Title:

Spatial analysis of suicide mortality in Australia: An investigation of metropolitan-rural-remote differentials of suicide risk across states/territories

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Keywords:

Suicide, geographical variation, mental health, spatial analysis, suicide clusters, Australia

Acknowledgements:

The authors would like to thank the Victorian Institute of Forensic Medicine for providing us with access to the National Coroners Information.

Abstract

Studies of the epidemiology of suicide in regions of Australia have been conducted, but the spatial pattern of suicides across the whole country has not been fully investigated. This study aimed to provide a visual representation of the sex-specific suicide pattern across Australia from 2004 to 2008, and to explore the metropolitan-rural-remote differentials in suicide across all states/territories. We applied a Poisson hierarchical model to yield smoothed sex specific, age standardized mortality ratios for suicide in all postal areas, and compiled the age-standardized suicide rates across different levels of remoteness and different jurisdictions. We identified area variations in suicide risk across states/territories, and higher rates of suicide in rural and remote areas for males. Spatial clusters with high suicide risk were also identified in some capital cities. Socio-economic deprivation, compositional factors, high levels of risk for Indigenous people and low access to mental health service were posited as underlying explanations for the elevated suicide risk in some areas. The findings suggest that it is important to take geographical variations in suicide risk into account in national policy making. Particular suicide prevention interventions might be targeted at males living in remote areas, and some localized areas in metropolitan zones.

Research highlights

- Greater suicide risk was found in the states/territories with less economic development and lower levels of urbanization.
- Male suicide risk was elevated in rural areas, and was even higher in remote areas.
- The metropolitan-rural-remote differential for male suicide was significant across states/territories, except in New South Wales and the Northern Territory.

Introduction

Suicide is a major public health issue in Australia. According to official mortality data from the Australian Bureau of Statistics (ABS), the age-standardized suicide rate in 2008 was 10.2 per 100,000, 16.0 for males and 4.5 for females. This made it the 17th leading cause of death overall, and the 10th leading cause of death for males (Australian Bureau of Statistics, 2010b).

Internationally, suicide rates have been shown to vary across different geographical areas. Several overseas studies have used spatial analysis to demonstrate the spatial patterns of suicide risk across a whole country, often breaking these patterns down by sex, age groups and methods (Chang et al., 2010; Congdon, 1997, 2000; Middleton et al., 2008b; Pirkola et al., 2009). These studies have applied a smoothing technique to estimate local standardized mortality ratios (SMRs) with Poisson hierarchical regression models and the Markov chain Monte Carlo method. These techniques have aided the visual inspection of suicide risks and generated maps that can enhance understanding of the geographical pattern of suicide. This, in turn, has assisted with the identification of areas that may warrant particular attention in terms of suicide prevention. Relatively little work of this kind has been conducted in Australia. Qi and colleagues used geographical information system (GIS) tools in Queensland to investigate the suicide rates in different local government areas (Qi et al., 2009, 2010), and several investigators have explored the differences in suicide rates between rural and urban areas at an aggregate level (Caldwell et al., 2004; Taylor et al., 2005; Yip et al., 2000). A country-level analysis of suicide risk with visual inspection of the spatial pattern is needed to identify the regions which should be

given priority in suicide prevention.

The majority of studies in other countries have observed higher suicide rates (or smaller reductions in suicide rates over time) in rural areas than in urban areas (Chang et al., 2011; Pearce et al., 2007; Pirkola et al., 2009; Pridemore and Spivak, 2003; Razvodovsky and Stickley, 2009), although a small number of studies have identified elevated suicide risk in urban areas (Middleton et al., 2008a; Qin, 2005). Recent studies of suicide mortality in Australia suggested that Australian remote and rural areas also have a higher suicide risk than urban areas (Qi et al., 2010; Taylor et al., 2005). It has been suggested that this phenomenon may be rooted in the fact that many rural areas have not experienced the same social and economic development as some urban areas, and suicide prevention activities may not have been as well targeted in these areas (Pearce et al., 2007).

The current study builds on previous aggregated comparisons of metropolitan, rural and remote areas, and extends this comparison to a deeper exploration of spatial differences in suicide risk within the geographical context of Australia. Area variations in health-related phenomena can be classified into three levels: (1) differences between states/territories; (2) differences across levels of remoteness; and (3) differences among areas according to remoteness level. The first and the second differential can be studied through inspection of suicide prevalence and spatial pattern across state/territory or remoteness level. There are differences in terms of socio-economic circumstances, healthcare service provisions, and general health status across these levels (Australian Bureau of Statistics, 2007, 2010c), so it might be expected that there would be variations in locality-based suicide risk across

states/territories. The third differential can be studied through exploring areas with unusual elevation of suicide risk which are not found in other areas in the same remoteness level. Such classification of area variation would facilitate a structured inspection and hence direct a targeted interpretation of area risk factors. Australia is an excellent country for conducting this analysis because it is split into eight states/territories and has significant numbers of rural and remote areas (which can be defined with a remoteness index).

Method

The study was approved by the Human Research Ethics Committee of the Victorian Department of Justice.

Suicide data from the National Coroners Information System (NCIS)

Since 2000, information about completed suicide deaths has been reported to Australian coroners and transferred to the National Coroners Information System (NCIS). In addition to assisting coroners to conduct death investigations, the NCIS archives valuable information about the reported deaths, which allows research and government bodies to utilize the information for community health and safety purposes. Previous literature has confirmed that suicide figures from the NCIS are good reflection of all suicides as the underestimation due to report delay was unbiased (Driscoll et al., 2003) .

For the purposes of the current study, deaths recorded on the NCIS with an ICD-10 diagnosis 'X60-X84' (deliberate self-harm) and/or with the 'intent' column registered as '2' (intentional self-harm) were interpreted as suicides. We aimed to provide the most recent geographical pattern of suicide risk, and it adopted a purely-spatial approach by including suicide cases occurring within in a specified time frame (2004 to 2008, inclusive). We considered that including suicide cases occurring within a longer time period than this might obscure some geographical variation. Deaths recorded in 2009 and 2010 were excluded on the grounds that sufficient time should be allowed for death investigation; had we not done this, a proportion of potential

suicide cases in these years may not have been 'closed' (Driscoll et al., 2003). Our time frame also allowed us to set the 2006 census year as the mid-year against which to derive population denominators (see below).

Using the above criteria, 10,616 suicide cases were identified. Twelve cases had postcodes that did not match to postcodes in the digital boundary map file (see below). Eighty two cases had unidentified postcodes of residence, possibly due to their being homeless at the time of death. By necessity, these individuals were excluded from the analysis; this is unfortunate because some of the factors associated with homelessness (e.g., mental illness) are significant predictors of suicide. In total, 10,522 suicide cases (99.1%) were finally included in the analysis. Postal areas (PAs) of usual residence of the suicide cases were recorded in the dataset and used as the spatial unit of analysis.

Population figures from the census

Population estimates for PAs were required for this analysis. They were obtained from the ABS national census, which is conducted every five years. Since the 2011 census had not been conducted at the time of data extraction, interpolation for compiling person-years for 2007 and 2008 was not feasible. Ideally, the population-at-risk for all PAs in 2004 and 2005 would have been interpolated using 2001 and 2006 census data. However, there were numerous additions and deletions of PAs between 2001 and 2006 (Australian Bureau of Statistics, 2001, 2006b), which meant the two sets of population data could not be easily matched. Therefore, the 5-year populations-at-risk by postal areas for the whole study period were

approximated by multiplying the population size in 2006 by five for each PA.

Maps for postal areas

There were 2,515 PAs in the 2006 census. Eight 'dump' postcodes were discarded because they could not be represented on a map, bringing the total to 2,507. These 'dump' postcodes accounted for off-shore areas and dummy postcodes allocated to individuals with no known postcode (see above). The most recent separate maps for each state/territory were contained in '2006 Census DataPacks'. These maps were merged to form a digital boundary map file of the whole of Australia, using a GIS tool. Findings from the analysis were imported into the boundary file to demonstrate spatial patterns.

Rural, Remote and Metropolitan Areas (RRMA) classification

The Rural, Remote and Metropolitan (RRMA) classification was developed in 1994 (Department of Primary Industries and Energy and Department of Human Services and Health, 1994). With the most up-to-date amendments made in 2009, it classifies all statistical local areas (SLA) to seven ordinal categories. SLAs which are located in a capital city (defined by Capital City Statistical Division boundaries) or in a metropolitan centre with a population greater than or equal to 100,000 are allocated to the metropolitan category. For other areas, allocation to rural and remote areas are referenced to the 'Index of Remoteness', which takes into account the population density and distance to the nearest centroid of an urban centre. In our analysis, concordance files of converting SLAs to PAs provided by ABS were used for assigning

a RRMA classification to each PA. The seven area divisions were collapsed into three levels: metropolitan areas (RRMA categories 1 and 2), rural areas (RRMA categories 3,4 and 5) and remote areas (RRMA categories 6 and 7).

Statistical methods

The original unsmoothed suicide SMR for each PA was calculated by dividing the actual number of suicides by the expected number. The expected number of suicides for each PA was the sum of the product between the national sex- and the age-specific suicide rates and the corresponding sex- and the age-specific population-years at risk.

To overcome the unreliable estimation of suicide risk due to small population sizes and small numbers of suicides, and to demonstrate a clear spatial pattern of suicide, Bayesian hierarchical modeling with a component of correlated heterogeneity was used to ‘smooth’ the SMR before mapping. The hierarchical model with a Poisson-link proposed by Besag, York and Mollie (BYM) was used to fit the SMRs and other covariates (Besag et al., 1991). The smoothing process was run by the built-in conditional autoregressive (CAR) model which incorporates a spatially correlated component and a non-spatially correlated component. The model is generally expressed as:

$$Y_i \sim \text{Poisson}(e_i \theta_i)$$

$$\log \theta_i = \alpha + h_i + b_i$$

$$\bar{b}_i = \frac{1}{\sum_j w_{ij}} \sum_j b_j w_{ij}$$

$$\tau_i^2 = \frac{\tau_u^2}{\sum_j w_{ij}}$$

$w_{ij} = 1$ if i, j shared borders, 0 if they did not

where $\theta_i = \frac{Y_i}{E_i}$ i. e. the standardized mortality ratio (SMR) for area i

α is the overall level of the relative risk

h_i is the uncorrelated heterogeneity, $h_i \sim N(0, \tau_h^2)$

b_i is the correlated heterogeneity, $[b_i | b_j, i \neq j, \tau_b^2] \sim N(\bar{b}_i, \tau_i^2)$

h_i represents the uncorrelated heterogeneity or the global variability, which means the extent to which the SMR is smoothed by the national mean. b_i represents the correlated heterogeneity or the local variability, which denotes the effect from neighbouring areas. Neighbouring areas were defined as two regional areas which shared a common boundary. For instance, if a certain area shared a border with five other areas, these five areas would exert the same amount of effect on the smoothing process, and areas other than these five would exert a zero smoothing effect. An adjacent matrix, containing information denoting the neighborhoods of the areas, was compiled by GeoBUGS. The adjacent matrix was then processed by WinBUGS to generate the values of b_i .

In a full Bayesian estimation, the above model was specified, and the least informative prior distributions were assigned to the estimated parameters $(h_i, b_i, \tau_h, \tau_b)$. Inference was carried out via Markov chain Monte Carlo (MCMC) simulation, in which samples were generated from the posterior distribution given the observed values. WinBUGS was used for the simulation and estimations. The first 5,000 iterations were discarded as a burn-in, and the final results were obtained

based on a further 10,000 iterations. Convergence was confirmed by looking into the graphical history of the simulated SMR values. Smoothed estimates were obtained by taking the exponential of the output parameters:

$$\text{Smoothed SMR}_i = \exp(\alpha + b_i + h_i)$$

In addition to the smoothed SMR, parameters τ_b^2 and τ_h^2 control the variability of b and h . The marginal variability of the correlated heterogeneity was approximated by compiling the empirical marginal variance. The ratio of τ_b^2 and τ_h^2 was used to indicate the relative importance of the two components to the total random effects (Mollie, 2000).

Smoothed SMRs were processed by Quantum GIS (1.5) for mapping. An empirical approach proposed by Middleton et al. (2008), in which seven classes were set for representation, was adopted to map the smoothed SMRs. The boundaries of these seven classes were determined by looking into the distribution of all smoothed estimates (Middleton et al., 2008b). The 'no risk' category, with the median SMR equal to 1, was taken as the middle category. Classes higher and lower than 1 were set based on 0.5, 1.5, 2.5 and more than 2.5 log standard deviations apart from the mean SMR. From the pool of smoothed estimates, the log standard deviation for all smoothed estimates was 0.3121. We set the categories into below 0.46, 0.46-0.63, 0.63-0.86, 0.86-1.17, 1.17-1.6, 1.6-2.18, and 2.18 or above. As PAs located in the metropolitan areas were relatively smaller in size, they were magnified in separate figures with a greater resolution for interpretation.

A shading scheme was chosen to reduce any misleading and confusing presentation.

The lightest shading represented the lowest risk areas, and the darkest shading represented the highest risk areas. Intermediate levels of risk were represented by graduated levels of shading between these two endpoints.

Spatial mapping enhanced the visual comparison of suicide risk between urban areas and rural areas, but we still required statistics on suicide rates to understand the metropolitan-rural-remote differentials. Using the same study period as the spatial analysis, sex- and age-standardized suicide rates for the three levels of RRMA classifications were compiled to see if the metropolitan-rural-remote suicide differential was similar in different states/territories. We applied a direct standardization method that used the age group distribution of metropolitan areas in each state/territory as the standard population for the rate compilation. The error factor for calculating the 95% confidence interval was generated by the product of age-, remoteness- and state-specific suicide count and the ratios between the corresponding standard population size and the actual specific population size (Breslow and Day, 1987).

Results

Overall findings from mapping of relative risks

The unsmoothed SMRs for PAs in Australia, which are calculated by dividing the observed number of suicide by the expected number, are shown in Appendix 1. The intervals of unsmoothed SMRs for males and females were 0 to 171.31 and 0 to 74.63 respectively. The standard deviations of unsmoothed SMRs were 5.02 and 3.88 respectively. As some PAs had very low population sizes, they had very low expected suicide counts and hence a few cases of suicide could result in extremely high SMR values. Also, PAs which had no cases of suicide within the period had crude SMRs of 0. These circumstances posed difficulties for visualizing the spatial pattern of suicide.

Smoothed SMRs of all PAs were obtained with the smoothing technique of the Poisson hierarchical model (Figures 1 and 2). The intervals of SMRs for males and females were 0.38 to 14.84, and 0.45 to 2.31, respectively, and their standard deviations were reduced to 0.52 and 0.3, respectively. The PAs with a high risk of suicide were located in the Northern Territory, Tasmania, northern Western Australia and northern Queensland. By contrast, the Australian Capital Territory, New South Wales and the metropolitan areas of Victoria had a lower suicide risk. The box-plots of the smoothed SMRs further supported this contrast (Figures 3 and 4). The ratios between the empirical variance for the structured random effects and unstructured random effects (τ_b^2 / τ_h^2) for both sexes, males and females were 9.44, 7.79 and 178.51, respectively. They supported the contention that the observed variability was mostly explained by the structured random effect, especially for females.

The visual inspection on the mapping of the spatial risk of suicide (Figures 1 and 2) and population density (Figure 5) enhances understanding of the association between them. While coastal areas are heavily populated, most of the inland areas of Australia have very sparse populations (Figure 5). There is a general increasing gradient of suicide risk from coastal areas to the inland areas. Country areas with lower population density tend to have a higher suicide risk than those coastal urban cities. Apart from the positive association between remoteness and suicide risk, the risk was elevated in some populated areas including Perth in Western Australia, Adelaide in South Australia, and Sydney in New South Wales.

For males, an 'urban-rural gradient' was observed in Queensland, New South Wales, Western Australia and Victoria, such that the further the PAs were from metropolitan areas, the higher was the suicide risk (Figure 1). In addition, a number of PAs of Brisbane in Queensland, Perth in Western Australia, around the North Haven and Port Adelaide areas of South Australia, the north-western parts of Victoria and along the Parramatta River in New South Wales had elevated SMRs. We refer to these groups of high-risk PAs as 'spatial clusters', meaning that PAs with high risk of suicide existed close together in space within a specific time frame. For females, no apparent urban-rural gradient of suicide was observed (Figure 2). Spatial clusters were found along the Brisbane River in Queensland, around the metropolitan areas of Western Australia and the south east suburbs of Victoria, and along the Parramatta River in New South Wales.

Metropolitan-rural-remote differences by sex

Table 1 shows that the metropolitan-rural-remote differential of suicide was quite significant for males but not for females. Overall, the male age-standardized suicide rates for metropolitan, rural and remote areas were 15.67, 18.19 and 30.0 per 100,000, respectively. The equivalent figures for females were 4.6, 4.56 and 5.54 per 100,000.

Except in the Northern Territory and New South Wales, remote or rural areas had significantly higher male suicide rates than metropolitan areas in all jurisdictions. In the Northern Territory, the male suicide rates in the three RRMA classifications had quite wide confidence intervals so they did not differ significantly from each other. New South Wales was the only state in which the metropolitan suicide rate was higher than the rural suicide rate, and comparable to remote areas. Male suicide rates in the remote areas of Victoria, South Australia and Western Australia were significantly higher than those in the rural areas.

There was no consistent metropolitan-rural-remote suicide contrast for female suicide rates across the jurisdictions. In the Northern Territory and Tasmania, the suicide rates were not significantly different across the three categories of remoteness. Victoria and Queensland had higher female suicide rates in rural than in metropolitan areas, whereas South Australia and New South Wales exhibited the opposite pattern. Western Australia had higher female suicide rates in metropolitan areas than in rural areas, but similar rates to those in remote areas.

Discussion

Interpreting the findings

This study explored the spatial pattern of suicide risks for the whole of Australia with a reliable set of suicide data from the NCIS. Higher risk of suicide was found in the Northern Territory, Tasmania, northern Queensland and northern Western Australia. By contrast, the Australian Capital Territory, the majority of New South Wales and Victoria had lower risk of suicide. Male suicide risk had an apparent metropolitan-rural-remote gradient, whereas females had a more homogenous pattern. In some states/territories, specific spatial clusters of high-risk PAs were identified in metropolitan areas. The comparison of age-standardized suicide rates for different states/territories and PAs grouped by remoteness classification showed an unequal metropolitan-rural-remote differential of suicide across the states/territories. Higher male suicide rates were found in rural and remote areas in six states/territories, but New South Wales had higher male suicide rates in its metropolitan areas compared to rural areas. In addition, South Australia and New South Wales had higher female suicide rates in metropolitan areas than in rural and remote areas.

Our findings supported the existence of urban-rural gradient of male suicide risk in six states/territories. Areas further from urban centres, which have a lower population density, generally had higher suicide risk. Also, the contrast between rural and remote areas was significant in three jurisdictions, supporting the existence of metropolitan-rural-remote differentials. These findings are consistent with those of

Caldwell et al. (2004) and Taylor et al. (2005), which also demonstrated that rural males had higher suicide rates than urban males. Our study also extended previous findings about the spatial pattern of suicide in Queensland to the whole of Australia (Qi et al., 2010). The urban-rural differential of suicide in Australia is similar to previous findings in Taiwan (Chang et al., 2011), New Zealand (Pearce et al., 2007), Scotland (Levin and Leyland, 2005), Finland (Pirkola et al., 2009) and Russia (Pridemore and Spivak, 2003). On the other hand, our findings are different from those in the UK and Denmark which indicated that suicide rates were higher in inner-city areas or coastal areas, though remote rural areas in England also show relatively high rates (Middleton et al., 2008b; Qin, 2005). Possible explanations for this discrepancy are the difference in distribution of urban areas and compositional factors between Australia and these countries. In Australia, economic activities are mainly concentrated in populated coastal areas, and those who live in metropolitan areas generally have better access to mental health services compared to their rural or remote counterparts (Caldwell et al., 2004). By contrast, in the UK, the greater risk in inner-city areas may be attributable to its deprived environment and the inward-shift of high risk individuals to these areas (Middleton et al., 2008b). In Denmark, the high prevalence of suicide was associated with the over-representation of people with lower socioeconomic status and minorities (Qin, 2005).

Socio-economic deprivation in rural or remote areas may have exerted an adverse impact on the mental health of people living in those places. This explanation is consistent with findings from other countries (Congdon, 1996; Pearce et al., 2007; Pridemore and Spivak, 2003). The unstable and less-developed economic environment in rural areas which means that rural residents are more likely to be

unemployed or underemployed than their city counterparts (Fragar et al., 2010). This can lead to out-migration problems. Employment options in rural areas are predominantly related to agriculture or to the infrastructure that supports it, and thus there are relatively limited work opportunities. Better job opportunities and easier-to-access social service in urban areas mean that cities attract migrants from rural areas (Qin, 2005), and those who are left behind can feel socially isolated (Nicholls et al., 2006). This may have been particularly problematic during the study period because of a drought that occurred at the time. Reduced rainfall and degraded soil conditions adversely impacted upon agricultural productivity during the study period, and this worsened the economic and emotional well-being of farmers and others living in rural and remote areas (Nicholls et al., 2006; Qi et al., 2009; Speldewinde et al., 2009).

Other factors may also play a role. Those living in rural and remote residents are, on average, more likely to have lower education levels than city-dwellers, and have higher levels of psychological distress (Kelly et al., 2010). In addition, men living in rural areas and working in the farming industry may be unlikely to seek help and more likely to personalize any experiences of failure (Alston, In press). Taken together, these factors may impact negatively on the mental health of rural and remote residents and make them more prone to suicide.

The elevated suicide risk in the Northern Territory and remote areas in other states/territories may be related to the high proportion of Indigenous people living in these areas. Indigenous people make up 29% of the overall population of the Northern Territory, compared with less than 4% of the total population in all

states/territories (Australian Bureau of Statistics, 2006a). About 45% of Indigenous males and 24% of Indigenous females live in regional remote areas. This compares with only 2% of the non-Indigenous Australian population (Australian Bureau of Statistics 2006a). Previous studies have confirmed that Indigenous Australians have significantly higher suicide mortality rates than their non-Indigenous counterparts (De Leo et al 2011, Hunter et al 1999, Pridmore & Fujiyama 2009). This has been attributed to various cultural and environmental factors, including their greater socio-economic deprivation (Hanssens, 2011) and higher prevalence of risk behaviours (e.g., use of alcohol and illicit drugs) (Australian Bureau of Statistics, 2006a). The spatial pattern of suicide among Indigenous people warrants further study.

In contrast to the pattern for men, the overall differences between metropolitan female and rural/remote females were not significant. Our results in this regard were consistent with previous Australian studies showing that female generally have a lower suicide rate than males (De Leo et al., 2011; Large and Nielssen, 2010; Taylor et al., 2005). A range of factors may underpin this finding. In particular, the socio-economic deprivation in rural and remote areas may have a more direct effect on the mental health of country males than country females (Alston, In press). Females are also more likely to seek help than males, irrespective of whether they are living in urban or rural areas (Cotton et al., 2006). It is also worth noting that the findings may have been different if we had considered suicide attempts as well as completed suicide. Females have higher rates of non-fatal suicide attempts than males (De Leo et al., 2005; Pirkis et al., 2000), possibly because they tend to choose less violent methods (Kushner, 1989). Ideally, future work would consider completed

and attempted suicide in tandem. The findings about the spatial pattern of suicide for females might be altered when attempted suicide data is incorporated.

In addition to elevated suicide risk in rural and remote areas, several spatial clusters of suicide were identified in metropolitan areas of Western Australia, South Australia, Queensland and New South Wales. This phenomenon mirrored the findings of 'bull's-eye' effect found in the UK, which was attributed to inner-city deprivation (Middleton et al., 2008b). However, it contrasts with the more general finding in this and other studies of lower risk of suicide in metropolitan areas due to factors like better healthcare access, socio-economic circumstances and employment opportunities (Caldwell et al., 2004; Taylor et al., 2005). These specific urban spatial clusters might be associated with a range of influences. Firstly, the availability of suicide means would alter the likelihood of suicide in urban areas. In Taiwan, the emergence of charcoal burning suicide method altered the geographic pattern of suicide, and directly led to elevated suicide rates in its major cities (Chang et al., 2010). The equivalent method in Australia may be jumping from heights, which occurs in cities where high-rise buildings and bridges are commonly found. A previous study suggested that the density of multi-storey buildings and the accessibility of cliffs around Sydney Harbour resulted in greater suicide rate of jumping in that city (Large and Nielssen, 2010). Interventions that restrict suicide means in urban areas may be an effective way to reduce the likelihood of the observed spatial clusters.

A second explanation for the specific spatial clusters in urban areas might be an imitation effect. Secondly, suicide imitation in urban areas could explain the presence

of spatial clusters. Baller and Richardson (2002) have suggested that a high level of social integration may increase an individual's exposure to suicide among those who are known to them and/or through media coverage, and thus increase the likelihood of suicide contagion. Evidence from elsewhere suggests that there is a dose-response effect operating in suicide imitation, such that the greater the number of models who reinforce suicidal behavior, the greater the likelihood of copycat acts (Blood and Pirkis, 2001; Chang et al., 2010). Both traditional and newer media are more readily accessed by people living in urban areas, and these might facilitate the spread of information and suicide modeling (Chang et al., 2010).

Our findings have important implications for national planning of suicide prevention activities. Australia's National Suicide Prevention Strategy (NSPS) has funded national initiatives and local projects in suicide prevention since 1999 (Headey et al., 2006). Our findings suggest that geographical considerations should be taken into account in future funding allocations. For example, health service provision – and particularly mental health service provision – varies by state/territory and is better in metropolitan areas than in rural and remote areas. Increasing access to community mental health service by rural/remote residents can substantially reduce suicide risk (Pirkola et al., 2009). Given that mental illness is the strongest risk factor for suicide, adequate mental health service provision across all localities should be a crucial plank of any suicide prevention policy. *Australia's Living is For Everyone* (LiFE) framework has emphasized the need for strategies to address mental health and wellbeing in rural males. We would concur, and suggest that males living in very remote areas warrant particular attention.

Study limitations

Our study had a number of methodological issues which must be acknowledged.

Firstly, we used postal area as the unit of analysis in the mapping exercise. Previous spatial studies in Australian suicide have used other spatial units like Local Government Area (LGA) and Census Collection District (CD). We did not use LGAs for several reasons: (a) according to the Australian Bureau of Statistics, LGAs do not cover unincorporated areas of Australia, where no local governing bodies have responsibility (Australian Bureau of Statistics, 2010a) ; and (b) the total number of LGAs in Australia was only 676 in 2006, whereas the total number of PAs was 2,515. We also did not use CDs on the following grounds: (a) since there were 38,704 CDs throughout Australia in 2006, many CDs would have very low or zero events; and (b) statistical modeling involving too large a number of spatial units requires significant computer capacity. Besides covering all regions of Australia, the advantage of using PAs is that the size is small enough ($n=2,515$) to reflect the suicide pattern at community level, avoiding an aggregation effect which might hinder identification of the true pattern (Waller and Gotway, 2004). Having said this, one drawback of using PAs was that PAs with different geographical sizes and population sizes were compared. This resulted in a certain degree of 'over-smoothing' of some inland areas which have generally more neighboring areas than coastal areas (Chang et al., 2011; Middleton et al., 2008b), and the suicide pattern within one particularly large PA may not be homogenous. In addition, some suicide cases had to be dropped because some postcodes from the NCIS data archive could not be matched with the postcodes of the PAs based on the Census Geographic Areas from ABS or unidentified with a proper residential address. In our suicide dataset, less than 1% of

our sample had such mismatch.

Secondly, our suicide mapping used smoothed SMRs for better visualization of the suicide pattern over given areas. The values were compiled from statistical modeling which took into account the neighbouring effect. Unlike the actual suicide rate, smoothed SMRs were relative measures of suicide risk, but not absolute suicide rates in particular areas.

Thirdly, it was not feasible to apply the modeling and mapping technique for different age groups. Suicide is a rare event, and a finer breakdown of the suicide figures would have led to fewer events, including zero events, in some areas. Taking males under the age of 40 as an example, our data showed that 1,308 PAs (51.9%) had no suicides within the study period. To demonstrate the age pattern, larger units of analysis (e.g. LGAs) would have been necessary to reduce the number of 'zero events' areas.

Fourthly, it was beyond our capacity to control for socio-economic conditions in either the mapping or suicide prevalence estimation. Other studies have shown that the excess area suicide risk would be reduced with adjustment by socio-economic condition or other compositional characteristics of the areas (Taylor et al., 2005).

Lastly, our spatial analysis aggregated the suicide cases from 2004 to 2008, which may have obscured the changes in the numerator (instances of suicide) and the denominator (population counts) during the study period. This limitation was inevitable as the strength of our aggregation was that more suicide cases could be

obtained for analysis to reduce statistical error.

Conclusions

Our findings suggest that it is important to take geographical variations in suicide risk into account in national policy making. Particular suicide prevention interventions might be targeted at males living in remote areas, and some localized areas in metropolitan zones.

References

- Alston, M., In press. Rural male suicide in Australia. *Social Science & Medicine* In Press, Corrected Proof.
- Australian Bureau of Statistics, 2001. *Statistical Geography Volume 2 - Census Geographic Areas* Canberra, Australia.
- Australian Bureau of Statistics, 2006a. *National Aboriginal and Torres Strait Islander Health Survey*. Australian Bureau of Statistics, Canberra, Australia.
- Australian Bureau of Statistics, 2006b. *Statistical Geography: Volume 2 - Census Geographic Areas*. Canberra, Australia.
- Australian Bureau of Statistics, 2007. *Household Wealth and Wealth Distribution*. Canberra, Australia.
- Australian Bureau of Statistics, 2010a. *Australian Standard Geographical Classification (ASGC)*. Canberra, Australia.
- Australian Bureau of Statistics, 2010b. *Causes of Death*. Canberra, Australia.
- Australian Bureau of Statistics, 2010c. *Deaths*. Canberra, Australia.
- Baller, R.D., Richardson, K.K., 2002. Social Integration, Imitation, and the Geographic Patterning of Suicide. *American Sociological Review* 67, 873-888.
- Besag, J., York, J., Mollie, A., 1991. Bayesian image restoration with two applications in spatial statistics. *Annals of the Insitute of Statistics and Mathematics* 43, 1-59.
- Blood, R.W., Pirkis, J., 2001. Suicide and the Media. *Crisis: The Journal of Crisis Intervention and Suicide Prevention* 22, 163-169.
- Breslow, N.E., Day, N.E., 1987. The design and analysis of cohort studies. In: Breslow, N.E. and Day, N.E. (Eds.), *Statistical methods in cancer research*. International

Agency for Research on Cancer, Lyon.

Caldwell, T.M., Jorm, A.F., Dear, K.B.G., 2004. Suicide and mental health in rural, remote and metropolitan areas in Australia. *Medical Journal of Australia* 181, S10-S14.

Chang, S.-S., Sterne, J.A.C., Wheeler, B.W., Lu, T.-H., Lin, J.-J., Gunnell, D., 2011. Geography of suicide in Taiwan: Spatial patterning and socioeconomic correlates. *Health & Place* 17, 641-650.

Chang, S.S., Gunnell, D., Wheeler, B.W., Yip, P., Sterne, J.A.C., 2010. The Evolution of the Epidemic of Charcoal-Burning Suicide in Taiwan: A Spatial and Temporal Analysis. *PLoS Medicine* 7, 1-10.

Congdon, P., 1996. Suicide and Parasuicide in London: A Small-Area Study. *Urban Studies* 33, 137-158.

Congdon, P., 1997. Bayesian models for spatial incidence: a case study of suicide using the BUGS program. *Health & Place* 3, 229-247.

Congdon, P., 2000. Monitoring Suicide Mortality: A Bayesian Approach. *European Journal of Population* 16, 251-284.

Cotton, S.M., Wright, A., Harris, M.G., Jorm, A.F., McGorry, P.D., 2006. Influence of gender on mental health literacy in young Australians. *The Australian And New Zealand Journal Of Psychiatry* 40, 790-796.

De Leo, D., Cerin, E., Spathonis, K., Burgis, S., 2005. Lifetime risk of suicide ideation and attempts in an Australian community: Prevalence, suicidal process, and help-seeking behaviour. *Journal of Affective Disorders* 86, 215-224.

De Leo, D., Svetcic, J., Milner, A., 2011. Suicide in Indigenous people in Queensland, Australia: trends and methods, 1994-2007. *Australian and New Zealand Journal of Psychiatry* 45, 532-538.

- Department of Primary Industries and Energy, Department of Human Services and Health, 1994. Rural, Remote and Metropolitan Areas classification. 1991 Census edition. Australian Government Publishing Service, Canberra.
- Driscoll, T., Henley, G., Harrison, J., 2003. The National Coroners Information System as an information tool for injury surveillance. Catalogue no. INJCAT 60. Australian Institute of Health and Welfare, Canberra.
- Duckett, S.J., 2007. The Australian Health Care System. Oxford, Australia.
- Fragar, L., Stain, H.J., Perkins, D., Kelly, B., Fuller, J., Coleman, C., Lewin, T.J., Wilson, J.M., 2010. Distress among rural residents: Does employment and occupation make a difference? *Australian Journal of Rural Health* 18, 25-31.
- Hanssens, L., 2011. "Suicide (Echo) Clusters" -- Are They Socially Determined, the Result of a Pre-existing Vulnerability in Indigenous Communities in the Northern Territory and How Can We Contain Cluster Suicides? *Aboriginal & Islander Health Worker Journal* 35, 14-19.
- Headey, A., Pirkis, J., Merner, B., VandenHeuvel, A., Mitchell, P., Robinson, J., Parham, J., Burgess, P., 2006. A review of 156 local projects funded under Australia's National Suicide Prevention Strategy: Overview and lessons learned. *Australian e-Journal for the Advancement of Mental Health* 5, 1-15.
- Kelly, B.J., Stain, H.J., Coleman, C., Perkins, D., Fragar, L., Fuller, J., Lewin, T.J., Lyle, D., Carr, V.J., Wilson, J.M., Beard, J.R., 2010. Mental health and well-being within rural communities: The Australian Rural Mental Health Study. *Australian Journal of Rural Health* 18, 16-24.
- Kushner, H.I., 1989. *American Suicide*. Rutgers University Press, New Brunswick and London.
- Large, M.M., Nielssen, O.B., 2010. Suicide in Australia: meta-analysis of rates and

- methods of suicide between 1988 and 2007. *Med J Aust* 19, 432 - 437.
- Levin, K.A., Leyland, A.H., 2005. Urban/rural inequalities in suicide in Scotland, 1981-1999. *Social Science & Medicine* 60, 2877-2890.
- McPhedran, S., Baker, J., 2008. Recent Australian suicide trends for males and females at the national level: Has the rate of decline differed? *Health Policy* 87, 350-358.
- Middleton, N., Sterne, J., Gunnell, D.J., 2008a. An atlas of suicide mortality: England and Wales, 1988-1994. *Health & Place* 14, 492 - 506.
- Middleton, N., Sterne, J.A.C., Gunnell, D.J., 2008b. An atlas of suicide mortality: England and Wales, 1988-1994. *Health & Place* 14, 492-506.
- Mollie, A., 2000. Bayesian mapping of Hodgkin's disease in France. In: Elliott, P., Wakefield, J.C., Best, N.G. and Briggs, D.J. (Eds.), *Spatial Epidemiology. Methods and Applications*. Oxford University Press, Oxford, pp. 267-285.
- Nicholls, N., Butler, C., Hanigan, I., 2006. Inter-annual rainfall variations and suicide in New South Wales, Australia, 1964–2001. *International Journal of Biometeorology* 50, 139-143.
- Pearce, J., Barnett, R., Jones, I., 2007. Have urban/rural inequalities in suicide in New Zealand grown during the period 1980-2001? *Social Science & Medicine* 65, 1807-1819.
- Pirkis, J., Burgess, P., Dunt, D., 2000. Suicidal Ideation and Suicide Attempts Among Australian Adults. *Crisis: The Journal of Crisis Intervention and Suicide Prevention* 21, 16-25.
- Pirkola, S., Sund, R., Sailas, E., Wahlbeck, K., 2009. Community mental-health services and suicide rate in Finland: a nationwide small-area analysis. *The Lancet* 373, 147-153.

- Pridemore, W.A., Spivak, A.L., 2003. Patterns of suicide mortality in Russia. *Suicide & Life - Threatening Behavior* 33, 132-150.
- Qi, X., Tong, S., Hu, W., 2009. Preliminary spatiotemporal analysis of the association between socio-environmental factors and suicide. *Environmental Health: A Global Access Science Source* 8, 46-57.
- Qi, X., Tong, S., Hu, W., 2010. Spatial distribution of suicide in Queensland, Australia. *BMC Psychiatry* 10, 106-106.
- Qin, P., 2005. Suicide risk in relation to level of urbanicity - a population-based linkage study. *international Journal of Epidemiology* 34, 846-852.
- Razvodovsky, Y., Stickley, A., 2009. Suicide in urban and rural regions of Belarus, 1990-2005. *Public Health* 123, 27-31.
- Speldewinde, P.C., Cook, A., Davies, P., Weinstein, P., 2009. A relationship between environmental degradation and mental health in rural Western Australia. *Health & Place* 15, 880-887.
- Taylor, R., Page, A., Morrell, S., Harrison, J., Carter, G., 2005. Social and Psychiatric Influences on Urban-Rural Differentials in Australian Suicide. *Suicide & Life - Threatening Behavior* 35, 277-290.
- Waller, L.A., Gotway, C.A., 2004. *Applied Spatial Statistics for Public Health Data*. John Wiley & Sons, New Jersey.
- Yip, P.S.F., Callanan, C., Yuen, H.P., 2000. Urban/rural and gender differentials in suicide rates: East and West. *Journal of Affective Disorders* 57, 99-106.

Table 1. Age-standardized suicide rates across states and RRMA classification

Figure 1. Smoothed standardized mortality ratios for males

Figure 2. Smoothed standardized mortality ratios for females

Figure 3: Box-plot comparison of male suicide smoothed relative risk across states

Figure 4: Box-plot comparison of female suicide smoothed relative risk across states

Figure 5. Population density (number of residents per sq. km.)

Appendix 1: Unsmoothed standardized mortality ratios of suicide in Australia

Appendix 2: Smoothed standardized mortality ratios (Both sexes)