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ORIGINAL ARTICLE

# Clusters of suicides and suicide attempts: detection, proximity and correlates

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**Background.** A suicide cluster is defined as a higher number of observed cases occurring in space and/or time than would typically be expected. Previous research has largely focused on identifying clusters of suicides, while there has been comparatively limited research on clusters of suicide attempts. We sought to identify clusters of both types of behaviour, and having done that, identify the factors that distinguish suicide attempts inside a cluster from those that were outside a cluster.

**Methods.** We used data from Western Australia from 2000 to 2011. We defined suicide attempts as admissions to hospital for deliberate self-harm and suicides as deaths due to deliberate self-harm. Using an analytic strategy that accounted for the repetition of attempted suicide within a cluster, we performed spatial-temporal analysis using Poisson discrete scan statistics to detect clusters of suicide attempts and clusters of suicides. Logistic regression was then used to compare clustered attempts with non-clustered attempts to identify risk factors for an attempt being in a cluster.

**Results.** We detected 350 (1%) suicide attempts occurring within seven spatial-temporal clusters and 12 (0.6%) suicides occurring within two spatial-temporal clusters. Both of the suicide clusters were located within a larger but later suicide attempt cluster. In multivariate analysis, suicide attempts by individuals who lived in areas of low socioeconomic status had higher odds of being in a cluster than those living in areas of high socioeconomic status [odds ratio (OR) = 29.1, 95% confidence interval (CI) = 6.3–135.5]. A one percentage-point increase in the proportion of people who had changed address in the last year was associated with a 60% increase in the odds of the attempt being within a cluster (OR = 1.60, 95% CI = 1.29–1.98) and a one percentage-point increase in the proportion of Indigenous people in the area was associated with a 7% increase in the suicide being within a cluster (OR = 1.07, 95% CI = 1.00–1.13). Age, sex, marital status, employment status, method of harm, remoteness, percentage of people in rented accommodation and percentage of unmarried people were not associated with the odds of being in a suicide attempt cluster.

**Conclusions.** Early identification of and responding to suicide clusters may reduce the likelihood of subsequent clusters forming. The mechanisms, however, that underlie clusters forming is poorly understood.

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**Key words:** Epidemiology, mental health, risk factors, suicide.

## Introduction

A suicide cluster is typically defined as an unusually high number of suicidal behaviours occurring closer together in time and/or space than would be expected by chance (Centers for Disease Control and Prevention, 1988; Joiner, 1999). Despite suicide being a rare event, and suicide clusters being even rarer (Niedzwiedz *et al.* 2014), there is nonetheless substantial community concern about suicide clusters because these may have a self-perpetuating effect. In recent years, the importance of detecting and monitoring suicide clusters has been increasingly recognised (Jones *et al.* 2013; Gould *et al.* 2014). Such work allows early interventions to be put in place at cluster areas to prevent additional injuries and deaths.

In suicidology, the vast majority of research on clusters has focused on clusters of deaths by suicide. Only one study, conducted over 20 years ago, has identified clusters of suicide attempts using a rigorous statistical approach (Gould *et al.* 1994). It showed evidence of clustering among people aged younger than 34 years and those aged between 55 and 64 years. In the current study, we sought to extend this work by identifying both clusters of suicide attempts and clusters of

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suicides using scan statistics – a standard method for identifying clusters of disease in space and time (Kulldorff & Nagarwalla, 1995; Niedzwiedz *et al.* 2014). Having identified several suicide attempt and suicide clusters, we then examined the proximity between them. We then focused on the suicide attempt clusters and use logistic regression to investigate the factors associated with the risk of a suicide attempt occurring in a cluster.

## Methods

### *Study sample and data*

We defined suicide attempts as those admissions to hospital for self-harm (regardless of whether or not there was intent to die) and suicides as deaths where the primary cause of death was intentional self-harm. We use hospital admission data to define suicide attempts (rather than emergency department presentation data) because emergency department data on self-harm is not collected systematically in Australia. Data on suicide attempts and suicides for residents in Western Australia between 1 January 2000 and 31 December 2011 were obtained from Data Linkage Western Australia (part of the Department of Health in Western Australia). This agency maintains a system that links health records from core administrative datasets at the individual level (Holman *et al.* 1999, 2008). A cohort of individuals who had been admitted to hospital for intentional self-harm (ICD-10 codes X60–X84) and/or who died as a result of intentional self-harm (using the same ICD-10 codes) were identified for us. Following this, the agency extracted hospital admission data from the Hospital Morbidity Data Collection and death data from the official death registry in Western Australia for each individual.

We constructed a dataset containing all suicide attempts and suicides occurring in the period of interest. The following individual-level information was retrieved for each included case: date of admission/death, age at the time of admission/death, sex, suicide method, ICD-10 code for cause of injury/death and statistical local area of usual residence. For each suicide attempt, information on marital status and employment status at the time of admission was also extracted. Data at statistical local area-level for each cases were obtained from the 2006 census of the Australian Bureau of Statistics (ABS). These area-level data included area remoteness, socioeconomic status, social fragmentation indicators and proportion of Indigenous people. We excluded those cases that had missing information on residential statistical local area (suicide attempts: $n = 9432$; suicides: $n = 917$) (Fig. 1).

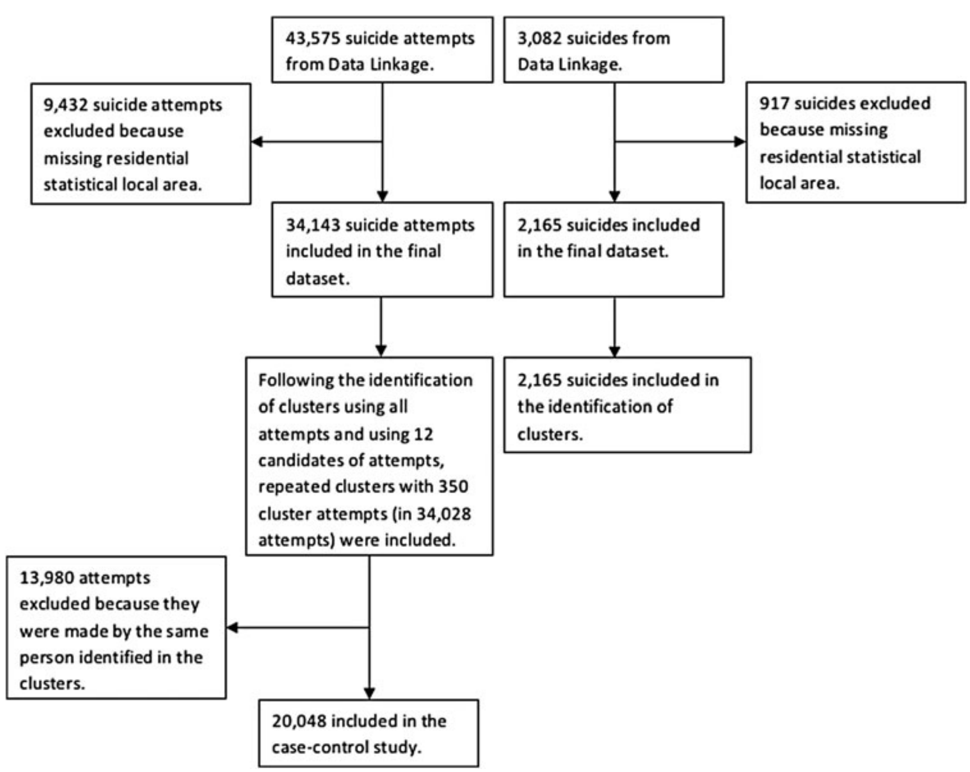


**Fig. 1.** Selection of suicide attempts and suicides for analyses.

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### *Statistical analysis*

We computed the annual suicide attempt rate and the annual suicide rate using the population in 2006 as the denominator as well as the ratio of attempts to suicides for the total population and by age and sex. To detect spatial-temporal clusters of high relative rate for suicide attempts and suicides across Western Australia, we first performed Poisson discrete scan statistics in SaTScan version 9.4.1 (Kulldorff, 2015). To run this analysis in SaTScan, data on cases in each Statistical Local Area as well as population estimates and spatial coordinates of the areas were required. We aggregated the number of suicide attempts and suicides by month of the event and residential statistical level area. We obtained population estimates from the 2006 census of ABS. We computed geographical coordinates of population weighted centroids using a mean centroid algorithm in ArcGIS 10.2.2. This was done using population estimates of the smallest available geographical unit (the collection district) and the statistical local area digital boundary map obtained from the 2006 ABS. These centroids represent a single summary reference point for the area based on the spatial distribution of the population in the area.

Subsequently, we set the time window from a minimum of 1 month to a maximum of 12 months, as suggested in a systematic review that summarised findings from the studies on suicide clusters (Larkin & Beautrais, 2012). To set the spatial scan window, we calculated the incidence rates for suicide attempts and suicides for all areas and obtained a maximum rate of 0.0109 and 0.0046 per person, respectively. We set these values as the maximum window size. The shape of the spatial scan window was fixed as circular. By doing this, a set of cylinders was used to scan the space-time region where the base of the cylinder represents the area of the potential cluster and its height defines the time interval of the cluster.

Monte Carlo stimulation was used to test the significance level of the detected clusters (Kulldorff, 1997). All potential clusters were explored and only classified as clusters if their $p$ value was <0.05. We created a map using ArcGIS to show the locations of these clusters and to assess the proximity of suicide attempt clusters to suicide clusters.

For suicide attempts, the detection of clusters was complicated by the fact that a single individual could have multiple attempts. If ignored, this could have led to a cluster being falsely identified because it consisted of multiple attempts by a single person rather than a single attempt by multiple individuals. Our approach to addressing this issue was to identify suicide attempt clusters using a two-step process. In the first step, all the available data were used to identify a set of candidate clusters. At the second step, we examined each candidate cluster to identify any individual who contributed multiple attempts to the cluster, and then kept just one randomly-selected observation within the cluster for that individual. We then re-identified the suicide attempt clusters, noting any difference between the candidate set of clusters and the new set of clusters. We repeated this multiple times, based on the maximum number of suicide attempts by any individual within a cluster, each time randomly selecting a different observation to delete. Our final set of suicide attempt clusters was therefore those clusters that were consistently identified after the random removal of repeated observations. (See Fig. 2 for an overview of this process.)

Having identified clusters of suicide attempts and suicides, we undertook a case-control study using logistic regression analysis to determine the factors associated with a suicide attempt being in a cluster (the small number of suicides in clusters prevented us being able to fit the same model to suicide clusters). The analysis was conducted at the suicide attempt level. The outcome was a binary variable representing whether the attempt was in a cluster or not. Because multiple suicide attempts were observed in some individuals during the study period, we only included one attempt per person for clustered cases and one attempt per person for non-clustered controls, both chosen at random. This meant that if a person made a suicide attempt that was included in a cluster and another attempt that was not included in a cluster that they could appear as both a case and a control. As a result, 13 980 attempts (41% of observations) were excluded from the analysis. Our predictors in the model were individual and area-level variables. These were sex, age group, marital status, employment status and suicide method at individual level and remoteness, socioeconomic disadvantage, social fragmentation, and proportion of Indigenous people at area level. We used cluster-adjusted robust standard errors (based on statistical local area) to account for a possible within-area correlation in the outcome. We initially performed univariate analyses to estimate unadjusted odds ratios (ORs) and then multivariate analysis to estimate adjusted ORs for clustered attempts and non-clustered attempts associated with variables at the individual and area level.

## Results

### *Descriptive results*

There were 34 143 suicide attempts (rate 145.7 per 100 000) and 2165 suicides during the study period (rate 9.2 per 100 000) (Table 1). The ratio of attempts to suicides was 15.8. The suicide attempt rate was higher for women than men (females: 186.3 per 100 000 *v.* males: 103.9 per 100 000) whereas the opposite was true for the suicide rate (males: 14.3 per 100 000 *v.* females: 4.1 per 100 000). Both

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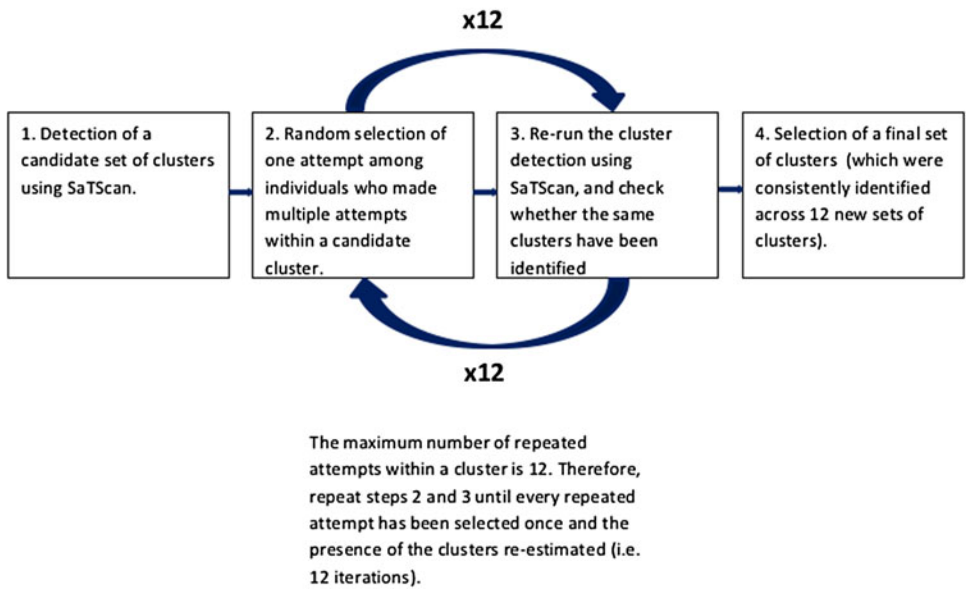


**Fig. 2.** Overview of the procedure used to identify suicide attempt clusters.

the suicide attempt rate and the suicide rate were higher for people aged 25–44 years than for other age groups. The ratio of attempts to suicides declined steadily with age. The ratio was highest for people age <25 years (30.6) and lowest for people >65 years (4.3), suggesting greater lethality (i.e., more attempts leading to death in older people). Poisoning was the most frequent used method for attempting suicide (73%) while hanging was the most common method used by individuals who died by suicide (55%).

**Table 1.** *Characteristics of suicide attempts and suicides in Western Australia 2000–2011*

| | Suicide attempts | | Suicides | | Ratio: attempts/suicides |
|---|---|---|---|---|---|
| | *n* | Rate (per 100 000 persons) | *n* | Rate (per 100 000 persons) | % |
| Total cases | 34 143 | 145.7 | 2165 | 9.2 | 15.8 |
| Sex | | | | | |
| Male | 12 171 | 103.9 | 1679 | 14.3 | 7.3 |
| Female | 21 972 | 186.3 | 486 | 4.1 | 45.4 |
| Age group | | | | | |
| <25 | 10 380 | 128.6 | 335 | 4.2 | 30.6 |
| 25–44 | 16 337 | 243.9 | 932 | 13.9 | 17.5 |
| 45–64 | 6320 | 106.8 | 645 | 10.9 | 9.8 |
| ≥65 | 1106 | 39.1 | 253 | 9.0 | 4.3 |
| | *n* | % | *n* | % | |
| Suicide method | | | | | |
| Poisoning | 24 763 | 72.5 | 278 | 12.8 | – |
| Motor vehicle exhaust | 453 | 1.3 | 297 | 13.7 | – |
| Hanging | 1004 | 2.9 | 1198 | 55.3 | – |
| Drowning | 24 | 0.1 | 43 | 2.0 | – |
| Firearms | 45 | 0.1 | 144 | 6.7 | – |
| Cutting/piercing | 6473 | 19.0 | 46 | 2.1 | – |
| Jumping from heights | 200 | 0.6 | 52 | 2.4 | – |
| Other | 1181 | 3.5 | 107 | 4.9 | – |

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### *Cluster detection*

For suicide, we detected two spatial-temporal clusters of high relative risk. For suicide attempts, we identified eight candidate clusters of the same kind. On the grounds that the maximum number of suicide attempts by a person within a cluster was 12 attempts, we performed 12 iterations where we selected one observation at random and repeated the cluster detection analysis. Based on these results, we excluded one cluster from our final set of suicide attempt clusters, leaving seven clusters, which were used for the remainder of the suicide attempts analysis.

One per cent of suicide attempts (350 of 34 028 suicide attempts) occurred in seven spatial-temporal clusters and 0.6% of suicides (12 of 2165 suicides) occurred in two spatial-temporal clusters, Table 2. The cluster size ranged from 20 to 79 cases for suicide attempts and four to eight cases for suicide. Figure 3 shows the geographical distribution of the detected clusters of suicide attempts and suicides. We observed that both of the suicide clusters (numbers 8 and 9) were located within the same area as a suicide attempt cluster (number 1). They were found in remote areas. These suicide clusters preceded the overlapping suicide attempt clusters. Approximately 64% of all suicide attempt clusters were found in urban or regional areas.

### *Factors associated with suicide attempts occurring in a cluster*

Table 3 shows that there was evidence that a number of variables were associated with a suicide attempt being in a cluster in the univariate analyses. Relative to the odds of people aged 45–64 being in a suicide attempt cluster (the reference category), those aged <25 years (OR = 1.57, 95% CI = 1.02–2.42) and those aged 25–44 years (OR = 1.76, 95% CI = 1.20–2.58) had higher odds of being in a suicide attempt cluster. Those who use hanging (OR = 4.05, 95% CI = 1.31–12.54) and cutting or piercing (OR = 2.59, 95% CI = 1·60–4.19) had higher odds of being in a suicide attempt cluster than those who used poisoning. People living in remote or very remote regions had seven times higher odds of being in a suicide attempt cluster compared with the odds of those living in major cities or regional areas (OR = 6.83, 95% CI = 2.18–21.40). Relatedly, those living in areas of socioeconomic disadvantage (quintiles 1 and 2) had odds of being in a suicide attempt cluster that were ten times higher than the odds for those living in areas with little disadvantage (quintiles 4 and 5; OR = 9.84, 95% CI = 1.14–85.1). All three measures of social fragmentation were associated with the odds of being in a suicide attempt cluster. A one percentage-point increase in the proportion of people living in rented accommodation in the area was associated with a 9% increase in the odds of being in a suicide attempt cluster (95% CI = 1.05–1.13). A one percentage-point increase in the proportion of people who have changed address in the last year was associated with a 28% increase in the odds of being in a suicide attempt cluster (95% CI = 1.15–1.41), and a one percentage-point increase in the proportion of unmarried people in the area was associated with a 15% increase in the odds of being in a suicide attempt cluster (95% CI = 1.06–1.24). Finally, a one percentage-point increase in the proportion of Indigenous people in the area was associated with a 5% increase in the odds of being in a suicide attempt cluster (95% CI = 1.03–1.06).

**Table 2.** *Information on spatial-temporal clusters of suicide attempts and clusters of suicides*

| Cluster | Start date | End date | Period in month | *p* value | Number of cases |
|---|---|---|---|---|---|
| Suicide attempts | | | | | |
| 1 | Jan 2011 | Dec 2011 | 12 | <0.001 | 79 |
| 2 | Oct 2010 | Sep 2011 | 12 | <0.001 | 57 |
| 3 | Nov 2010 | Oct 2011 | 12 | <0.001 | 58 |
| 4 | Dec 2010 | Oct 2011 | 11 | <0.001 | 20 |
| 5 | Sep 2010 | Nov 2010 | 3 | 0.011 | 25 |
| 6 | Dec 2008 | Nov 2009 | 12 | 0.022 | 59 |
| 7 | Mar 2004 | Feb 2005 | 12 | 0.036 | 52 |
| Suicides | | | | | |
| 8 | Dec 2005 | Aug 2006 | 9 | 0.002 | 8 |
| 9 | Dec 2007 | Jan 2008 | 2 | 0.008 | 4 |

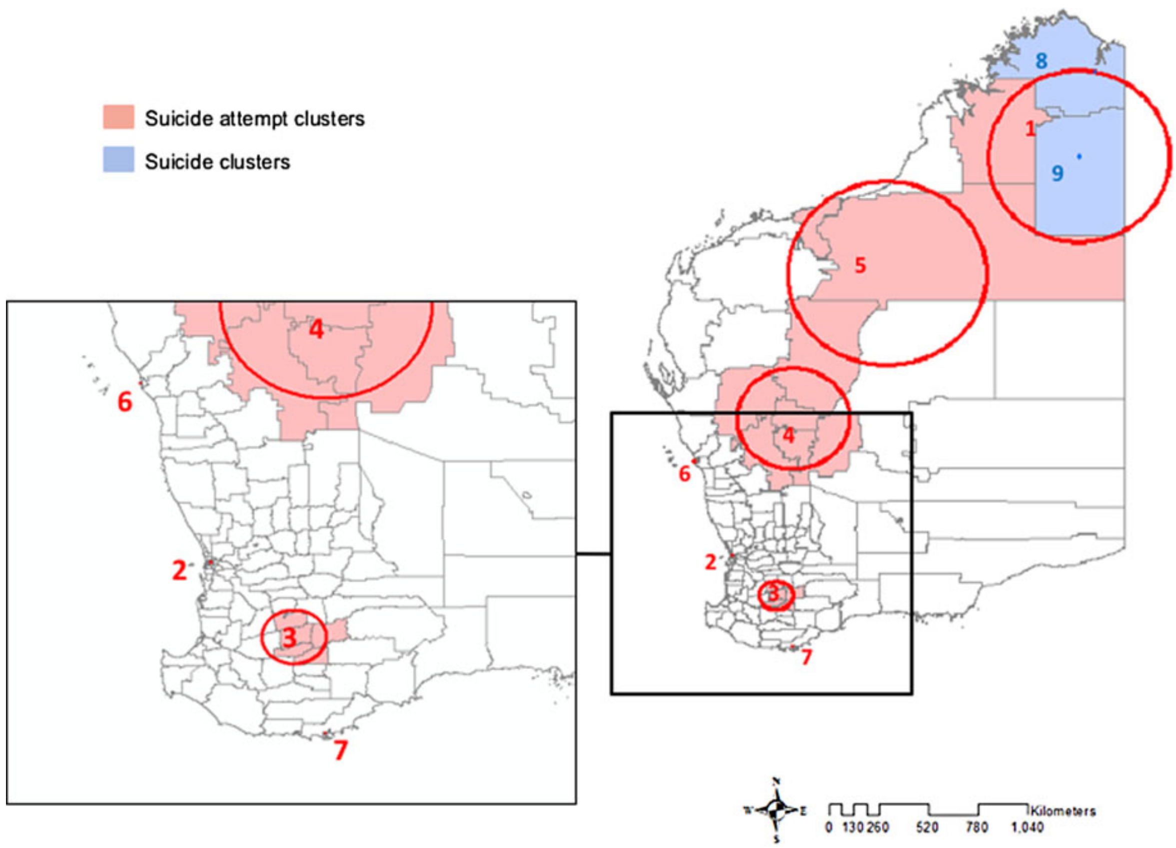


**Fig. 3.** Geographical locations of suicide attempt clusters and suicide clusters identified in Western Australia over a 12-year period.

In multivariate analysis only three of these factors remained associated with an attempt being in a cluster. The odds of being in a cluster differed by the socio-economic status of the area of residence. Compared with those living in areas of high socioeconomic status (quintiles 4 and 5), those in the bottom two quintiles had 29 times higher odds of being in a cluster (OR = 29.14, 95% CI = 6.27–135.45). As the proportion of people in the area of residence who had moved in the previous year increased, the odds of being in a cluster increased (OR = 1.60 per 1 percentage-point increase, 95% CI = 1.29–1.98). Finally, as the proportion of Indigenous people in the area increased, the odds of being in a suicide attempt cluster increased by 7% (OR = 1.07 per 1 percentage-point increase, 95% CI = 1.00–1.13).

## Discussion

We found suicide attempts and suicides clustered in time and space but they were rare, representing 1% of all suicide attempts and 0.6% of all suicides. Only one previous study has used a statistical approach to identify clusters of suicide attempts using data from New Zealand (Gould *et al.* 1994). We extend this work by accounting for the repetition of suicide attempts, which is common (Carroll *et al.* 2014), and by identifying suicide clusters as well.

A recent study by two of us (M. S., J. P.) identified in 15 spatial-temporal suicide clusters in Australia, which accounted for 2.4% of all suicides (Cheung *et al.* 2013). The findings reported here may differ from our previous work due to differences in the methods we used for cluster detection. In the previous study, we set the maximum spatial window parameter from 1 to 50% of the population at risk; in this study we used a specific percentage based upon incidence data. Regardless of this difference, both studies indicate that an appropriate response should be given to clusters. This could include developing a community response plan, educational and psychological debriefings, providing counselling to affected individuals, and promotion of mental health recovery within the community (Cox *et al.* 2012).

We also found both of the suicide clusters were located within the area of one suicide attempt cluster. This finding may have important implications for

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**Table 3.** *Clustered and non-clustered suicide attempts: descriptive results on individual- and area-characteristics and odd ratios from logistic regression analyses*

| | Suicides attempts – *n* (%)/mean | | | | | |
|---|---|---|---|---|---|---|
| | Clustered | Non-clustered | Unadjusted odds ratio (95% CI) | *p* value | Adjusted odds ratio (95% CI) | *p* value |
| Total number | 321 | 19 727 | | | | |
| Sex | | | | 0.056 | | 0.381 |
| Male* | 144 (45) | 7885 (40) | 1.00 | | 1.0 | |
| Female | 177 (55) | 11 842 (60) | 0.82 (0.67–1.01) | | 1.11 (0.88–1.39) | |
| Age group | | | | <0.001 | | 0.262 |
| <25 | 108 (34) | 6419 (33) | 1.57 (1.02–2.42) | | 1.00 (0.58–1.75) | |
| 25–44 | 166 (52) | 8840 (45) | 1.76 (1.20–2.58) | | 1.15 (0.70–1.89) | |
| 45–64* | 39 (12) | 3648 (18) | 1.00 | | 1.00 | |
| ≥65 | 8 (2) | 820 (4) | 0.91 (0.29–2.89) | | 1.47 (0.46–4.64) | |
| Marital status† | | | | 0.098 | | 0.482 |
| Never married | 189 (63) | 10 773 (56) | 1.18 (0.79–1.76) | | 1.04 (0.76–1.43) | |
| Widowed, divorced or separated | 22 (7) | 2508 (13) | 0.59 (0.36–0.97) | | 0.72 (0.42–1.23) | |
| Married (including defacto)* | 89 (30) | 5991 (31) | 1.00 | | 1.00 | |
| Employment status | | | | 0.477 | | 0.651 |
| Employed* | 89 (28) | 5893 (30) | 1.00 | | 1.00 | |
| Unemployed | 66 (20) | 3140 (16) | 1.39 (0.82–2.35) | | 0.81 (0.54–1.21) | |
| Not in the labour force | 112 (35) | 7116 (36) | 1.04 (0.74–1.47) | | 0.82 (0.56–1.19) | |
| Other | 54 (17) | 3578 (18) | 1.00 (0.56–1.79) | | 0.84 (0.56–1.27) | |
| Method | | | | 0.001 | | 0.182 |
| Poisoning* | 171 (53) | 14 616 (74) | 1.00 | | 1.00 | |
| Hanging | 32 (10) | 675 (3) | 4.05 (1.31–12.54) | | 1.51 (0.70–3.28) | |
| Cutting/piercing | 101 (32) | 3339 (17) | 2.59 (1.60–4.19) | | 1.39 (1.03–1.88) | |
| Other | 17 (5) | 1097 (6) | 1.32 (0.72–2.44) | | 1.10 (0.56–2.19) | |
| Remoteness | | | | 0.001 | | 0.060 |
| Major cities/regional* | 201 (63) | 18 142 (92) | 1.00 | | 1.00 | |
| Remote/very remote | 120 (37) | 1585 (8) | 6.83 (2.18–21.40) | | 0.09 (0.01–1.10) | |
| Area socioeconomic status (SES) | | | | <0.001 | | <0.001 |
| 1 or 2 (Low SES) | 251 (78) | 4106 (21) | 9.84 (1.14–85.08) | | 29.14 (6.27–135.45) | |
| 3 | 18 (6) | 7250 (37) | 0.40 (0.04–4.54) | | 0.55 (0.10–3.13) | |
| 4 or 5 (High SES)* | 52 (16) | 8371 (42) | 1.00 | | 1.00 | |
| Social fragmentation indicators | | | | | | |
| % persons in rented accommodation | 40.6 | 26.9 | 1.09 (1.05–1.13) | <0.001 | 0.98 (0.90–1.07) | 0.678 |
| % persons in different address 1 year ago | 22.7 | 18.8 | 1.28 (1.15–1.41) | <0.001 | 1.60 (1.29–1.98) | <0.001 |
| % unmarried persons | 45.6 | 40.2 | 1.15 (1.06–1.24) | 0.001 | 1.04 (0.96–1.12) | 0.377 |
| Other area indicator | | | | | | |
| % Indigenous people | 20.6 | 3.9 | 1.05 (1.03–1.06) | <0.001 | 1.07 (1.00–1.13) | 0.037 |

*Reference categories.
†Marital status was missing for 476 (2.37%) of the total suicide attempts.

preventing suicide attempt clusters because the suicide clusters existed prior to the suicide attempt clusters. It is possible that a suicide death often attracts more community and media attention than a suicide attempt, and thus the contagious effect of a suicide may be relatively stronger. However, the mechanisms underlying the forming of suicide attempt clusters remains largely unknown.

Related to this, although we found a number of factors were associated with the likelihood of a suicide attempt being within a cluster in univariate analyses (age, method, remoteness, socioeconomic status, the proportion of people in rented accommodation, the proportion of people who have moved address in the last year, the proportion of unmarried individuals, and the proportion of Indigenous people in the area), when these factors were evaluated simultaneously in a multivariate model we found only three of them remained associated with a suicide attempt being in

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a cluster. None of these were measured at the individual level. These factors were: the proportion of Indigenous people in the area, the proportion of people who have changed their address in the past year and the socioeconomic status of the area. Differences between the results of the univariate analyses and the multivariate analyses may be due to the relative rarity of suicide attempt clusters, meaning there is low statistical power to detect small effects. Nonetheless, the findings we observe are consistent with other studies (Exeter & Boyle, 2007; Cheung *et al.* 2012, 2013; Niedzwiedz *et al.* 2014), but it is unclear what the mechanism underlying this is. It is possible that these variables are proxies for other risk factors that operate within the area. This may include poor access to mental health services (Tondo *et al.* 2006; Bridge *et al.* 2012), high unemployment (Beautrais *et al.* 1998; Blakely *et al.* 2003) or other aspects of the social and environmental circumstance (Gunnell *et al.* 2012). Another possibility is that there are confounder variables related both to the risk of being in a suicide cluster and each of these three predictors. Two plausible confounders (neither of which were measured in our study) are the individual's mental health status and their level of alcohol use. Our lack of understanding of these processes hampers prevention efforts.

### *Strengths and limitations*

This study provides an important piece of evidence about the clustering of suicide attempts and suicides in space and time. Our ability to address the problem of suicide attempts being at the event level (meaning that an individual could have repeated attempts) while suicides are the person level, is innovative. Second, we have refined previous analyses by using population weighted centroids (as opposed to the cruder midpoint of an area) and by carefully selecting values for the spatial and temporal windows for detecting clusters. These refinements meant that we are able to accurately detect clusters (cross-checked by visualizing local suicide attempt and suicide rates).

However, our study has several limitations. First, we defined suicide attempts and suicides by the ICD codes that designate deliberate self-harm, which meant we were unable to comment on the intent behind these suicidal events. Our data may have included individuals who intended to harm themselves, but did not intend to die. The extent to which using this definition biases the results is unknown; however, we note that because all suicide attempt cases involved admission to hospital, we can assume that these cases were medically serious, and therefore of interest in their own right. Second, and relatedly, our reliance on hospital admission data to define attempts, instead of the more typically used emergency department data (e.g., Bergen *et al.* 2012; Hawton *et al.* 2012; Kapur *et al.* 2015), means that we may have excluded many of the less serious attempts. It is conceivable that additional suicide attempt clusters may have been present but that we were unable to detect them, or that the clusters we did identify may have truly been larger. Taken together, these first two limitations point to the problem of identifying the threshold at which an attempt has occurred. We have used a high threshold (admissions), but this means that attempts that fall below the threshold (e.g., emergency department presentations) have been excluded.

Third, because we only detected a small number of clustered cases for suicide, we could not reliably identify the factors associated with suicides occurring in a cluster in univariate or multivariate analyses. For the same reason, we also could not compare cluster-related suicides with cluster-related suicide attempts in terms of their individual-level and area-level characteristics. It would be well worth exploring these issues in a larger study. Fourth, by removing 22% of suicide attempts and 30% of suicides with missing information on residential statistical local area, we may have missed some clustered suicide attempts or suicides. This will be of less concern if the missingness is random, although we have no way of knowing whether it is or not. Fifth, our analysis of the differences between clustered and non-clustered suicide attempts relied largely on only those variables that were collected routinely in hospital admission datasets. Unmeasured variables such as direct exposure to suicide, mental illness, psychiatric hospitalization and alcohol misuse may distinguish those who are part of a suicide attempt cluster from those who are not, especially if these variables are confounders (i.e., on the casual pathway). Sixth, we examined the associations between proxy variables (e.g., social fragmentation) and risk of cluster involvement but did not include variables on direct exposure to a suicide attempt (e.g., whether the person knew others who had attempted suicide). This form of contagion is likely to be important, especially for some groups (e.g., Indigenous people) where the rates of suicide and attempted suicide are high. Seventh, our methodology only allowed the detection of clusters occurring within contiguous spatial regions and did not allow the identification of clusters through other mechanisms (e.g., via online social networks). This limitation is inherent to the methodology we used. Other methods are required to better identify clusters in these settings. Last, we only used a cylindrical scan and could not therefore detect clusters that were non-circular or of irregular shape. To the best of our knowledge, only one other study in this area has allowed the shape of the window to vary (Jones *et al.* 2013).

### *Conclusions*

Clusters of suicide attempts and suicides are rare, but when they exist, they present a problem for communities because they may lead to copycat acts. The factors that explain the causes of both types of clusters are poorly understood, but understanding these mechanisms is crucial if prevention efforts (especially once a cluster has formed) are to be successful.


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## Conflicts of Interests

None.

## Ethical standards

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. This study received full ethical approvals from the Health Sciences Human Ethics Committee (the University of Melbourne) and the Department of Health Western Australia Human Research Ethics Committee.

## Contributors

All authors participated in the design of the study. M. J. S., J. P. and A. M. obtained funding for this study. L. S. T. was involved in data collection and management with guidance from M. J. S. L. S. T performed the statistical analyses with help from M. J. S., J. P. and A. M. All authors interpreted the findings. L. S. T. wrote the first draft of the manuscript. All authors revised the earlier drafts and approved the final draft.

## Availability of data and materials

The data used in the study is owned by the Department of Health Western Australia. Those wishing to access the data can apply to Data Linkage Western Australia (http://www.datalinkage-wa.org.au). The authors are willing to share all code used to generate the datasets used for analysis, and the code used to analyse the data.

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