linkage study. *Int. J. Epidemiol.* **34**, 846–52 (2005).
42. Kapusta, N. D. *et al.* Rural-urban differences in Austrian suicides. *Soc. Psychiatry Psychiatr. Epidemiol.* **43**, 311–318 (2008).
43. Middleton, N., Gunnell, D., Frankel, S., Whitley, E. & Dorling, D. Urban–rural differences in suicide trends in young adults: England and Wales, 1981–1998. *Soc. Sci. Med.* **57**, 1183–94 (2003).
44. Pitman, A., Kryszynska, K., Osborn, D. & King, M. Suicide in young men. *Lancet* **379**, 2383–92 (2012).

Figures

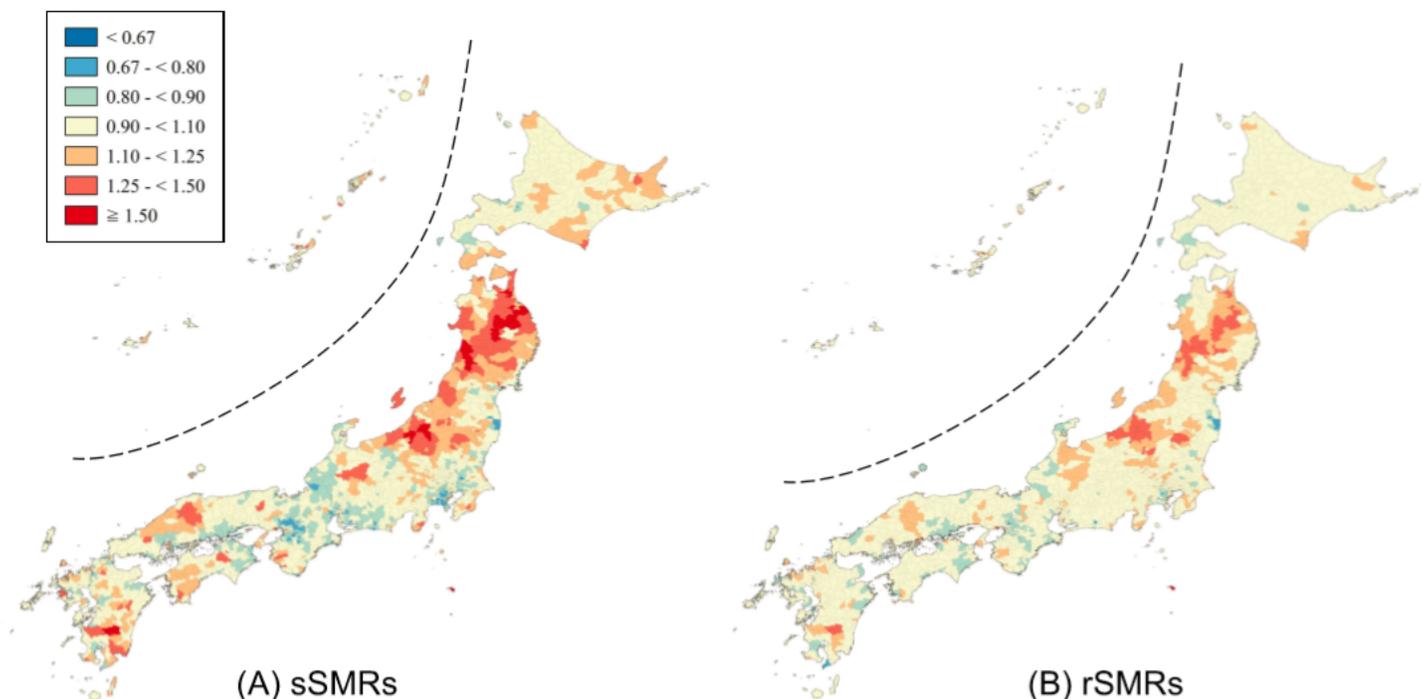


Figure 1

Maps of (A) smoothed standardized mortality ratios (sSMRs), and (B) residual standardized mortality ratios (rSMRs) after adjusting for the five area characteristics, for suicide among total Japanese population across 1887 municipalities, 2009–2017. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.