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Mapping suicide mortality in Ohio: A spatial epidemiological analysis of suicide clusters and area level correlates

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ABSTRACT

Previous studies have investigated spatial patterning and associations of area characteristics with suicide rates in Western and Asian countries, but few have been conducted in the United States. This ecological study aims to identify high-risk clusters of suicide in Ohio and assess area level correlates of these clusters. We estimated spatially smoothed standardized mortality ratios (SMR) using Bayesian conditional autoregressive models (CAR) for the period 2004 to 2013. Spatial and spatio-temporal scan statistics were used to detect high-risk clusters of suicide at the census tract level ($N = 2952$). Logistic regression models were used to examine the association between area level correlates and suicide clusters. Nine statistically significant ($p < 0.05$) high-risk spatial clusters and two space-time clusters were identified. We also identified several significant spatial clusters by method of suicide. The risk of suicide was up to 2.1 times higher in high-risk clusters than in areas outside of the clusters (relative risks ranged from 1.22 to 2.14 ($p < 0.01$)). In the multivariate model, factors strongly associated with area suicide rates were socio-economic deprivation and lower provider densities. Efforts to reduce poverty and improve access to health and mental health medical services on the community level represent potentially important suicide prevention strategies.

1. Introduction

Suicide is a major public health problem. In 2014, suicide was the 10th leading cause of death for all ages, the 2nd leading cause of death for ages 10–34, and the 4th leading cause of death for ages 34–54 years (Centers for Disease Control and Prevention, 2014). From 1999 through 2014, the US suicide rate rose from 10.5 per to 13.0 per 100,000 persons, increasing 24% across every age group except the elderly (Curtin et al., 2016). Men die by suicide nearly four times more often than women in the US, with white males accounting for 7 out of 10 suicides in 2014 (Center for Disease Control and Preventions, n.d.).

Suicide rates also vary widely across geographical areas. Previous studies investigating differences in rural and urban suicide rates found higher rates of suicide in rural areas, with rural-urban disparities increasing in recent years (Fontanella et al., 2015; Singh and Siahpush, 2002). Studies using spatial analysis techniques have been able to identify geographic areas with high suicide rates relative to other regions, as well as highlight area characteristics associated with elevated suicide rates within specific geographic regions. A suicide cluster may be defined as a higher number of suicides occurring within a defined space and/or time than would otherwise be expected for a particular region (Niedzwiedz et al., 2014). Chang et al. (2011) examined the spatial patterning of suicide in Taiwan and found that the factors most strongly associated with area suicide rates were median household income, population density, and single parent households. Another study in Quebec found that clusters of heightened suicide risk were most likely to be found in remote rural areas and in neighborhoods with higher proportions of immigrants and individuals living alone (Ngui et al., 2014). Lower socio-economic status and higher levels of indigenous population were characteristics associated with spatial

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clusters of elevated suicide risk in Australia (Qi et al., 2012), and a Hong Kong study (Hsu et al., 2015) similarly reported high rates of suicide concentrated in socioeconomically deprived areas, with the most deprived quintile exhibiting suicide rates twice as high as the least deprived.

Few comparable studies using spatial analysis techniques have been done in the United States. Saman et al. (2010) reported on high-risk suicide clusters at the county level in Kentucky and identified two significant high risk clusters involving 15 counties. A study of the spatial patterns of suicide deaths in Florida (Johnson et al., 2016) at the census tract level examined area characteristics of both high and low risk suicide clusters and reported that high levels of elderly concentration and household singularity were associated with high-risk clusters and that higher economic deprivation and residential density were associated with low risk clusters.

Understanding the spatial distribution of suicide can inform the planning, implementation, and evaluation of suicide prevention efforts. In Ohio, a state often considered to be nationally representative and quite diverse with regard to communities across the urban-rural continuum, there were 1491 suicides in 2014, corresponding to suicide rates of 20.1 per 100,000 for males and 5.7 per 100,000 for females (Center for Disease Control and Preventions, n.d.). Suicide rates have increased 29.9% overall since 1999, from 9.7 to 12.6 per 100,000 persons (Center for Disease Control and Preventions, n.d.), with Ohio now ranking 21st highest in per capita suicide in the United States. This study aims to: 1) identify spatial and spatio-temporal clusters of high suicide rates in Ohio; and 2) assess the relationship between demographic and socioeconomic contextual factors and suicide clusters. Based on prior research (Rehkope and Buka, 2006; Tondo et al., 2006), we hypothesized that socio-economic deprivation and lower levels of access to health and mental health services would be correlates of being in a high-risk suicide cluster.

2. Methods

2.1. Design and data

This ecological study included all people who died by suicide in Ohio between January 1, 2004 to December 31, 2013. Suicide decedents were identified from death certificate data obtained from the Ohio Department of Health. Deaths by suicide were identified based on the *International Classification of Diseases*, 10th revision (ICD-10) external cause of death codes (X60-X84, Y87.0, *U03). Data elements included age, sex, race/ethnicity, marital status, education, date of death, residential address, and suicide method. The unit of analysis was the census tract ($N = 2952$). A census tract has an average of 2000 residents and was chosen because it is the unit of analysis for which numerous types of data are readily available. It is also large enough to allow the calculation of standardized mortality ratios, yet small enough to reasonably approximate a neighborhood. To identify suicide clusters, each suicide case was assigned to a census tract based on the residential address recorded in the death certificate.

2.2. Contextual level variables

Data on area characteristics at the census tract level were extracted from the 2008–2012 American Community Survey. These variables included the proportion of the population: living in poverty; unemployed; without a high school diploma; receiving public assistance; without health insurance; median household income; living alone; divorced; renting a home; moved in the last year. Because health service utilization variables from the 2010 Area Resource File were only available at the county level, individual census tracts were classified using county level data for: the number of primary care physicians and psychiatrists per 100,000 population, the number of community mental health centers, federally qualified health centers, and number of psychiatric beds. These area level characteristics were selected based on prior research which has shown suicide mortality is associated with socio-economic characteristics such as poverty, income and socio-economic status, unemployment (Rehkope and Buka, 2006); indicators of social fragmentation (i.e. living alone or residential mobility) (Middleton et al., 2004); and access to services (Tondo et al., 2006).

2.3. Spatial analysis

To examine the geographic distribution of suicide rates, standardized mortality ratios (SMRs) were generated for each census tract. The rate in tract i is estimated as the observed number of suicide deaths in each tract (O_i) divided by the expected number of deaths (E_i; calculated by applying age- and sex-specific death rates to population counts of the area). SMRs were standardized using total death/population at risk in Ohio. Sparsely populated areas with few (or zero) cases often generate extreme values of the SMR, as the variance of the SMR is inversely related to E_i and small populations will have large variability in these estimated rates. To account for this variability, we used a Bayesian hierarchical conditional autoregressive model (CAR) with spatial random effects to create spatially smoothed estimates of relative risk in each area (Lawson, 2013). The smoothed SMR is essentially a weighted average of the observed SMR, the state (global) mean, and rates of neighboring areas (local mean). The greater the uncertainty in estimating the SMR (as the denominator decreases), the more it is smoothed towards the global mean or the local mean. Spatial smoothing was done using the *diseasemapping* package in the R software.

In order to explore geographic clustering of suicide, we used both spatial and space-time scan statistics to determine location and evaluate the statistical significance of geographic clusters of suicide events. We ran two separate analyses, both using the census tract as the unit of analysis. First, we employed a spatial discrete Poisson probability model to search for high suicide clusters. The maximum spatial cluster size was set to 30% of the population at risk. We repeated this analysis separately for the three main methods of suicide: firearm, hanging/suffocation, and poisoning. Second, we employed a space-time discrete Poisson model to search for high rates using a 1-month time aggregation period. We also repeated this analysis by method of suicide. The maximum spatial cluster size was set to 30% of the population at risk with a maximum temporal window of 3 years. In all instances, statistical inference was evaluated using 999 Monte Carlo replications, and the null hypothesis of no clusters was rejected at a probability (p) value of ≤ 0.05. We used elliptical scanning windows with a high non-compactness penalty since several regions of interest in Ohio follow along elongated geographic features such as lakes and mountain ranges (e.g., The Appalachian Mountains). All analyses were implemented in SatScan v9.4.2 software (Kulldorff, 2011) and adjusted for age and gender distributions at the census-tract level using population estimates derived from the US Census Bureau's Population Estimates Program obtained from the Surveillance, Epidemiology, and End Results (SEER) Program at the National Cancer Institute (Census Bureau Population Estimates Program, 1969). Cartographic displays of spatial clusters were made using ArcGIS 10.4 (ESRI, 2011).

2.4. Multivariate analysis

Contextual level variables that are constant across census tracts are presented as means and SD for the 483 tracts with high suicide clusters, the 2469 tracts that do not have high suicide clusters, and the entire 2952 tracts for Ohio. Similarly, contextual level variables that are constant across county are presented as means and standard deviations (SD) for the 29 counties that have high suicide clusters, the 59 counties that do not have high suicide clusters, and all of Ohio's 88 counties. Differences in contextual level variables were compared across these two groups based on a two-sample t-test. Because many of the variables