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臺北市 432 個里的自殺空間分布、相關變項與不平等

Spatial patterning, correlates, and inequalities of suicide across 432 neighborhoods in Taipei City, Taiwan

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本論文係林倩宇君（R05850001）在國立臺灣大學健康行為與社區科學研究所完成之碩士學位論文，於民國 107 年 4 月 24 日承下列考試委員審查通過及口試及格，特此證明

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誌謝

進入研究所就讀的這段時間，由衷感謝書森老師的指導，在各方面均提供我諸多協助與機會，讓我能夠針對自殺領域的研究有更紮實的瞭解，同時也從老師身上學習到一輩子受用的為人處事的態度，能夠在書森老師的指導下進行學術研究真的是非常幸運的一件事情！此外，也非常感謝嘉月、龍玉在統計分析上的協助，讓我能夠在短時間內瞭解複雜的統計方法，並實際完成結果。對於研究室中的夥伴們也很感謝每次會議中的回饋與建議，每次的會議都提供我許多思考方向，提醒我注意先前不曾注意的細節，給予我莫大啟發與鼓勵。對於家人們絕對的支持與陪伴也有莫大的感謝！最後，也想特別感謝廖邕老師所提供的協助與支持，在我生活中的轉捩點總是給予真誠的建議。

謹希望此論文能夠提供未來學術研究、政策方面更多資訊，進一步落實於自殺防治的實際行動，使該研究發揮其最大效果。

林倩宇

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中文摘要

背景：超過半數的世界人口居住於都市地區，瞭解都市地區的自殺空間分布能應用於防治。過去針對城市內部的自殺空間分布進行分析的多為西方國家的研究。本研究的目標為探討臺北市的自殺空間模式、以及與其相關的因子。

方法：我們使用貝氏階層模型估計臺北市 2004-2010 年 432 個里 (平均人口數：5,500 人) 的整體、性別年齡別、與自殺方法 (上吊、燒炭、墜落、溺水、與其他) 別標準化自殺死亡比的平滑估計值。我們並分析一系列地區層級變項，包含社會解離、社會經濟剝奪、連接型社會資本、所得不平等、與方法可近性指標等等，與里自殺率之間的關聯性。

結果：臺北市中心地區的整體自殺率低於全市平均值，但部分都市的邊陲地區的自殺率則高於全市平均值。不同年齡層的男性自殺率呈現相似的地理分布，但不同年齡層女性自殺率的地理模式則有明顯差異。在控制其他變項之後，兩個地區變項與里自殺率相關：離婚/分居人口比例 (為社會解離指標；每增加一個標準差的自殺率比值=1.08，95%置信區間 1.01-1.16) 與家庭所得中位數 (為社會經濟剝奪指標；自殺率比值=0.80，95%置信區間 0.73-0.86)。除了墜落自殺沒有明顯的地理分布，不同方法別自殺率與整體自殺率的空間分布相似。在控制其他變項後，除了墜落自殺外，不同方法別的自殺率都與家庭所得中位數 (自殺率比值介於 0.64-0.84) 相關。燒炭自殺額外與離婚/分居人口比例 (為社會解離指標；自殺率比值=1.12，95%置信區間 1.03-1.23) 與獨居家戶比例 (為在居住單位燒炭的容易度指標；自殺率比值= 1.14，95%置信區間 1.03-1.26) 有關。墜落自殺僅與居住在六樓以上家戶比例 (為高樓可近性指標；自殺率比值=1.18，95%置信區間 1.05-1.31) 有關。溺水與居住地區是否鄰近河川 (為河川可近性指標；自殺率比值=1.24，95%置信區間 0.90-1.67) 無顯著相關。在最低與最高的家庭所得中位數地區間的整體自殺率差異達 1.8 倍，且中年男性有最大的梯度存在 (3.2 倍的差異)。

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結論：在一個人口密集的亞洲城市，與西方國家的城市相比，自殺率的地理分布顯示獨特的空間分布模式，以及與社會經濟變項和方法可近性的相關性。研究發現對於未來在城市內辨識自殺的特定因子與預防策略有所啟發。

關鍵詞：自殺、空間分析、社會經濟特徵、社會資本、所得不平等、自殺方法

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Abstract

Introduction: More than half of the world's population now lives in urban areas. Understanding the spatial distribution of suicide in these settings may inform prevention. Previous analyses of the spatial distribution of suicide in cities were mostly restricted to Western nations. We investigated the spatial patterns of suicide, and factors associated with it's spatial distribution in Taipei City, Taiwan.

Methods: We estimated smoothed standardized mortality ratios for overall suicide and suicide by sex/age group and method (hanging, charcoal burning, jumping, drowning and other methods) across 432 neighborhoods ('Li'; mean population size: 5,500) in Taipei City, Taiwan (2004–2010) using Bayesian hierarchical models. A range of area-level characteristics including social fragmentation, socioeconomic deprivation, linking social capital, income inequality, and means accessibility indicators were investigated for their associations with neighborhood suicide rates.

Results: Overall suicide rates were below average in the city center, whereas above average rates were found in some suburbs. Male suicides of different age groups showed similar geographic patterns, while the geographic distribution of female suicides differed across age groups. After adjusting for all other variables, only two area characteristics were found to be associated with area suicide rates: the proportion of divorced/separated adults (rate ratio [RR] per one standard deviation increase =1.08, 95% confidence interval 1.01-1.16), an indicator of social fragmentation; and median household income (RR=0.80, 95% CrI=0.73-0.86), an indicator of socioeconomic deprivation. Method-specific suicide rates showed similar spatial patterning to that of overall suicide with the only exception of jumping suicide rates, which showed no spatial patterning. In adjusted analyses, neighborhood suicide rates of different methods, except jumping, were associated with median household income

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(RR ranged 0.64-0.84). Charcoal-burning suicide rates were additionally associated with the proportions of divorced/separated adults (RR=1.12, 95% CrI=1.03-1.23), an indicator of social fragmentation, and single-person households (RR=1.14, 95% CrI=1.03-1.26), an indicator of ease with burning charcoal in the living units. Jumping suicide rates were only associated with the proportion of households living on sixth floor or above (RR= 1.18, 95% CrI=1.05-1.31), an indicator of access to high places. Drowning suicide rates were non-significantly associated with neighborhoods' adjacency to rivers (RR=1.24, 95% CrI=0.90-1.67). There was a 1.8-fold difference in suicide rates between neighborhood quintiles with the lowest and the highest median household income, with middle-aged males showing the largest gradient (3.2-fold difference).

Conclusions: In a densely populated city in Asia, the geography of suicide showed distinct patterns of spatial distribution and associations with socioeconomic and means accessibility factors compared to cities in Western nations. Findings have implications for identifying specific determinants and prevention strategies for suicide in cities.

Keywords: suicide, spatial analysis, socioeconomic characteristics, social capital, income inequality, suicide method

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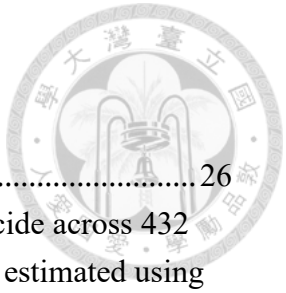

Tables and Figures

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1. Introduction

Suicide is a leading cause of premature mortality worldwide (World Health Organization, 2014). There are pronounced variations in suicide rates across different countries (World Health Organization, 2014) and different areas within a country e.g. England and Wales (Gunnell et al., 2012; Middleton et al., 2004), Germany (Helbich et al., 2017) and the United States (Trgovac et al., 2015). More than half of the world's population now resides in urban areas (United Nations, 2014). Recent studies, mostly from Western nations, revealed marked geographic variations in suicide incidence within cities (Gotsens et al., 2013). Most of the world's largest cities locate in Asia (Satterthwaite, 2007); however, few previous studies have investigated the spatial patterning of suicide in Asian cities e.g. Hong Kong, China (Fong & Yip, 2003; Hsu et al., 2015) and Seoul, South Korea (Yoon et al., 2015). It is expected that Asian countries will continue to experience massive urbanization in the coming decades (Satterthwaite, 2007) and there is a need to better understand the pattern of suicide in Asian cities.

1.1 Socioeconomic correlates of area suicide rates

Systematic reviews, largely based on studies carried out in the West, indicate that areas characterized by high levels of socioeconomic deprivation (e.g. high unemployment, or high composite deprivation indices) have increased suicide incidence (Cairns et al., 2017; Rehkopf & Buka, 2006). In addition to socioeconomic deprivation, social fragmentation (Congdon, 2004), a concept based on Durkheim's theories of social integration that postulates that reduced connectiveness between individuals and the society may increase population suicide rates (Durkheim, 1951), was also shown to be associated an area's suicide rate (Collings et al., 2009;

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Congdon, 1996). Recent studies also indicated a protective effect on suicide of high social capital (Okamoto et al., 2013; N. D. Smith & Kawachi, 2014) and low inequality (Machado et al., 2015). Social capital is theorized as an asset of social connections or resources at individual or community level that may produce and promote some social profits (Putnam, 2000), including the emotional and material supports that may reduce suicide risk (Okamoto et al., 2013). On the other hand, increased income inequality may contribute to social comparisons between individuals and result in a feeling of relative deprivation, a sense of unfairness, and thus psychosocial stress that might in turn contribute to increased risk of suicide (Hong et al., 2011). Nevertheless, previous comprehensive investigations are limited regarding above-mentioned variables in relation to the spatial distribution of suicide in cities.

1.2 Area suicide rates and means accessibility

Restricting the access to lethal suicide methods is an important strategy for suicide prevention (Yip et al., 2012; Zalsman et al., 2016). If a lethal means of suicide is not easily accessible at the moment of crisis, suicidal impulse may pass without a fatal consequence, or the chances of survival would increase significantly when the person turns to a less lethal means (Yip et al., 2012). The accessibility of some suicide methods varies markedly across areas, and previous studies showed that there were marked geographic variations in suicide rates of specific methods such as firearm (Miller et al., 2002), pesticide poisoning (Chang et al., 2012), and jumping (Lin & Lu, 2006). To design local effective programs of suicide prevention applying the means restriction approach, relevant studies investigating the geographic patterns of method-specific suicide rates and related area characteristics are required.

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1.3 The study setting

Taipei City, Taiwan, provides a unique setting to investigate the spatial patterning and determinants of suicide in this context. Taipei City is the capital of Taiwan, and its most densely populated city. Taipei not only has the highest average household income among all Taiwanese cities; but it also has the largest variation in household income (Fiscal Information Agency, 2014). The city is typical among emerging Asian cities for its rapid population growth and economic development (P. K.-C. Liu & Tung, 2003); over the last four decades, its population more than tripled and average disposable income per person increased 74%. The average annual standardized suicide rate in Taipei City was 11.8 per 100,000 population in 2004-2010, lower than 15.1 per 100,000 population in Taiwan as a whole over the same period (Taipei City Suicide Prevention Center, 2017).

1.4 Aim of the study

The aim of this study was to investigate the spatial distribution and correlates of suicide across 432 neighborhoods in Taipei City. Specifically, we examined i) the spatial patterning of overall and sex/age- and method-specific suicide rates, ii) their associations with a wide range of neighborhood socioeconomic characteristics and means accessibility indicators, and iii) inequalities in suicide based on neighborhoods' economic circumstances.

2. Method

2.1 Suicide and population data

Mortality data files for suicide (2004-2010) for people aged 10 years or above in Taipei City were provided by the City government. A previous study in Taiwan

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indicated that many deaths classified as undetermined death, accidental pesticide poisoning, or accidental suffocation were likely to be misclassified suicides (Chang et al., 2010). Therefore, we included all deaths certified as suicide (International Classification of Diseases, Tenth Revision [ICD-10] codes X60–X84), undetermined death (Y10-Y34), accidental pesticide poisoning (X48), or accidental suffocation (W75-W76, W83-W84) in our analyses. To assess the impact of including potentially misclassified suicides on our findings, we conducted sensitivity analyses based on deaths certified as suicide only. For simplicity, we used the term 'suicide' when referring to both certified suicides and deaths in the above alternative categories of death throughout the paper. Each suicide was assigned to one of 432 area units (Li, the smallest administrative level for which detailed population data were available) based on the registered residential address recorded in the mortality data files. In 2004-2010, the mean population aged 10 years or above for neighborhood was 5,500 (range 840-31,300).

2.2 Data for neighborhood-level characteristics

Data on the following 16 neighborhood-level socioeconomic characteristics were extracted from the 2000 census (i-ix, xii-xiv, xvi), Income Tax Statistics (x, xii) (years: 2004-2010), and 2002 Election Reports (xi), and they were grouped into five domains:

a) indicators of social fragmentation: the proportions of: i) single-person households; ii) people whose residences were different from those five years ago (an indicator of population mobility); iii) unmarried adults; iv) divorced/separated adults; and v) lone-parent households (i.e. households with a single, divorced, separated or widowed parent living with his/her unmarried child/children);
b) indicators of socioeconomic deprivation: vi) households not owner occupied (i.e.

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households where the occupants did not own their house); vii) overcrowded households (i.e. households with more than two people per room); viii) non-employed adults (i.e. people aged 15+ who were neither in paid employment nor in school); ix) population aged 15–17 not at school; and x) median household income;

c) indicator of linking social capital: xi) election participation (i.e. percent of eligible voters who turned out for the election);
d) indicator of income inequality: xii) coefficient of variation in household income within the neighborhood;
e) other indicators: xiii) population with limiting long-term illness; xiv) indigenous people; xv) agricultural workers; and xvi) population density (people per square kilometer).

These neighborhood-level characteristics investigated were selected based on findings from previous research which showed associations of suicide with area-level social fragmentation (Congdon, 1996), socioeconomic disadvantage (Rehkopf & Buka, 2006), low social capital (N. D. Smith & Kawachi, 2014), inequality (Machado et al., 2015), indigenous people (I. C. Liu et al., 2011), agricultural workers (Chang et al., 2012), and population density (Stark et al., 2007).

When investigating the correlates of method-specific suicide rates, we used the following means accessibility indicators –

i) the proportion of single-person households: an indicator of ease of burning charcoal in the living units, as it is assumed that it is easier to burn the charcoal at the house/apartment where people live for those who live alone than those who live with others; however, this variable was also used as an

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indicator for social fragmentation (Congdon, 1996) in the analysis of overall/sex-age-specific suicide rates and area socioeconomic characteristics;

ii) the proportion of households living on the sixth floor or above: an indicator of access to high places; and

iii) adjacency to river (a binary variable): an indicator of access to river where people may drown themselves by categorizing neighborhoods into a) those which are adjacent to a river or a river passes thru and b) those which are not adjacent to a river or no rivers pass thru.

2.3 Statistical analysis

Age-standardized suicide rates were calculated based on World Health Organization world standard population (Ahmad et al., 2000). To investigate the spatial patterning of suicide, we calculated 'raw' (unsmoothed) standardized mortality ratios (SMRs) for suicide among people aged 10 or above for each neighborhood during the period 2004-2010. Expected deaths were calculated by multiplying the city-level sex-age-specific suicide rates by the corresponding sex-age-specific population years at risk in each neighborhood. SMRs for males and females aged 10-44 (early working age), 45-64 (late working age) and 65+ years (post-retirement) were also calculated separately.

Although data over the entire study period (2004-2010) were aggregated to ensure sufficient suicides across neighborhoods, the relative rarity of suicide might still impact on neighborhood SMRs due to a minor change in the number of suicide (Lawson, 2013). Bayesian hierarchical models were thus used to estimate the 'smoothed' SMRs for each neighborhood and examine the associations of neighborhood-level characteristics with suicide. The model was based on Poisson distribution and included both unstructured variability (i.e. heterogeneity among the

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whole study region) and structured variability (i.e. heterogeneity among the neighboring areas), taking into consideration of spatial autocorrelation between adjacent neighborhoods (Besag et al., 1991; Congdon, 1997). The adjacent neighbors were defined as neighborhoods that shared a common border.

Associations with neighborhood-level characteristics were examined before and after adjusting for all other variables in multivariable Bayesian hierarchical models. Rate ratios (RRs) and their 95% credible intervals (CrIs) were estimated. We also estimated and mapped 'residual' SMRs after adjusting for all studied neighborhood variables to investigate the spatial patterning of variations which could not be explained by studied variables. Standardized values of neighborhood characteristics, or their log-transformed values when the distributions of raw values were skew, were used in the regression analyses. A binary variable for agricultural neighborhoods was derived from the percentage of agricultural workers using 5% as the cut-off (≥5% versus <5%) as the majority of neighborhoods had <5% agricultural workers. To investigate the socioeconomic inequalities in neighborhood suicide rates, we estimated RRs by quintile of median household income, using the quintile of the highest income as the reference group. Analyses were conducted for overall suicide and suicide by sex/age group. For method-specific suicide rates, tertile of the median household income groups were used; this would produce more stable estimates as the suicide number for some methods (e.g. drowning) was much smaller than that for other methods (e.g. hanging).

Bayesian hierarchical models were estimated through Markov-Chain Monte Carlo methods (Gilks et al., 1996) in WinBUGS version 1.4 (David et al., 2003). The built-in conditional autoregressive distribution was used to incorporate spatially correlated

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components. We checked the convergence of models by visual inspection of three chains and examining the Gelman-Rubin diagnostic (Gelman, 2006).

To examine evidence for global spatial patterning of suicide incidence, we calculated Moran's I statistics using GeoDa, taking into account the different population sizes across areas (Anselin et al., 2006). The interpretation of Moran's I statistics was a value of zero indicating no spatial autocorrelation, and a positive or negative value indicating positive or negative spatial autocorrelation respectively (Moran's I could range from 1 to -1).

2.4 Mapping

Raw and smoothed SMRs for suicide were mapped using seven category breaks that are symmetrical on the logarithmic scale (<0.5, 0.5-0.65, 0.65-0.9, 0.9-1.1, 1.1-1.56, 1.56-2.0 and >2.0) with a divergent red-blue color scheme (Brewer, 1996). When calculating SMRs we used the whole study region as the reference group; thus a value of one indicates a level equal to the whole city average and is included in the middle category (SMR=0.9-1.1). Red and blue with varying lightness were used to demonstrate categories with a value that is higher (red) and lower (blue) than the middle category (white), respectively. All maps were produced using ArcGIS Version 10.4.

3. Results

There were 2,994 suicides in people aged 10 years or above (males 65.3%) in Taipei City between 2004-2010. Of these, there were 2,655 (88.7%) certified suicides, 323 (10.8%) undetermined deaths, 8 (0.3%) deaths classified as accidental pesticide

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poisoning, and 8 (0.3%) deaths classified as accidental suffocation. Among male suicides, 40.6% were 10-44 years old, 36.3% 45-64 years old, and 23.1% 65+ years old; the corresponding figures for female suicides were 42.5%, 35.2%, and 22.2%, respectively. The four major methods were hanging (n=892; 29.8%), charcoal burning (n=859; 28.7%), jumping (n=566; 18.9%), and drowning (n=275; 9.2%), accounting for 86.6% of all suicides.

3.1 Spatial distributions and socioeconomic correlates of overall suicide rates

After excluding neighborhoods with no suicides (n=4, 0.9%), raw SMRs showed marked variations (range 0.12-4.62) and a 5.33-fold difference after excluding the 10% extreme values (mid-90% range 0.36-1.94). Smoothed SMRs ranged between 0.54-1.70 and a nearly two-fold difference in the mid-90% values (range 0.73-1.43) (Table 1). Moran's I was 0.17 ($p<0.001$), indicating evidence for spatial autocorrelation of suicide incidence between neighboring areas (Table 1).

The geographic distribution of smoothed SMRs across 432 neighborhoods is shown in Figure 1A, after taking into account statistical uncertainty in small area suicide incidence. The central areas of Taipei City tended to show below average suicide rates, while above average suicide rates were found in some peripheral areas of the city. When only certified suicides were mapped, the overall spatial patterning was similar (Figure 2).

Table 2 presents the associations between suicide rate and neighborhood-level socioeconomic characteristics. In the unadjusted models, 10 out of the 16 characteristics investigated were associated with suicide. Overall, suicide rates were positively associated with social fragmentation (e.g. a higher proportion of single-

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person households and divorced/separated adults), socioeconomic deprivation (e.g. a lower median household income or higher proportion of not-owner-occupied households), low social capital (indicated by low election participation), and the proportion of indigenous people. After controlling for all other variables, the strength of most associations attenuated while there was still evidence for an association (i.e. the 95% credible intervals did not include one) of suicide rates with the proportion of divorced/separated adults (RR=1.08, 95% CrI=1.01-1.16) and median household income (RR=0.80, 95% CrI=0.73-0.86). The spatial distributions of these two area characteristics were shown in Figure 3.

These neighborhood socioeconomic characteristics explained 60.1% of the variation of area suicide rates, based on comparing the estimates of geographic variability in the constant-only models and the fully adjusted models that included all investigated socioeconomic characteristics. Figure 1B presents the map of residual SMRs after taking into account all studied variables. There was still a 1.3-fold difference in the mid-90% range of SMRs (0.87-1.15). Compared with the smoothed map (Figure 1A), the spatial concentration of high or low risk areas attenuated to some extent in the residual map, indicating that the spatial patterning of suicide can be explained to some extent by the neighborhood variables investigated. However, pockets of low suicide rate areas were still seen mainly in the central region of the city, and some concentration of above average suicide rates remained in the southwestern and southern areas.

3.2 Spatial distributions and socioeconomic correlates of sex-age-specific suicide rates

Figure 4 shows the maps of sex-age-specific smoothed SMRs for suicide. The

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'central-peripheral' contrast in suicide incidence as seen for overall suicides was generally found in males across age groups and was especially marked in males aged 45-64 years. By contrast, the two younger female groups aged 10-44 and 45-64 years showed no clear evidence for the 'central-peripheral' pattern; females aged 65+ years showed similarly low suicide rates in the central region while high rates were found in the north and south areas of the city.

Table 1 presents the distribution of smoothed SMRs and spatial autocorrelation by sex and age group. Males showed greater geographic variations in neighborhood smoothed SMRs than females; differences in the mid-90% values were 2.32-fold and 1.24-fold in males and females respectively. Across sex-age groups, males aged 45-64 years showed the largest variations (3.02-fold difference) while females aged 10-44 years showed the smallest (1.30-fold difference). Similarly, the level of spatial clustering or autocorrelation was higher in males (Moran's I=0.15, $p<0.001$) than females (Moran's I=0.06, $p=0.02$), with males aged 45-64 years showing the highest level (Moran's I=0.11, $p<0.001$) across sex/age groups. By contrast, there was no evidence for spatial clustering or autocorrelation in the two younger female groups aged 10-44 and 45-64 years.

Table 3 shows sex-age-specific fully adjusted results of the regression analyses. Median household income, which was associated with overall suicide rates, showed similar associations with male and female suicide rates in the two younger groups aged 10-44 and 45-64 but not in the elderly group aged 65+. Of note, suicide rates of males aged 45-64 were strongly and negatively associated with median household income (RR=0.68, 95% CrI=0.57-0.80). Neighborhood suicide rates in males aged 10-44, females aged 10-44, and females aged 45-64 were additionally associated with

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the proportions of non-schooling among people aged 15-17 (positively), overcrowded households (negatively), and population mobility (positively) respectively. Elderly females' suicide rates were associated with the proportions of unmarried adults (positively), not-owner-occupied households (negatively), and election participation (negatively).

3.3 Method-specific patterns

Based on Moran's I, charcoal-burning suicide showed the strongest spatial clustering (Moran's I=0.17; p<0.001), followed by drowning (Moran's I=0.07, p=0.01), hanging (Moran's I=0.05, p=0.04) and other methods (Moran's I=0.05, p=0.04); by contrast, there was no evidence for spatial clustering for jumping suicide (Moran's I=-0.01, p=0.42) (Table 4). Figure 5 shows striking differences in the geographic distribution of suicides of different methods - the spatial patterning of suicides by hanging, charcoal burning, drowning, and other methods was generally similar to that of overall suicides, while suicides by jumping showed no obvious spatial patterning.

Table 5 shows the associations of method-specific suicide rates with area socioeconomic characteristics and means accessibility indicators. The pattern differed marked by suicide method. In adjusted models, neighborhood suicide rates of different methods, with the only exception of jumping, were negatively associated with median household income (RR ranged 0.64-0.84). Charcoal-burning suicide rates were additionally associated with the proportion of divorced/separated adults (RR=1.12, 95% CrI=1.03-1.23) and the proportion of single-person households (RR=1.14, 95% CrI=1.03-1.26). By contrast, jumping suicide rates were only associated with the proportion of households living on sixth floor or above (RR=1.18, 95% CrI=1.05-1.31). However, there were no statistical evidence for the association

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of drowning suicide rates with neighborhoods' adjacency to rivers (RR=1.24, 95% CrI=0.90-1.67).

3.4 Socioeconomic inequalities in suicide

Figure 6 shows suicide rate ratios by quintile of median household income. There existed a marked gradient of increasing suicide rates in neighborhoods with decreasing levels of median household income. Compared to the first (wealthiest) quintile of neighborhoods, suicide rate ratios were 1.3 (95% CrI=1.1-1.5), 1.4 (1.2-1.6), 1.6 (1.4-1.9), 1.8 (1.5-2.0) for the second to the fifth quintiles respectively. Overall, the socioeconomic gradient in neighborhood suicide incidence was more marked in males than females, and in younger groups than the elderly groups. The socioeconomic gradient in suicide was most marked in males aged 45-64 years; in this group there was a 3.2-fold difference in suicide rates between the most deprived and the wealthiest quintiles.

Figure 7 shows age-standardized suicide rates (A) and suicide rate ratios (B) by tertile of median household income for different suicide methods. When all methods were combined, there existed a gradient of increasing suicide rates in neighborhoods with decreasing levels of median household income - age-standardized suicide rates were 10.1, 13.4, and 16.6 per 100,000 in the tertiles of the highest, middle, and the lowest income groups respectively (Figure 7A). Of note, age-standardized suicide rates of jumping were almost equal across tertiles. By contrast, suicide rates of hanging, charcoal burning, drowning, and other methods demonstrated similar trends to that of all methods combined, with drowning suicides showing the largest gradient (Figure 7B) - the suicide rate ratios between the tertiles with the lowest income and the highest income were 1.7 (95% CrI=1.4-2.0), 1.9 (95% CrI=1.5-2.4), 2.7 (95%

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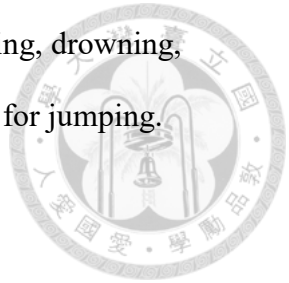
CrI=1.8-3.8), and 1.6 (95% CrI=1.2-2.0) for hanging, charcoal burning, drowning, and other methods respectively, compared to 0.9 (95% CrI=0.7-1.2) for jumping.



4. Discussion

Our data showed a 'central-peripheral' pattern of suicide in Taipei City; there were below average suicide rates in the central areas and above average suicide rates in some peripheral areas of the city. Males of different age groups showed similar geographic patterns to that of overall suicides, while there was no clear spatial pattern in younger females. Overall suicide rates were associated with indicators of both social fragmentation (i.e. proportion of divorced/separated adults) and socioeconomic deprivation (i.e. low median household income). Furthermore, median household income also showed negative associations with male and female suicide rates in the two younger groups, with males aged 45-64 years showing the strongest association.

The spatial patterning of method-specific suicide rates was generally similar to that of overall suicides, with the only exception of suicides by jumping which showed no obvious spatial patterning. Neighborhood suicide rates of different methods, except jumping, were negatively associated with median household income. Charcoal-burning suicide rates were additionally associated with the proportions of divorced/separated adults, an indicator of social fragmentation, and single-person households, an indicator of ease with burning charcoal in living units. Jumping suicide rates were only associated with the proportion of households living on sixth floor or above, an indicator of access to high places. Drowning suicide rates were non-significantly associated with neighborhoods' adjacency to rivers.

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There were marked socioeconomic inequalities in suicide rates, with higher rates found in neighborhoods with lower income; middle-aged males aged 45-64 years showed the largest gradient. Furthermore, there was a socioeconomic gradient in suicide rates of different suicide methods except jumping, which showed similar rates across tertiles of income groups.

4.1 Strengths and limitations

Our study is among the few detailed investigations into the spatial patterning and correlates of suicide in non-Western cities. A wide range of neighborhood characteristics including social fragmentation, socioeconomic deprivation, social capital, income inequality, and means accessibility indicators were examined, and analyses stratified by sex and age and method demonstrated subgroup-specific patterns.

There were several limitations that needed to be taken into consideration. First, this is an ecological study and the associations identified could not be directly inferred at the individual level. The study design could not differentiate the contextual effect (i.e. the influences of area characteristics on individual suicide risk) from the compositional effect (i.e. the concentration of high risk individuals that contributes to high local suicide rates). Second, data were aggregated across years to ensure sufficient number of suicides in small areas and any changes in the spatial patterning of suicide during the study period were not considered. Third, we did not include some area characteristics such as the prevalence of mental disorders and the provision of mental health care for which data were not available. However, in the present study we focused on more 'upstream' socioeconomic variables that may influence local suicide rates, and these mental health related factors were more likely to be 'downstream'

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factors that would not confound the association of socioeconomic variables with suicide. Forth, the studied area characteristics included several indicators in the domains of social fragmentation and socioeconomic deprivation; by contrast, we included only one indicator for social capital and socioeconomic inequality respectively due to limited measures available to us in the two areas and thus these domains might be less thoroughly investigated in our analysis. Fifth, the studied area characteristics were not stratified by sex and age, and this might somewhat limit the interpretability of findings in subgroups. Lastly, means accessibility indicators used in the study may not reflect means accessibility for all suicides using specific methods. Not all of the suicides by jumping and charcoal burning occurred in the place where the deceased lived before death; therefore, the proportions of household living on sixth floor or above and single-person households may not indicate access to or ease of using the methods for all suicides by the two methods. Furthermore, some drowning suicides occurred in other water bodies than rivers and thus distance to the river was irrelevant for these deaths. However, a previous study from Taipei City showed that private residential buildings comprised the majority (67%) of all jumping sites (Chen et al., 2009). An recent unpublished report also indicated that, in Taipei City, the majority (71%) of charcoal-burning suicides occurred at residence and river comprised 70% of all locatable drowning sites (Chang, 2017).

4.2 Spatial patterning of overall and sex-age-specific suicide

Our results showed a 'central-low and peripheral-high' pattern of suicide rates in Taipei City; this is in contrast to the pattern of high suicide rates in central, inner city areas found in some cities such as London (Rezaeian et al., 2007), Amsterdam (Gotsens et al., 2013), Sydney (Burnley, 1994), and Hong Kong (Hsu et al., 2015). The difference in spatial patterning of suicide between Taipei City and other cities

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might be attributable to the difference in the geographic distribution of socioeconomic deprivation. Similar to findings from other cities, we found a strong association of suicide rates with an area's socioeconomic circumstances (indicated by median household income) and, in Taipei City, the central areas were the most affluent region of the city (see the map of the distribution of median household income in Figure 3). By contrast, the inner city areas tended to be the most socioeconomically deprived in other cities. Historically, the economic and administrative center of Taipei City had moved from the western to the central areas of the city, and the 'old center' in the western areas now showed high suicide rates, in contrast to low suicide rates in the relatively 'new', central areas. Changes in the spatial patterning of suicide in relation to urban development deserve further investigations. In London, the UK, a recent study showed that the 'bull's eye' pattern of increased young men's suicide rates in the city's central region was gradually abolished between 1981-2005 but the reasons underlying such a change in the spatial patterning of suicide were unclear (Gunnell et al., 2012).

Our findings showed that, males of different age groups illustrated similar spatial patterning of suicide to that of overall suicides, with a 'central-low and peripheral-high' pattern, while females of different age groups showed less consistent findings. There were only few previous studies that investigated sex and age-specific spatial patterns of suicide in cities (Hsu et al., 2015; Qi et al., 2010). One study from Queensland, Australia, found similar spatial patterns of suicide in males and females, while detailed sex-age-specific patterns were less clear as many areas had no suicide recorded (Qi et al., 2010). Another recent spatial analysis of suicide from Hong Kong showed similar findings to those from the present study – the younger groups of males aged 10-44 and 45-64 years showed the largest spatial variations in suicide and

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similar spatial distributions to that of overall suicides, while their female counterparts showed no clear spatial patterning of suicides (Hsu et al., 2015). However, the sex/age differences in the spatial patterning of suicides should be interpreted with caution as the number of suicide was smaller in females than males and was very low or even zero in small areas in some age-specific groups of females, leading to less precise estimates of small-area suicide rates and greater uncertainty in the spatial patterns in females than males.

4.3 Neighborhood-level characteristics associated with suicide rates

Our data showed that indicators of social fragmentation and socioeconomic deprivation were both associated with suicide, in keeping with some previous studies from Hong Kong, China (Hsu et al., 2015) and Seoul, South Korea (Yoon et al., 2015). When considering the relative explanatory power of characteristics representing social fragmentation and socioeconomic deprivation on suicide, our data appeared to suggest a stronger effect of socioeconomic deprivation than social fragmentation – every one standard deviation (SD) increase in median household income was associated with a 20% reduction in suicide rates while every one SD increase in the proportion of divorced/separated adults was associated with an 8% rise in suicide rates. By contrast, several previous ecological studies of suicide, mostly from the UK, tended to show that the association of suicide with social fragmentation were generally stronger than that with socioeconomic deprivation (Congdon, 1996; Evans et al., 2004; Middleton et al., 2004; G. D. Smith et al., 2001; Whitley et al., 1999). For example, in a study from Bristol, the UK, after adjusting for the area level of psychiatric admission rate and socioeconomic deprivation, every one quartile increase in social fragmentation was associated with a 23% rise in suicide rates; by contrast, there was no statistical evidence for an association of suicide with

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socioeconomic deprivation either before or after adjusting for psychiatric admission rate and social fragmentation (Evans et al., 2004). There are several possible explanations for the difference in findings between our study and these UK studies. The Townsend deprivation index used in the UK studies includes several indirect indicators of socioeconomic deprivation and may underestimate the effect of deprivation on suicide compared to income, which was included in our analysis. Furthermore, social protection measures may be relatively more comprehensive in the UK than in Taiwan, Hong Kong, and South Korea, and offset some of the suicide risk in the deprived population.

Some studies reported that social capital might protect against suicide (Okamoto et al., 2013; N. D. Smith & Kawachi, 2014). One distinction has been made to categorize social capital into 'bonding' and 'bridging' types. Bonding social capital refers to relationships between homogeneous groups who share some similar sociodemographic or socioeconomic characteristics, while bridging social capital refers to relationships between heterogeneous groups at the same level of hierarchy (Putnam, 2000). 'Linking' social capital is a more recent conceptualization, referring to the amount of trust between individuals and societal institutions (Szreter & Woolcock, 2004). We included only an indicator for the linking type of social capital in our analysis because the neighborhood-level data for bonding and bridging social capital were not available. Future investigations with more comprehensive measures of social capital are needed.

Our data showed that election participation, a proxy indicator of linking social capital, was associated with reduced suicide rates but the association was attenuated after adjusting for other area socioeconomic characteristics. In keeping with our findings,

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Kunst et al. (2013) found that the association of social capital indicators with area suicide rates was weakened considerably after adjusting for individual- and area-level factors. It is thus important to investigate the effect of social capital on suicide in the context of other important socioeconomic variables. Of note, in the adjusted analysis stratified by sex and age group, linking social capital was associated with suicide rates in females aged 65+ years. A multi-level Swedish study, which measured social capital using neighborhood election participation, found that there was some weak evidence for an association of elderly suicide with linking social capital after adjusting for individual-level factors (Sundquist et al., 2014). Future research is needed to investigate whether social capital is specifically associated with suicide in the elderly population.

Our data showed that area suicide rates were not associated with income inequality (indicated by coefficient of variance) across small areas. One small area analysis of suicide from Hong Kong used Gini index as a measure of income inequality also found no evidence of the association of area suicide rates with income inequality (Hsu et al., 2015). Our study and the Hong Kong study used measures of income inequality at small area level; however, an individual's suicide risk may not be related to the level of local inequality but inequality level at a higher geographic scale, as individuals' distress may not result from comparing themselves with others in the same neighborhood but others in a larger region. In one recent study of suicide rates across Brazilian municipalities, there was evidence of an association of income inequality (measured by Gini index) with area suicide rates (Machado et al., 2015). This suggests that geographic scale needs to be considered when studying the effect of income inequality on suicide.

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Our data showed that the associations of suicide with area socioeconomic characteristics varied across sex/age groups. One striking pattern was that the association of suicide with median household income was found only in non-elderly males and females but not the elderly groups. Two previous studies from Sydney, Australia and Hong Kong, China, showed an association of area suicide rates with income in non-elderly males, but not in their female counterparts (Burnley, 1994; Hsu et al., 2015). A recent systematic review of European studies indicated that the association between area-level socioeconomic disadvantage and suicidal behavior tended to be stronger in men than in women (Cairns et al., 2017). By contrast, our data showed age difference but not sex difference in such an association, suggesting that the sex/age moderation effect may vary by context. We found that one deprivation indicator, i.e. the proportion of non-schooling among people aged 15-17, was specifically associated with suicide rates in males aged 10-44 years, suggesting that, in our study setting, this indicator may capture some aspects of an area's socioeconomic circumstances e.g. access to educational resources that particularly contributed to suicide risk in this group. Two indicators of social fragmentation, i.e. population mobility and the proportion of unmarried adults, were associated with suicide rates in females aged 45-64 and 65+ years respectively, suggesting that social fragmentation may be more related to female than male suicides. However, previous studies showed no consistent pattern of sex difference in the association of suicide with social fragmentation (Chang et al., 2011; Hsu et al., 2015; Middleton et al., 2004).

4.4 Method-specific spatial patterning of suicide

In addition to the association with median household income, charcoal-burning suicide rates were additionally associated with the proportions of divorced/separated

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adults and single-person households. Similarly, some previous person-based studies showed that divorced individuals had increased risk of charcoal-burning suicide compared to their married counterparts (Ji et al., 2014; Pan et al., 2010). To kill oneself by burning barbecue charcoal requires an enclosed space in which carbon monoxide can accumulate to a lethal level. Therefore, we assumed that individuals living alone would have a higher chance of attempting suicide using this method than those living with others. Our results provided support for this hypothesis when using single-person households as an indicator of ease with burning charcoal in the living unit. Area level of the proportion of single-person households was also used as an indicator for social fragmentation in previous studies (Congdon, 2004); however, in our adjusted analyses this indicator was not associated with overall suicide rates or method-specific suicide rates except charcoal-burning suicide rates.

Jumping suicide rates were only associated with the proportion of households living on sixth floor or above, an indicator of access to high places for jumping, but with the two socioeconomic characteristics investigated (the proportion of divorced/separated adults and median household income). Our findings suggested that the spatial distribution of jumping suicide was only related to means accessibility but not socioeconomic variables. Marzuk et al. (1992) compared suicide incidence across five counties in New York City and found that, compared to Brooklyn, jumping suicide rates were higher in Manhattan (3.75 times higher) and The Bronx (1.97 times higher), where the proportion of residents living in tall buildings were higher than Brooklyn. In Taiwan, Lin and Lu (2006) also found strong positive associations of jumping suicide rates with the proportion of households living in high buildings across 23 cities/counties. Access to high buildings appeared to be an important factor influencing local suicide rates by jumping in cities; however, it is challenging to

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restrict access to high buildings in the urban setting, although there may be a potential to increase the safety by restricting access to or installing high fences at the roof of the building.

In unadjusted analysis, there was a strong association of drowning suicide rates with neighborhoods' adjacency to river. However, the association was attenuated considerably after adjusting for other variables. The number of drowning suicides was relatively small (n=275) compared to other methods, and this might lead to insufficient statistical power to identify an association. Furthermore, although the latest data from Taipei City showed that river comprised around 70% of all locatable drowning sites (Chang, 2017), river was not the only location where drowning suicide occurred. In addition, neighborhoods' adjacency to river might not be a good accessibility indicator in the city because of the ease to access the river using public or private transportations.

4.5 Socioeconomic inequalities in suicide

Previous studies consistently showed a positive association of suicide rates with area-level socioeconomic deprivation (Cairns et al., 2017; Rehkopf & Buka, 2006); however, the strength of association, or the level of socioeconomic inequalities in suicide, was selfdom compared across different study settings. Based on small areas' median household income, a recent study from Hong Kong, China showed a 2.2-fold difference in suicide rates between the wealthiest and the poorest quintiles (Hsu et al., 2015), compared to a 1.8-fold difference shown in our study. Another recent study from Seoul, South Korea, showed a 1.4-fold difference in suicide rates between neighborhoods of the most and the least deprived quintiles based on a composite deprivation index (Yoon et al., 2015). However, the comparison was complicated by

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the differences in the size of small areas investigated and the deprivation indices used across studies. Future studies of comparing socioeconomic inequalities in suicide across cities or countries should take into account the area units studied and use the same deprivation index across settings.

Our data showed that the socioeconomic inequalities in suicide were more marked in males than females, in keeping with findings from several European cities (Cairns et al., 2017; Gotsens et al., 2013) and Hong Kong (Hsu et al., 2015). Furthermore, middle-aged males presented the strongest association compared to other sex/age groups; similar findings were shown in two studies from London (Rezaeian et al., 2007) and Hong Kong (Hsu et al., 2015). These findings suggest that men of working age are more susceptible to economic disadvantage than other groups and those living in deprived areas in the city are likely to be high risk groups for suicide.

4.6 Implications

Our findings showed that there were prominent spatial and socioeconomic inequalities in suicide in an Asian city that is typical for its rapid economic development in the region. This has implications for urban planning that takes into account potential adverse impact of city development on citizens' wellbeing and the segregation of vulnerability. There is a need for future research to better understand factors that are associated with changes in the geographic distribution of suicide over the process of urban development. The spatial analysis of suicide can be used to identify high risk areas for suicide prevention in cities. The gradient of socioeconomic inequalities in suicide indicates a need of social and health policies that address socioeconomic disparity across all income groups, not only the most deprived population. Middle-

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aged men living in deprived areas in Taipei City should be targeted in terms of high suicide risk.

Abbreviations

ICD-10: International Classification of Diseases Tenth Revision; SMR: standardized mortality ratio; RR: rate ratio; CrI: credible interval

Acknowledgements

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Conflicts of Interest

The authors declare that they have no competing interests.

Ethical Standards

This study was approved by the Taipei City Hospital Institutional Review Board (TCHIRB-1010601-E).

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Figure

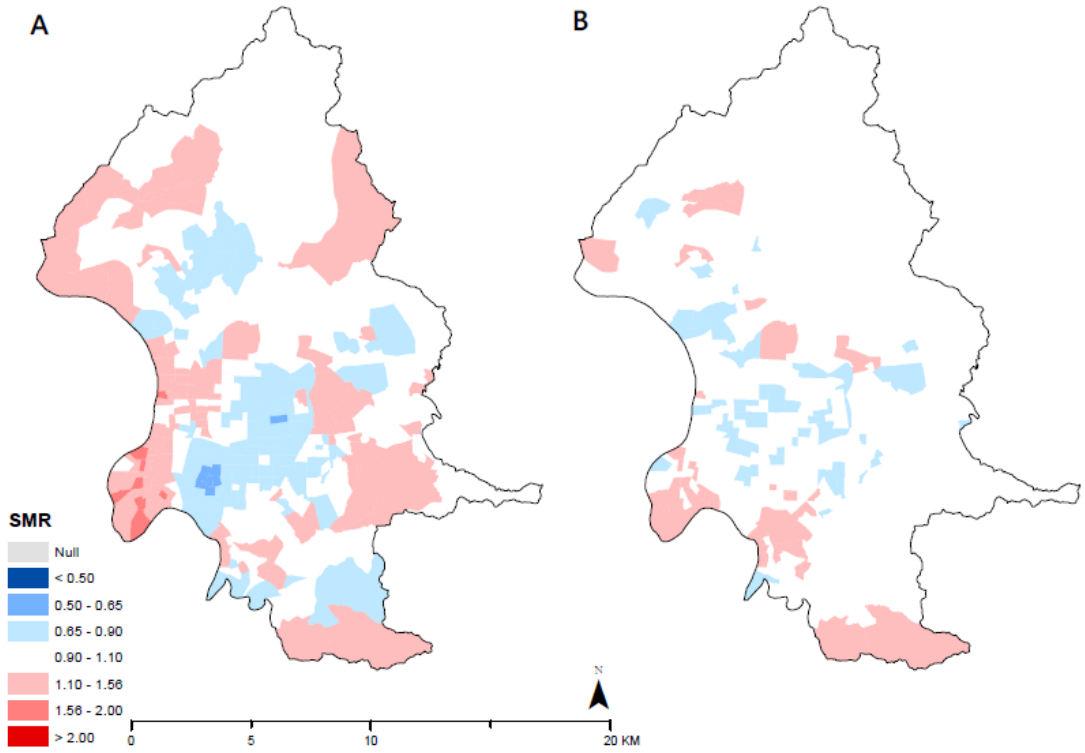

Figure 1. Maps of standardized mortality ratios (SMRs) for suicide across 432 neighborhoods in Taipei City, 2004-2010: (A) smoothed SMRs estimated using Bayesian hierarchical models; and (B) residual SMRs after adjusting for 16 area socioeconomic characteristics.

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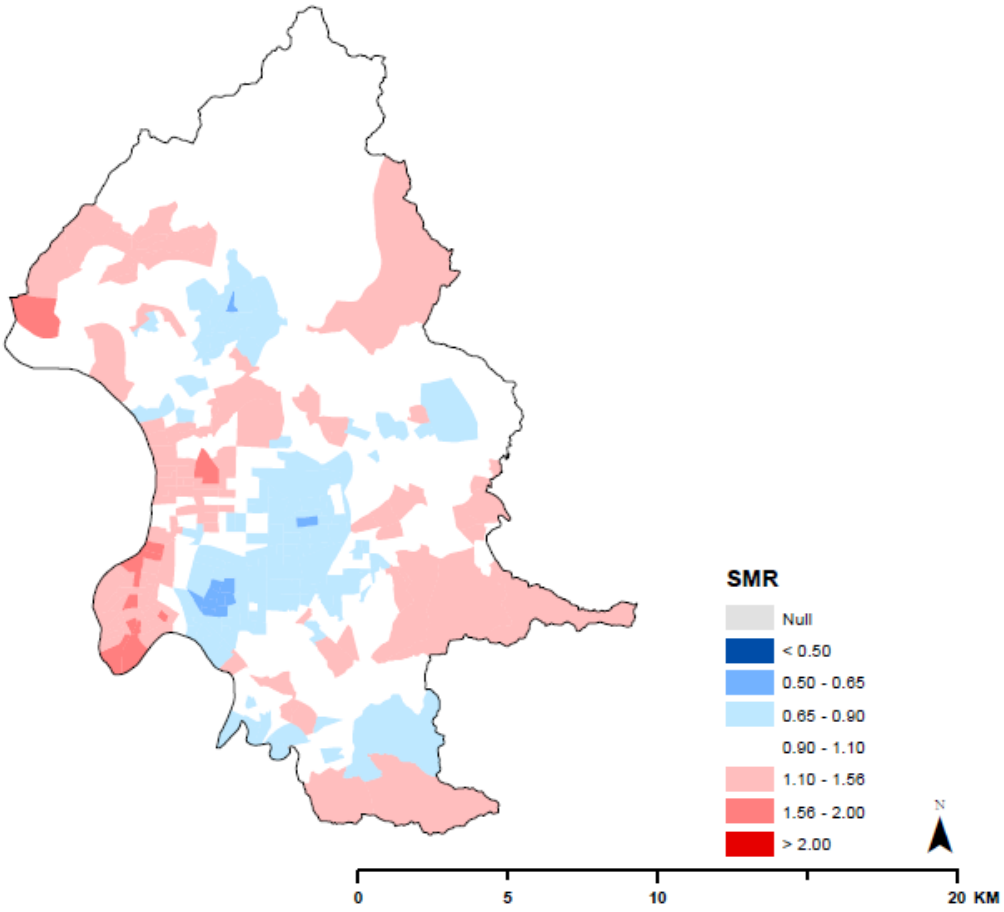

Figure 2. Maps of smoothed standardized mortality ratios (SMRs) for certified suicide only in Taipei City, 2004-2010.

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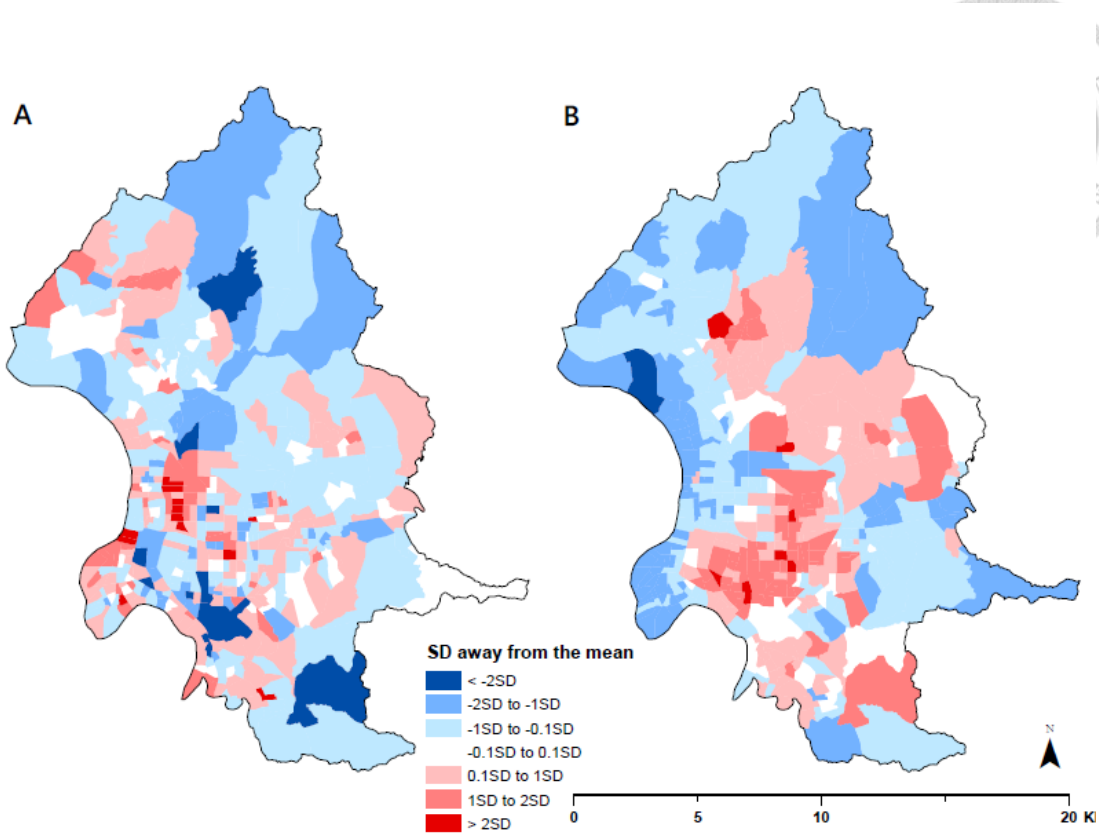

Figure 3. Maps of (A) the proportion of divorced/separated adults; and (B) the median household income across 432 neighborhoods in Taipei City, 2004-2010.

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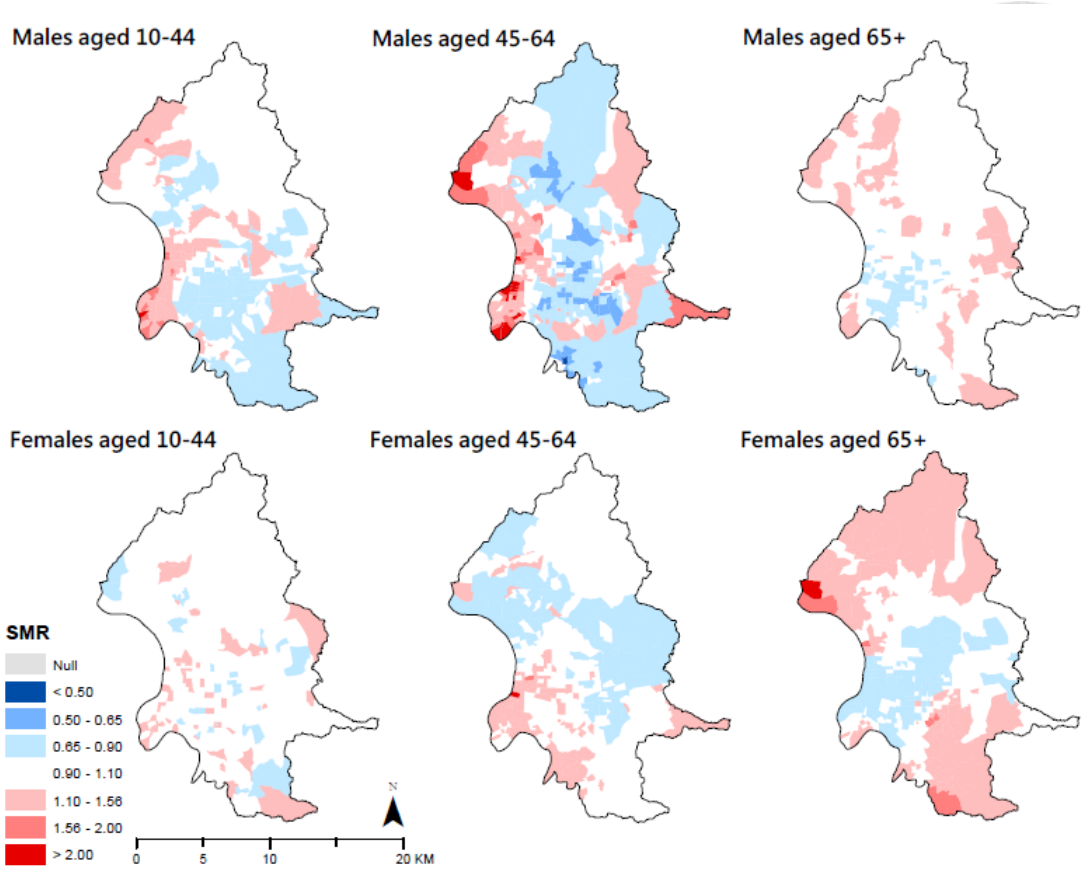

Figure 4. Maps of smoothed standardized mortality ratios (SMRs) for suicide in males and females aged 10-44, 45-64, and 65+ years in Taipei City, 2004-2010.

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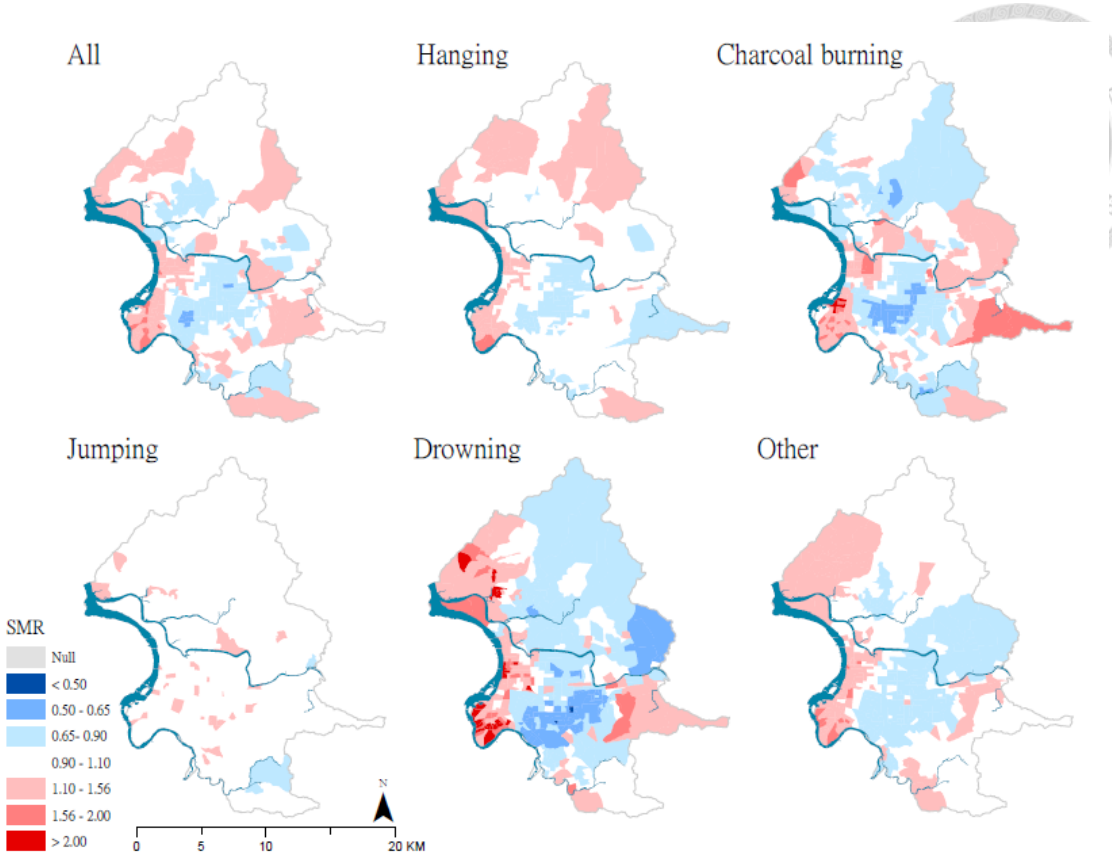

Figure 5. Maps of smoothed standardized mortality ratios (SMRs) for suicide by method in Taipei City, 2004-2010.

* The region highlighted by aquamarine is the river distribution in Taipei City, Taiwan.

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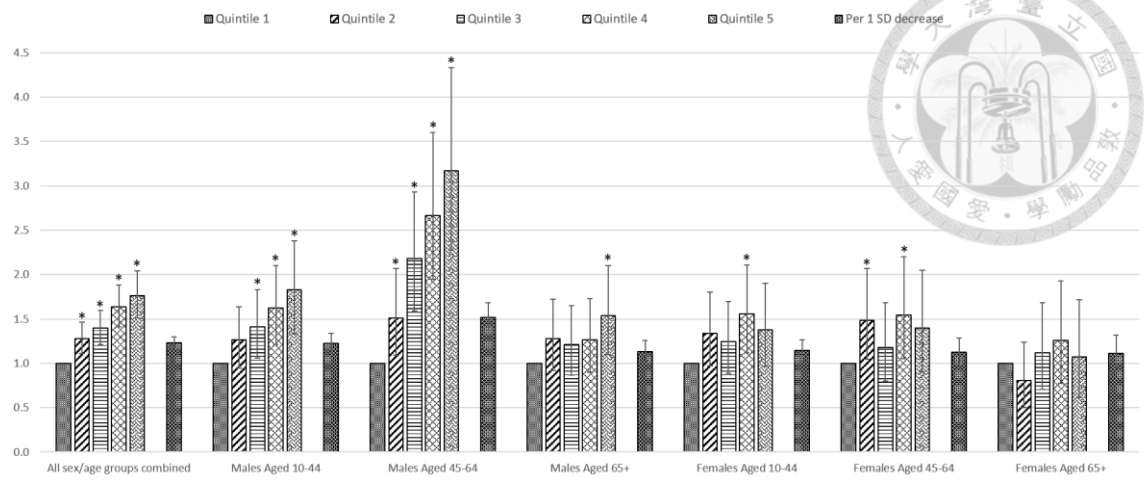

Figure 6. Rate ratios of suicide associated with quintiles of decreasing levels in median household income by sex/age group in Taipei City, 2004-2010 (reference group: the quintile with highest median household income).

* 95% credible intervals of rate ratios that do not include one are highlighted.

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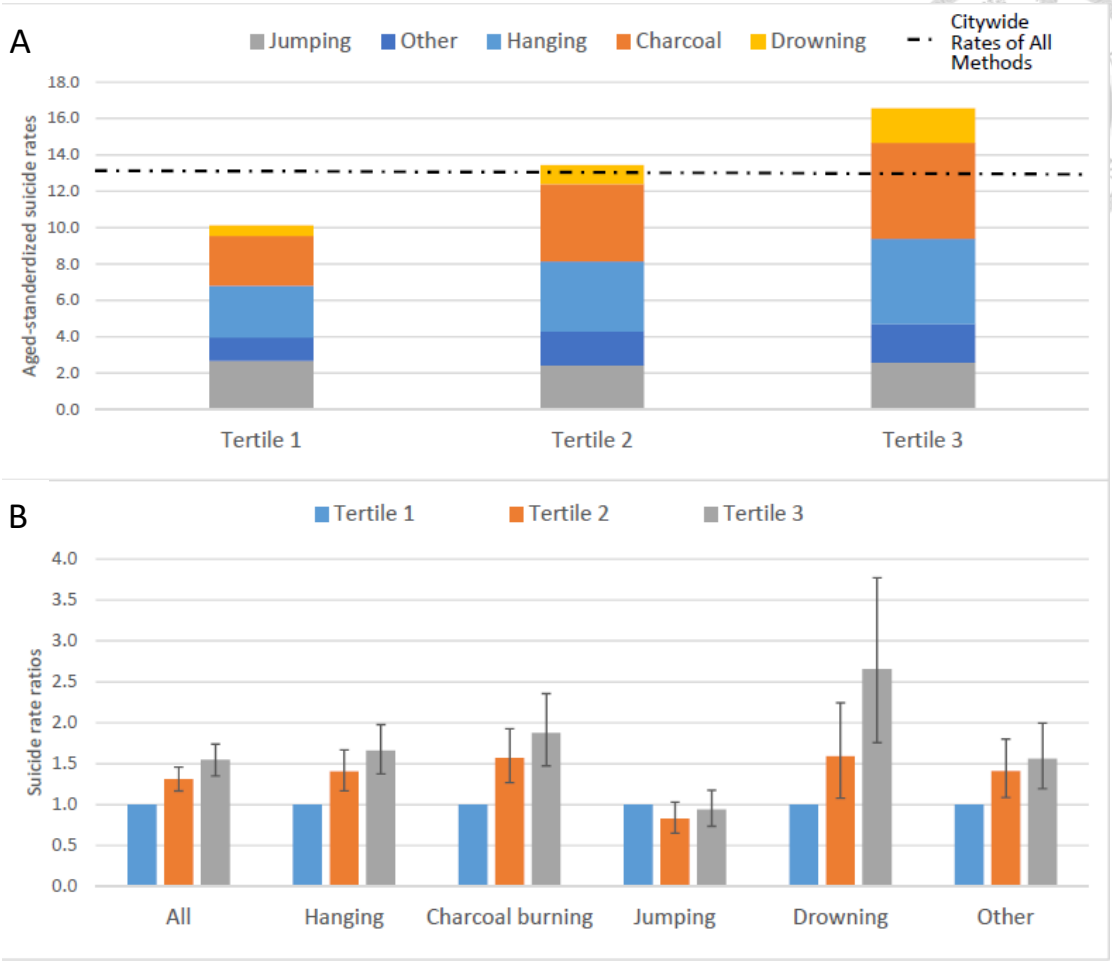

Figure 7. (A) Aged-standardized suicide rates and (B) rate ratios of suicide associated with tertiles of decreasing levels in median household income by method-specific in Taipei City, 2004-2010.

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Table

Table 1. Summary statistics of the distribution of smoothed standardized mortality ratios (SMRs) for sex-age-specific suicidea across 432 neighborhoods in Taipei City, 2004-2010.

	Mean	SD	5%	Median	95%	90% ratio[b]	Moran's I	p value
All sex/age groups combined	1.01	0.21	0.73	0.97	1.43	1.95	0.17	<0.001
Males								
All ages combined	1.01	0.27	0.67	0.95	1.56	2.32	0.15	<0.001
Aged 10-44	1.00	0.25	0.71	0.95	1.47	2.07	0.06	0.02
Aged 45-64	1.03	0.41	0.59	0.93	1.79	3.02	0.11	<0.001
Aged 65+	1.00	0.10	0.86	0.99	1.21	1.40	0.04	<0.001
Females								
All ages combined	1.00	0.07	0.92	0.99	1.14	1.24	0.06	0.02
Aged 10-44	1.00	0.08	0.90	0.99	1.17	1.30	-0.01	0.34
Aged 45-64	1.01	0.17	0.79	0.99	1.29	1.63	0.00	0.50
Aged 65+	1.00	0.20	0.75	0.98	1.36	1.82	0.07	0.02

[a] Including deaths certified either as suicide, undetermined death, accidental suffocation or accidental pesticide poisoning.

[b] Differences over the 90% mid-range, i.e. the values at 95% divided by the values at 5%.

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Table 2. Rate ratios (and 95% Credible Intervals) of suicidea in population aged 10 years or above associated with one standard deviation increase in levels of each of the area socioeconomic characteristics across 432 neighborhoods in Taipei City, 2004-2010.

Area characteristics	Unadjusted			Adjusted for all other variables		
Social fragmentation						
Single-person households (%) [b]	**1.10**	**(1.05 ,**	**1.17)**	1.00	(0.94 ,	1.07)
Population mobility (%) [b]	1.01	(0.96 ,	1.06)	1.04	(0.98 ,	1.10)
Unmarried adults (%) [b]	**1.09**	**(1.04 ,**	**1.14)**	1.06	(0.98 ,	1.14)
Divorced/separated adults (%) [b]	**1.10**	**(1.05 ,**	**1.16)**	**1.08**	**(1.01 ,**	**1.16)**
Lone-parent households (%) [b]	**1.07**	**(1.01 ,**	**1.12)**	0.97	(0.91 ,	1.04)
Socioeconomic deprivation						
Not-owner-occupied households (%) [b]	**1.09**	**(1.03 ,**	**1.15)**	0.99	(0.92 ,	1.06)
Overcrowded households (%) [b]	**1.07**	**(1.01 ,**	**1.13)**	0.96	(0.90 ,	1.03)
Non-employed adults (%) [b]	1.00	(0.96 ,	1.05)	0.99	(0.91 ,	1.07)
Non-schooling among people aged 15-17 (%) [b]	**1.08**	**(1.03 ,**	**1.14)**	1.04	(0.99 ,	1.10)
Median household income [b]	**0.81**	**(0.77 ,**	**0.85)**	**0.80**	**(0.73 ,**	**0.86)**
Social capital: election participation (%)	**0.95**	**(0.90 ,**	**0.99)**	0.96	(0.91 ,	1.01)
Inequality: coefficient of variation in household income [b]	0.99	(0.94 ,	1.04)	1.03	(0.98 ,	1.09)
Others						
Population with limiting long-term illness (%) [b]	1.01	(0.97 ,	1.06)	0.98	(0.93 ,	1.04)
Indigenous people (%) [b]	**1.06**	**(1.01 ,**	**1.11)**	1.00	(0.95 ,	1.04)
Agricultural workers (≥5% versus <5%) [c]	1.31	(0.91 ,	1.83)	1.21	(0.82 ,	1.71)
Population density (people/km^2)	0.95	(0.90 ,	1.00)	0.99	(0.94 ,	1.03)

[a] Deaths certified as suicide, undetermined death or accidental pesticide poisoning/suffocation were all included.

[b] These variables were firstly log-transformed because of their skewed distributions.

[c] Except 'agricultural workers', which was a binary variable (≥5% versus <5%; the latter as the reference group).

[d] 95% credible intervals of rate ratios that do not include one are highlighted in bold.

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Table 3. Rate ratios (and 95% Credible Intervals) of suicidea in males and females aged 10-44, 45-64, and 65+ years associated with one standard deviation increase in levels of each of the area socioeconomic characteristics after controlling for all other variable across 432 neighborhoods in Taipei City, 2004-2010.

Area characteristics	Males aged 10-44			Females aged 10-44		
Social fragmentation						
Single-person households (%) [b]	0.97	(0.86 ,	1.09)	1.06	(0.92 ,	1.23)
Population mobility (%) [b]	1.07	(0.96 ,	1.18)	0.95	(0.83 ,	1.09)
Unmarried adults (%) [b]	0.99	(0.85 ,	1.15)	0.85	(0.69 ,	1.02)
Divorced/separated adults (%) [b]	1.09	(0.95 ,	1.25)	1.08	(0.90 ,	1.28)
Lone-parent households (%) [b]	1.05	(0.91 ,	1.20)	0.98	(0.81 ,	1.16)
Socioeconomic deprivation						
Not-owner-occupied households (%) [b]	0.96	(0.84 ,	1.09)	1.06	(0.90 ,	1.25)
Overcrowded households (%) [b]	0.98	(0.85 ,	1.11)	**0.80**	**(0.68 ,**	**0.94)**
Non-employed adults (%) [b]	0.97	(0.81 ,	1.14)	0.87	(0.70 ,	1.07)
Non-schooling among people aged 15-17 (%) [b]	**1.13**	**(1.02 ,**	**1.26)**	1.13	(0.98 ,	1.28)
Median household income [b]	**0.82**	**(0.70 ,**	**0.96)**	**0.77**	**(0.63 ,**	**0.93)**
Social capital: election participation (%)	1.01	(0.91 ,	1.12)	0.97	(0.87 ,	1.10)
Inequality: coefficient of variation in household income [b]	1.06	(0.95 ,	1.16)	0.96	(0.85 ,	1.09)
Others						
Population with limiting long-term illness (%) [b]	1.07	(0.96 ,	1.18)	1.02	(0.89 ,	1.16)
Indigenous people (%) [b]	0.98	(0.89 ,	1.07)	0.98	(0.87 ,	1.09)
Agricultural workers (≥5% versus <5%) [c]	0.92	(0.41 ,	1.75)	1.23	(0.39 ,	2.70)
Population density (people/km^2)	0.94	(0.85 ,	1.03)	0.94	(0.83 ,	1.05)
	Males aged 45-64			Females aged 45-64		
Social fragmentation						
Single-person households (%) [b]	1.02	(0.91 ,	1.14)	1.09	(0.93 ,	1.26)
Population mobility (%) [b]	1.00	(0.89 ,	1.12)	**1.36**	**(1.18 ,**	**1.57)**
Unmarried adults (%) [b]	1.10	(0.95 ,	1.28)	1.06	(0.87 ,	1.28)
Divorced/separated adults (%) [b]	1.11	(0.96 ,	1.28)	1.06	(0.88 ,	1.26)
Lone-parent households (%) [b]	0.89	(0.77 ,	1.02)	0.99	(0.83 ,	1.19)
Socioeconomic deprivation						
Not-owner-occupied households (%) [b]	1.10	(0.95 ,	1.26)	0.98	(0.82 ,	1.18)
Overcrowded households (%) [b]	1.02	(0.88 ,	1.17)	1.05	(0.88 ,	1.25)
Non-employed adults (%) [b]	0.97	(0.81 ,	1.14)	0.97	(0.77 ,	1.19)
Non-schooling among people aged 15-17 (%) [b]	0.98	(0.88 ,	1.09)	0.92	(0.81 ,	1.06)
Median household income [b]	**0.68**	**(0.57 ,**	**0.80)**	**0.76**	**(0.61 ,**	**0.92)**
Social capital: election participation (%)	1.06	(0.94 ,	1.21)	0.92	(0.82 ,	1.05)

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Inequality: coefficient of variation in household income [b]	0.94	(0.84 ,	1.05)	1.10	(0.97 ,	1.25)
Others						
Population with limiting long-term illness (%) [b]	0.95	(0.85 ,	1.05)	1.01	(0.88 ,	1.16)
Indigenous people (%) [b]	1.02	(0.92 ,	1.12)	0.91	(0.79 ,	1.03)
Agricultural workers (≥5% versus <5%) [c]	1.15	(0.51 ,	2.17)	2.06	(0.57 ,	4.84)
Population density (people/km^2)	1.04	(0.94 ,	1.14)	1.13	(0.99 ,	1.27)
	Males aged 65+			Females aged 65+		
Social fragmentation						
Single-person households (%) [b]	1.01	(0.87 ,	1.17)	0.88	(0.70 ,	1.11)
Population mobility (%) [b]	0.94	(0.82 ,	1.07)	1.02	(0.83 ,	1.22)
Unmarried adults (%) [b]	1.15	(0.97 ,	1.36)	**1.32**	**(1.00 ,**	**1.69)**
Divorced/separated adults (%) [b]	1.00	(0.85 ,	1.18)	1.23	(0.96 ,	1.57)
Lone-parent households (%) [b]	1.05	(0.89 ,	1.24)	0.92	(0.71 ,	1.17)
Socioeconomic deprivation						
Not-owner-occupied households (%) [b]	0.96	(0.82 ,	1.12)	**0.73**	**(0.58 ,**	**0.92)**
Overcrowded households (%) [b]	0.90	(0.76 ,	1.06)	1.11	(0.87 ,	1.40)
Non-employed adults (%) [b]	1.11	(0.93 ,	1.30)	1.11	(0.81 ,	1.46)
Non-schooling among people aged 15-17 (%) [b]	1.06	(0.93 ,	1.21)	1.01	(0.84 ,	1.21)
Median household income [b]	1.00	(0.75 ,	1.32)	1.10	(0.71 ,	1.63)
Social capital: election participation (%)	0.93	(0.83 ,	1.04)	**0.87**	**(0.77 ,**	**0.99)**
Inequality: coefficient of variation in household income [b]	1.03	(0.91 ,	1.16)	1.17	(0.99 ,	1.37)
Others						
Population with limiting long-term illness (%) [b]	0.93	(0.82 ,	1.05)	0.96	(0.80 ,	1.14)
Indigenous people (%) [b]	1.08	(0.96 ,	1.20)	0.92	(0.77 ,	1.08)
Agricultural workers (≥5% versus <5%) [c]	0.89	(0.29 ,	1.96)	1.42	(0.39 ,	3.46)
Population density (people/km^2)	0.96	(0.85 ,	1.07)	0.99	(0.84 ,	1.15)

[a] Deaths certified as suicide, undetermined death or accidental pesticide poisoning/suffocation were all included.

[b] These variables were firstly log-transformed because of their skewed distributions.

[c] Except 'agricultural workers', which was a binary variable (≥5% versus <5%; the latter as the reference group).

[d] 95% credible intervals of rate ratios that do not include one are highlighted in bold.

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Table 4. Summary statistics of the distribution of smoothed standardized mortality ratios (SMRs) for method-specific suicidea across 432 neighborhoods in Taipei City, 2004-2010.

	Mean	SD	5%	Median	95%	90%ratio	Moran's I	p value
Overall	1.01	0.21	0.74	0.97	1.43	1.94	0.17	<0.001
Hanging	1.01	0.14	0.83	0.98	1.27	1.53	0.05	0.04
Charcoal burning	1.00	0.31	0.60	0.94	1.58	2.65	0.17	<0.001
Jumping	1.00	0.05	0.93	0.99	1.11	1.20	-0.01	0.42
Drowning	1.02	0.47	0.55	0.89	2.07	3.77	0.07	0.01
Other	1.01	0.23	0.73	0.95	1.47	2.01	0.05	0.04

[a] Including deaths certified either as suicide, undetermined death, accidental suffocation or accidental pesticide poisoning.

[b] Differences over the 90% mid-range, i.e. the values at 95% divided by the values at 5%.

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Table 5. Rate ratios (and 95% Credible Intervals) of method-specific suicidea associated with one standard deviation increase in levels of each of the area-level characteristics across 432 neighborhoods in Taipei City, 2004-2010, adjusted for all other characteristics.

	All		Hanging		Charcoal burning		Jumping		Drowning		Other	
	RR	95% CrI	RR	95% CrI	RR	95% CrI	RR	95% CrI	RR	95% CrI	RR	95% CrI
Unadjusted												
Socioeconomic characteristics												
Divorced/separated adults (%) b	**1.10**	**(1.05 , 1.16)**	1.03	(0.96 , 1.11)	**1.21**	**(1.11 , 1.31)**	**1.14**	**(1.04 , 1.25)**	**1.16**	**(1.00 , 1.34)**	1.03	(0.92 , 1.15)
Median household income b	**0.81**	**(0.77 , 0.85)**	**0.80**	**(0.74 , 0.86)**	**0.77**	**(0.70 , 0.84)**	1.00	(0.92 , 1.10)	**0.62**	**(0.54 , 0.71)**	**0.82**	**(0.74 , 0.91)**
Accessibility indicators												
Single-person households (%) b (for charcoal burning)	**1.10**	**(1.05 , 1.17)**	**1.11**	**(1.02 , 1.21)**	**1.24**	**(1.12 , 1.36)**	1.05	(0.96 , 1.15)	1.01	(0.85 , 1.19)	1.00	(0.89 , 1.12)
Household living on sixth floor or above (%) (for jumping)	0.96	(0.91 , 1.02)	**0.88**	**(0.81 , 0.95)**	0.96	(0.87 , 1.05)	**1.15**	**(1.05 , 1.25)**	0.86	(0.73 , 1.01)	**0.90**	**(0.80 , 1.00)**
Adjacency to river (for drowning)	**1.17**	**(1.04 , 1.32)**	1.15	(0.96 , 1.35)	1.17	(0.95 , 1.43)	0.96	(0.78 , 1.18)	**1.59**	**(1.11 , 2.18)**	**1.31**	**(1.03 , 1.63)**
Adjusted												
Socioeconomic characteristics												
Divorced/separated adults (%) b	1.05	(1.00 , 1.10)	0.97	(0.90 , 1.05)	**1.12**	**(1.03 , 1.23)**	1.10	(0.99 , 1.22)	1.08	(0.92 , 1.26)	0.98	(0.87 , 1.10)
Median household income b	**0.83**	**(0.77 , 0.88)**	**0.82**	**(0.74 , 0.90)**	**0.84**	**(0.74 , 0.95)**	0.94	(0.83 , 1.06)	**0.64**	**(0.52 , 0.78)**	**0.82**	**(0.71 , 0.95)**
Accessibility indicators												
Single-person households (%) b (for charcoal burning)	1.04	(0.99 , 1.09)	1.07	(0.99 , 1.16)	**1.14**	**(1.03 , 1.26)**	0.96	(0.87 , 1.06)	0.92	(0.78 , 1.08)	0.98	(0.87 , 1.10)
Household living on sixth floor or above (%) (for jumping)	1.02	(0.96 , 1.08)	0.96	(0.87 , 1.06)	0.97	(0.87 , 1.08)	**1.18**	**(1.05 , 1.31)**	1.07	(0.88 , 1.27)	1.03	(0.89 , 1.18)
Adjacency to river (for drowning)	1.08	(0.97 , 1.20)	1.02	(0.86 , 1.19)	1.09	(0.90 , 1.32)	1.00	(0.80 , 1.24)	1.24	(0.90 , 1.67)	1.16	(0.90 , 1.46)

[a] Including deaths certified either as suicide, undetermined death, accidental suffocation or accidental pesticide poisoning.

[b] These variables were firstly log-transformed because of their skewed distributions.

[c] 95% credible intervals of rate ratios that do not include one are highlighted in bold.

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