Suicide and Alcohol: Do Outlets Play a Role?

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Abstract

Background—The purpose of this study was to determine whether the number of alcohol outlets in local and adjacent areas, in particular bars, was related over time to completed suicide and suicide attempts. There is evidence both from studies of individuals and time series aggregate studies, mostly at the national level, of substantial alcohol involvement in suicide, but no small-area, longitudinal studies have been carried out. The present study is the first that is both longitudinal and based on a large number of small spatial units, California zip codes, a level of resolution permitting analysis of the relationship between local alcohol access and suicide rates over time.

Method—Longitudinal data were obtained from 581 consistently defined zip code areas over 6 years (1995–2000) using data from the California Index Locations Database, a geographic information system that contains both population and place information with spatial attributes for the entire state. Measures obtained from each zip code included population characteristics (e.g., median age) and place characteristics (e.g., numbers of retail and alcohol outlets) which were related in separate analyses to (i) suicide mortality and (ii) the number of hospitalizations for injuries caused by suicide attempts. The effect of place characteristics in zip code areas adjacent to each of the 581 local zip codes (spatial lags) was also assessed. Analysis methods were random effects models corrected for spatial autocorrelation.

Results—Completed suicide rates were higher in zip code areas with greater local and lagged bar densities; and higher in areas with greater local but not lagged off-premise outlet densities. Whereas completed suicide rates were lower among blacks and Hispanics, completed suicide rates were higher among low income, older whites living in less densely populated areas, that is, rural areas. Rates of suicide attempts were higher in zip code areas with greater local but not lagged bar densities, and higher among low income younger whites living in smaller households and in rural areas. Rates of attempted suicide were also higher among blacks. Completed suicide and suicide attempt rates were lower in zip code areas with greater local restaurant densities; there were no lagged effects for restaurants.

Conclusions—Bar densities in particular appear related to suicide, meaning, because this is an aggregate-level spatial analysis, that suicides, both attempted and completed, occur at greater rates in rural community areas with greater bar densities. Because the suicide rate is highest in rural areas, this study suggests that although the number of completed and attempted suicides is no doubt greater in absolute numbers in urban areas, the suicide rate, both completed and attempted, is greater in rural areas, which draws attention, perhaps much needed, to the problems of rural America.

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Keywords

Suicide; Alcohol Outlets; Spatial Analysis; Panel Model

ALTHOUGH THERE IS considerable research on the role alcohol plays in suicide, there are few studies that relate alcohol availability, the number and location of alcohol outlets, bars, in particular, to suicide. Most published studies have been either cross-sectional individual-level analyses of clinical populations or time series aggregate-level analyses of entire states or nations. The current study uses a new approach to studies on suicide, spatial analysis, a method that has proven useful in studying at a more local level the interpersonal violence associated particularly with bars (Gorman et al., 2001; Gruenewald and Remer, 2006; Scribner et al., 1995). The current study, also carried out at the local level, asks whether physical alcohol availability, most specifically the number of bars, has any relationship to suicide, what social mechanism might connect bars to suicide, and would reducing the number of bars reduce the number of suicides? Few empirical studies have examined the relationship of bars or other alcohol outlets to suicide and, not surprisingly with so few studies, no theory has been advanced to explain the relationship of alcohol outlets to suicide. The most well-known theory of suicide (Durkheim, 1897) explains suicide in terms of the "social facts" of "anomie," "social integration," and "social regulation." Although Durkheim distinguished among several types of suicide, the aspects of his theory applied by alcohol researchers focus on those suicides that occur when individuals are not well integrated into the larger society of which they are necessarily a part even though they may benefit from the primary ties they experience as members of a family. Durkheim himself dismissed the importance of alcohol in suicide, but as the following literature review shows, there is a strong relationship between drinking, perhaps most often to the point of alcohol dependence, and taking one's own life. The paper then presents panel analyses of data for 6 years both on completed suicide and on suicide attempts from a large number of local spatial units, postal zip code areas, a level of resolution that has proven useful in other studies (for example, Gruenewald and Remer, 2006; Gruenewald et al., 2002; Treno et al., 2007) relating alcohol outlets to problematic alcohol-related outcomes.

In any given year, more than 20% of suicides in the general population are committed by the alcohol dependent (Duffy and Kreitman, 1993). Based on a meta-analysis of 32 studies of suicide among alcohol-dependent drinkers, Harris and Barraclough (1997) estimated the rate of suicide among such drinkers at 6 times the expected rate in the general population; and based on a meta-analysis of 27 studies of alcohol-dependent suicides, Inskip et al. (1998) estimated the life-time risk of suicide among alcoholics at 7%. Some 80 to 90% of alcohol-dependent suicides are men, mostly white (Murphy and Wetzel, 1990). Reviewing the recent international literature on individual-level studies of suicide, Cherpital et al. (2004) found that in 37 studies of completed suicide and in 16 studies of attempted suicide, acute alcohol use averaged 37 and 41% in completed and attempted suicides, respectively.

A number of aggregate-level studies have shown that suicide is related to overall alcohol consumption. Using similar time series methods, estimates of national level per capita alcohol consumption, and employing few covariates beyond unemployment and divorce rates as measures of Durkheim's social integration, a positive association of alcohol consumption with suicide has been shown in Sweden (Rossow, 1993); Norway (Norstrom, 1988); France (Norstrom, 1995); Hungary (Skog and Elekes, 1993); in Portuguese men (Skog et al., 1995); and in younger, under age 45, Finnish men (Makela, 1996). No relationship was found, however, between aggregate alcohol consumption and suicide among Portuguese women (Skog et al., 1995) nor among Swiss women, and a weak negative relationship was found for Swiss men (Gmel et al., 1998). In the United States,

Wasserman (1989) found that suicide rates decreased during the U.S. prohibition era; Gruenewald and colleagues (1995) found that suicide rates were related to per capita consumption of spirits, but not beer or wine; and Caces and Harford (1998) found that alcohol consumption increased the suicide risk for men and women younger than age 60 when unemployment was included in their models. On balance, the evidence seems to support the existence of a relationship between suicide and alcohol consumption at the aggregate level, especially among males.

Comparison of overall alcohol consumption in each of these European countries with the U.S. and California might place the current study in context. Alcohol consumption in European nations changed considerably over time and varied widely in different countries, with Norway being lowest in per capita consumption, 1.1 gallons of pure ethanol (Norstrom, 1988), and France highest in per capital consumption, 4.5 gallons of pure ethanol in 1980 (Norstrom, 1995), the most recent year for which data could be obtained for most nations. By comparison, U.S. per capita consumption of pure ethanol in 1980 was 2.76 gallons and in California, 3.38 gallons. By 2000, per capita U.S. consumption of alcohol had declined to 2.18 gallons and California per capita consumption to 2.19 gallons.

An estimate of average venue use in California would also be helpful, but can only be estimated for relatively small samples of the total California population. General population survey data obtained in the mid-1990s from 8,702 respondents on venue use over the 28-day period preceding the day on which they were interviewed indicated that, on average, Californians used bars some .58 days and restaurants some .84 days in the 4 weeks preceding the interview (Gruenewald et al., 2002).

There are, of course, factors other than alcohol involvement both in completed suicides and attempts. In the United States, suicide rates are higher among whites, men, and the elderly (Centers for Disease Control and Prevention, 2005); more common in western states (Goldsmith et al., 2002); and related to occupation, employment, and socioeconomic status (Stack, 2000). Goldsmith and colleagues suggested that the higher rate of completed suicides in western states might be due to higher rates of firearm possession there. Supporting this, Fiske and colleagues (2005) found that firearms were involved in 57% of rural California suicides, but only 49% of urban California suicides; and Singh and Siahpush (2002) found that, nationally, during the period from 1979 to 1997, firearms were involved in 75% of rural suicides but only 50% of urban suicides.

The completed suicide rate for men in the U.S. was more than 4 times the rate for women (Stack, 2000). There is a similar gender disparity in California, and suicide rates are higher for whites and the elderly in California as well as nationally (Fiske et al., 2005). In 2000, suicides totaled about 30,000 nationally (Goldsmith et al., 2002) and 3,033 in California (California Public Use Files).

In the U.S., the rural–urban continuum is an important factor in completed suicide. Wilkinson and Israel (1984), using a sample of 299 northeastern counties, found rurality, age, male gender, poverty, divorce, and levels of interstate migration all related to suicide. Although early in the last century, urban completed suicide rates were higher than rural rates and the 2 rates remained approximately equal through the 1950s and 1960s (Fiske et al., 2005; Wilkinson and Israel, 1984), by 1970 rural rates began to exceed urban rates particularly for men. Using a 10-point urban–rural gradient developed by the U.S. Agriculture Department, Singh and Siahpush (2002) showed that in the 1970–74 period, the U.S. rural completed suicide rate per 100,000 population for men exceeded the urban rate by just 4%, but by the 1995–97 period, the rural completed suicide rate for men exceeded the urban rate by 54%, with virtually all of this change due to an increase in rural suicides. In

contrast during the 1970–74 period, the rural completed suicide rate for women was less than half (48%) that of the urban rate, although by the 1995–97 period, the rural completed suicide rate for women was almost equal to the urban rate (99%), but nearly all this change was due to a decrease in urban suicides rather than an increase in rural suicides as was the case for men. Overall, suicide rates in California have declined in recent years. The age-adjusted overall suicide rate in California during 1993 was 11.3 per 100,000 population but declined to 8.5 per 100,000 by 2001 (Fiske et al., 2005).

Suicide attempts are far more common than completed suicides, more frequent among women than men, and far more common among the young (Krug et al., 2004). The difference in completed suicide rates and attempts, and particularly in rates by age and gender, suggests that suicide attempts are different in kind from completed suicide. Suicide attempts often have a different motive than ending one's life, and may be a cry for help, a means of escaping the situation, or an effort to manipulate others rather than a desire to end one's life although, as indicated above, alcohol plays a large role in suicide attempts as well as in completed suicide (Rossow, 1993; Rossow et al., 1999).

If suicide is related to alcohol consumption at the individual and aggregate levels, is suicide related to alcohol availability? Taking advantage of "natural experiments," 2 studies have shown that suicide is affected by alcohol availability as measured by overall per capita alcohol consumption. Skog (1993) showed that suicide rates in Denmark decreased during World War I, even though Denmark was not involved in the war, when severe constraints were placed on commodities and taxes on alcohol were raised dramatically, reducing alcohol availability. Wasserman (1989) found that during prohibition in the United States from 1920 to 1933, a period of complete legal restraint on alcohol availability, the suicide rate declined even though alcohol use increased illegally and substantially from the start of the prohibition era. In a cross-sectional analysis of all 49 counties in Ontario, Canada using direct measures of alcohol outlet densities (number of on- and off-premise outlets per 1,000 adults in the population; off-premise outlets are stores where alcoholic beverages are purchased for consumption elsewhere), Rush and colleagues (1986) found higher suicide rates associated with greater outlet densities. Thus, there is both longitudinal and cross-sectional evidence that alcohol availability is related to suicide.

In the first studies to focus on the relationship of alcohol availability to problematic outcomes in relatively local units of analysis, Scribner and colleagues (1994, 1995) showed that alcohol access as measured by alcohol outlet densities (bars, restaurants, mini-markets, and liquor stores) was related to motor vehicle accidents and to assaultive violence measured at the city level rather than the state or national levels. More recently, studies have shown that alcohol outlet densities are related to other social problems. Thus, greater alcohol outlet densities are related to higher rates of sexually transmitted diseases (Cohen et al., 2006), motor vehicle crashes (Gruenewald and Ponicki, 1995; Gruenewald et al., 2002; Treno et al., 2007), and child abuse and neglect (Freisthler, 2004; Freisthler et al., 2004). Bar densities in particular are related to assaultive violence (Gorman et al., 2001; Gruenewald and Remer, 2006; Lipton and Gruenewald, 2002) and to pedestrian injuries (LaScala et al., 2001). Is suicide among the problems related to alcohol outlet densities, specifically bar densities?

The purpose of this study was to determine whether the physical availability of alcohol was related to suicide rates, both completed and attempted, over time at more local levels than previously studied, and to shed empirical light on a possible link between bars and off-premise alcohol outlets with suicide. Using aggregate-level data for a 6-year period from zip code areas in California, the current study investigated whether densities of 3 outlet types, bars, off-premise establishments, and restaurants, were related to both completed suicide and suicide attempts. Because completed suicides most often involve heavy drinking, in the

United States, heavy drinking of spirits (Gruenewald and Ponicki, 1995), and because bars are primarily sought for alcohol rather than some other commodity such as food, it is hypothesized that bar densities in particular will be directly related to completed suicide. Because off-premise outlets are sources of hard liquor and cheap wine and because Rush and colleagues (1986) found off-premise outlets related to suicides, it is hypothesized that they too will be directly related to completed suicide rates. Restaurants are venues where food rather than alcohol is the commodity primarily sought and are also venues families are likely to patronize; it is therefore hypothesized that restaurant densities will be either unrelated or inversely related to completed suicide rates. Spatially lagged outlet density effects were included in the analysis models and predictions similar to those for local effects are made regarding the lagged outlet densities; bar and off-premise outlet densities in spatially lagged areas will be associated with higher completed suicide rates in local areas, and restaurants in lagged areas will be either unrelated or negatively related to completed suicide rates in local areas. Because suicide attempts differ from completed suicide, we are agnostic regarding outlet density effects on suicide attempts although finding outlet effects on suicide attempts similar to those on completed suicide would be unsurprising. As described more fully below in the Methods section, spatial lags are areas physically adjacent to or surrounding local areas wherein features, outlet densities, may be related to local outcomes in a manner similar to local outlet densities.

METHODS

This study adopted a population-based ecological approach to the examination of rates of completed suicide and suicide attempts across community areas over 6 years time, 1995 through 2000. The data were aggregate archival data on demographic and retail measures including 3 types of alcohol outlets, restaurants, off-premise establishments, and bars. The 6-year data panel was collected from 581 index zip codes consistently defined geographically over the 6-study years.

Geographic Basis

The geographic basis for the study was regions defined using electronic maps of the state of California obtained from Claritas (Ithaca, NY) and Environmental Systems Research Institute, Inc. (ESRI, 2001, 2002) of Redlands, CA. These maps were developed by GDT (Geographic Data Technology, Lebanon, NH) by geocoding U.S. postal route zip code information and estimating unspecified areas based on topology. The resulting electronic zip code base maps had 100% coverage of the state, but included synthetic zip codes for extremely low population density areas, such as national forests and state parks, and included some zip codes such as post offices and government buildings with negligible geographic area. Considering only zip codes with some geographic extent, all 1,628 populated zip codes from the year 2000 served as the source of the 581 "stable" zip codes for the panel analyses. "Stable" areas were defined as those zip codes that maintained a consistent area definition over the 6 years of the study (adjudicated by reference to Census 2000 block internal points). These areas, by definition, were consistent over time, thus obviating the severe interpretive problems that arose in analyzing data from continuously modifiable area units (Openshaw, 1984). The 581 zip codes included a broad selection of urban, rural, coastal, and inland regions of California, covering much of the demographic and geographic diversity of the state. The use of stable geographic areas lends other benefits to the current project. The infilling and loss of retail businesses and alcohol outlets in these areas could be simply represented by counts, distributed within consistently defined areas over time rather than as ratios of outlet counts denominated by roadway miles, population, or zip code area as in other studies using zip codes or census tracts that change over time. The count data of businesses were contained in the California Index Locations Database, a

geographic information system that compiled population and individual-level data into frames suitable for spatial analysis.

It might be helpful to provide some general information on zip codes. First, it should be noted that the population unit of interest was the household, each of which had a single address, because zip codes were established by the post office to improve mail delivery. The mean and median number of households per zip code in California for the year 2000 were 6,984 (SE = 165.9) and 5,223, respectively. The mean and median area in square miles per zip code were 94 (SE = 6.2) and 16, respectively (U.S. Census Bureau, 2001). Our work group has found that individual zip codes could differ substantially in many ways. Some rural zip codes in California's southeastern deserts are as large as counties in many states, while those in urban areas have much smaller physical extent. Zip codes near military installations have large numbers of young males and thus may have much higher rates of drug abuse than other zip codes. Zip codes including college campuses have highly peaked (leptokurtic) age distributions due to large numbers of youth. Zip codes in downtown urban areas have much higher alcohol outlet densities, while suburban zip codes may have few alcohol outlets, most of which will be restaurants.

Patient Discharge and Death Data

For the 2 outcomes, deaths by suicide and serious but unsuccessful suicide attempts, there were 2 data sources. Data on deaths by suicide were obtained from the California Death Public Use Files (State of California Department of Health Services Center for Health Statistics, 2000). The E-codes associated with the Public Use File death data for years 1995 through 1997 were ICD-9 E-codes E950 through E959, and after 1997, when the Public Use Files adopted newly revised ICD-10 codes, the E-codes were X60 through X84 and Y87. Information on suicide attempts, the second measure, was obtained from patient discharge data (PDD) from the California Office of Statewide Health Planning and Development (OSHPD). PDD records provide information on all admissions that result in at least 1 overnight hospital stay including up to 5 event, or "E-codes," codes that identify the cause of injury. In the hospital discharge data for injury resulting from suicide attempts, this includes E-codes E950 through E959.9 for all 6-study years eliminating deaths to avoid duplication with the first measure. Because these data included only suicide attempts involving at least 1 overnight hospital stay, they excluded less injurious attempts that required only emergency room treatment and release, outpatient, or nonhospital residential recovery treatment. Emergency department data that would include these less severe attempts did not become available until July 2005. Both outcome measures, public use data for deaths and patient discharge data for suicide attempts, were geocoded to the residential zip code of the person either dead or discharged. The 2 outcome variables, suicide deaths and attempts, were filtered for persons aged 15 or older as was the population measure to maintain consistent scales. OSHPD's policy on human subjects prohibits public dissemination of any data on persons under age 15.

In California, with the exception of medical misadventures, E-codes are obtained from 99% of all injury admissions to hospitals in the state that result in at least 1 overnight stay (Abellera et al., 2005). Also in California, E-coded injury records have a sensitivity and specificity of better than 90% in record check and patient follow-up studies (Abellera et al., 2005; Meux, 1993; Meux et al., 1990). Discounting persons below age 15, homeless persons, out-of-state residents, the very few patients without zip code information, and converting postal box zip codes to the zip code in which the post office was located, geocoding to electronic base maps exceeded 99%. Each outcome measure, suicide deaths and suicide attempts, were transformed to 1,000 times the natural logarithm of the number of deaths or attempts per 1,000 population aged 15 or older, substituting 5 for zip codes with zero deaths or attempts as zeroes have no log value.

Alcohol Outlets

Data on the locations of alcohol outlets were obtained from California Alcohol Beverage Control. Outlet locations were geocoded to their zip code based on the street address of the establishment. Numbers of active alcohol outlets by zip code were tabulated for off-premise establishments, restaurants, and bars plus pubs. Geocoding rates exceeded 99%, a rate comparable with those obtained in previous investigations (e.g., Gruenewald and Remer, 2006; Treno et al., 2007) and by previous investigators using other data at this level of geographic resolution (e.g., Alaniz et al., 1998; Gorman et al., 2001). Alcohol outlet density was indexed in counts per zip code area because the units of analysis, stable zip code areas, remained unchanged over time.

Retail Data

County business pattern data on all retail establishments are collected annually by U.S. Department of Commerce and published electronically as Zip Code Business Patterns by U.S. Census Bureau. The data included counts of retail establishments within zip codes by type (NAICS, North American Industry Classification System codes), although counts may be low because the census is voluntary for small businesses that have no paid employees. Numbers of all retail establishments were tabulated for 1 broad category termed "Total Retail" (NAICS 44, 45, and 72). Converting nonspatial zip codes (PO boxes and single building zip codes) to the surrounding zip code, geocoding rates exceeded 99%. Densities of all retail establishments were calculated in parallel to those for alcohol outlets, as counts.

Demographic Data

Variables that characterized the population living in zip code areas were obtained from Sourcebook America (CACI Marketing Systems, 1996, 1997, 1998, 1999, 2000; ESRI, 2001, 2002) annual estimates. At the zip code level, these estimates were available for a limited number of measures that represent changes in core population characteristics: population size ($\times$1000) filtered for age 15 and older both in the death and PDD data, average household size, percent male population, median household income ($\times$1000, not adjusted for inflation), median age, and percent of population white, black, and Hispanic.

Statistical Analyses

As stated earlier, the 2 dependent measures for these analyses were obtained by taking the natural logarithm of the number of completed suicides and suicide attempts per 1,000 population and multiplying the logged value by 1,000. Transforming the dependent variable rescaled the data to a common population denominated rate and normalized truncated and highly skewed distributions of raw counts. Converting the numbers of deaths and attempts to rates makes possible comparisons between zip code areas with small and large populations that cannot be made with raw count data. The final multiplication of the logged value by 1,000 improved the readability of the model coefficients.

All independent measures, demographic and retail, were obtained for each of the 581 zip codes over the 6-study years. Because the measures were obtained for all zip codes, lagged measures could be created for each given, or local, zip code, by averaging counts of, for example, off-premise alcohol outlets for all the zip codes adjacent to each given zip code, to create lagged (i.e., geographically adjacent or immediately neighboring) feature densities for each local zip code. These geographically adjacent densities were included in analysis models as measures of spatially lagged effects, the effects of physically external characteristics on local outcome rates in each of the 581 zip code areas. Thus, 3 different effects of local and lagged population and place characteristics were considered in the

analysis, (i) demographic and (ii) retail characteristics measured within "local" zip code areas and (iii) retail characteristics measured in geographically adjacent "lagged" areas.

Spatial random effects models (REM) were applied for the statistical analysis of associations between covariates and rates of hospital discharges over space (zip codes) and time (years). All analyses were weighted by population size, a procedure that reduced the influence of population effects in estimates of statistical associations, particularly the effect of suicides in zip codes with small populations (Greene, 1993). The REM analyses were conducted using inhouse research grade software, S3 (Ponicki and Gruenewald, 2005), programmed in Mathematica (Wolfram, 2002). A statistical problem that often occurs in the analysis of spatially arrayed data is the loss of unit independence due to spatial autocorrelation, the tendency of measures in 1 geographic unit to be correlated with measures in adjacent and nearby units. Spatial autocorrelation can lead to bias in statistical tests unless corrected by use of appropriate statistical procedures (Waller and Gotway, 2004). One means of assessing spatial autocorrelation is the Moran coefficient (MC) computed here on the raw data for each outcome measure, suicide deaths and attempts, and those reported below. A second assessment of spatial autocorrelation, rho, was computed on regression residuals by the REM procedure, and was the model-based estimate of spatial autocorrelation used to correct bias in the REM. Because they were computed from 2 different sources, raw and residual data, it is possible for the MC and rho not only to differ in magnitude but also in statistical significance.

Spatial autocorrelation was corrected in the REM procedure by constructing a block diagonal connection matrix, each block having 581 rows and columns for each of the 6-study years, with a "one" recorded for each given zip code sharing any boundary with a neighboring zip code, including so called "bishops" cases sharing only a single point. The connection matrix is made row stochastic by dividing each nonzero row entry by the row sum. S^3 corrects for spatial autocorrelation in the error term by using the connection matrix in a generalized least squares (GLS) estimator calculated with a minimization algorithm described in Griffith (1988) and SEs of estimate calculated using the method presented by Upton and Fingleton (1985, 1989). The GLS model for correcting spatial autocorrelation is shown in previous work by the second author (see Gruenewald et al., 1996, Appendix I; Gorman et al., 2001). It should be noted that although S^3 corrects for spatial autocorrelation and offered a number of useful features including identification of outliers and highly leverages cases, it does not report the 2 error variance components normally associated with random effects models for aggregate-level data. These 2 error components are ε_{it} for individual error, in these analyses, aggregate error within time frames; and u_i, the error attributable to the deviation of each zip code intercept from the overall intercept (Greene, 1993).

RESULTS

One prerequisite of panel analysis is sufficient variation over time to justify the analyses. This is particularly important in "wide," "shallow" data sets such as the data set used here, which had 581 zip code units of analysis and 6 years of data (total $n = 3,486$). To demonstrate that there was sufficient variation among both the outcomes and predictors in this analysis, the percent change over the 6 years of panel data was computed from the difference between the first (1995) and final (2000) panel years using 1995 as the base year.

As shown in Table 1, there is sufficient variation to justify the analyses and provide efficient estimates of outlet effects. Across zip code units over the 6-study years, the number of suicide deaths and attempts have adequate range, with the mean number of deaths per zip code being substantially fewer than the mean number of attempts as expected. Most

importantly for a panel model of temporal change, the difference in suicide deaths over the 6-study years was also adequate, about 10%, as was the number of suicide attempts, about 15.4%. Both outcome measures had large ranges of percent change. Similar levels of within-unit variation existed in the predictor measures, in particular the outlets. The mean percent change in restaurant outlets was adequate, 5.3%, with a large range. Percent change in bars averaged about –4.0, also with a substantial range; and although the mean percent change for off-premise outlets was minimal at –0.4, the range of percent change was substantial.

Table 2 presents the results of the spatial random effects panel model (REM) analyses for 6 years across 581 zip code areas for the 2 outcome measures in the study, deaths by suicide and suicide attempts serious enough to warrant at least 1 overnight hospital stay, both per population. Only local demographic effects were included in the models, but for total retail and alcohol outlets, both local and lagged effects were modeled. The lagged effects show the relationship of total retail and alcohol outlets in areas surrounding local zip code units with suicide deaths and attempts in the associated local units. Time dummies were also included in both panel analyses, with the first year, 1995, as the reference year excluded from the dummies. Coefficient estimates, t-values, and 2-tailed tests of significance were provided for each measure.

In the raw outcome data, there was significant spatial autocorrelation both among deaths (MC = 0.472, z = 32.007, $p < 0.001$) and attempts (MC = 0.282, z = 19.117, $p < 0.001$). As shown in the table, the 2 model-based spatial autocorrelations, rho, for the suicide death and attempt REM procedures, were 0.026 and 0.156, respectively. Although the model-based spatial autocorrelation for suicide deaths was nonsignificant, the spatially corrected REM procedure was performed for the analysis of suicide deaths to make the 2 analyses, for completed and attempted suicide, in the study consistent. The apparently contradictory results for the Moran coefficient (0.472) and rho (0.026) regarding the spatial autocorrelation for suicide deaths illustrates, the possibility noted earlier that the 2 estimates of spatial autocorrelation, the Moran coefficient and rho, may differ not only in magnitude but in significance as well, because the Moran coefficient is based on raw data and rho on model-derived residuals.

As seen in Table 2, there was a nearly significant drop in suicide deaths during Time 1 and a significant decrease in deaths during Times 4 and 5 relative to the base year, 1995 (Time 0); and although the remaining time coefficients for suicide deaths were nonsignificant, they were all negative, suggesting a decline in suicide deaths over time. The demographic effects indicate that the suicide death rate was higher in less populous zip code areas with larger numbers of older, lower income, whites. Areas with larger numbers of blacks and Hispanics had lower suicide death rates. Completed suicide rates were higher in areas with greater densities of general retail establishments; among the 3 local alcohol outlet measures, areas with greater numbers of restaurants had lower rates of completed suicide; but areas with greater bar and off-premise densities had higher completed suicide rates. Among the lagged retail measures, there was a negative effect for off-premise outlets and a positive effect for bars. Thus, bar densities were directly related to completed suicide both locally and in lagged areas.

For suicide attempts, the coefficients for Times 1 and 2 were positive and significant whereas the coefficient for Time 4 was negative and significant, indicating first an increase in suicide attempts relative to the base year and then a decrease, but no consistent trend. The demographic effects indicated that rates of suicide attempts were higher in less populous zip code areas with smaller household sizes and larger numbers of young low income blacks and whites. There were more suicide attempts in areas with more general retail establishments; and among the 3 local alcohol outlet measures, higher rates of suicide

attempts occurred in areas with greater bar densities and lower restaurant densities, as they did for completed suicide. But unlike completed suicide, local off-premise outlet density was unrelated to suicide attempt rates. Also unlike suicide deaths, there were no significant lagged alcohol outlet effects for attempts.

DISCUSSION

In general, the results bear out the hypotheses with regard to completed suicide. Local bar and off-premise outlet densities were positively related and local restaurant densities negatively related to completed suicide rates. Lagged bar densities were positively related to higher completed suicide rates, but contrary to the hypotheses, lagged off-premise densities were negatively related to completed suicide rates. The only difference between the results of this analysis and the demographic correlates of completed suicide noted in the introduction is the nonsignificance of the gender measure, percent male. The key finding here was that both local and lagged bar densities were significantly related to completed suicides suggesting that bars are of particular importance in the etiology of some completed suicides.

Regarding suicide attempts, local bar densities were positively related and local restaurant densities negatively related to higher suicide attempt rates; but local off-premise densities were unrelated to suicide attempt rates. There were no significant lagged outlet effects for suicide attempts.

With the exception of the nonsignificant gender finding, the results here are consistent with the literature; completed suicide is more common among rural, older, lower income whites and less common among blacks and Hispanics even though the latter may have less income and experience higher rates of unemployment, and among blacks, higher rates of single parent families. Note that suicide *rates* were higher in rural than urban areas, but suicide *counts* were lower in rural than urban areas because of the great differences in population size between rural and urban areas. The greater crime rates of rural areas relative to urban areas despite the much smaller population of rural areas are often referred to as the "rural–urban paradox." This study suggests that the same paradox exists with respect to suicide.

Wilkinson and Israel (1984) noted that rural Americans, in Durkheim's terms, were less socially integrated than their urban counterparts. Isolated by distance, they have fewer social contacts with others outside their immediate families, they belong to fewer social groups, and have fewer social ties with others. Wilkinson and Israel also noted that social and demographic disruption might raise rural suicide rates. Singh and Siahpush (2002) enumerated several broad national trends creating rural–urban disparities that might be disruptive. These included declining population due to outmigration from rural areas and differential rural–urban birth rates; increasing rural unemployment and higher divorce rates; growing income disparities between men and women; and declining household size, which further increases social isolation although we did not find this in our California data (Table 2). Yacoubian (2007) and Iritani and colleagues (2007) reported that rural communities have recently become the center of a national epidemic of methamphetamine use, abuse, and addiction that both reflect and increase deterioration in rural life.

As noted, Singh and Siahpush (2002) found that, nationally, firearm suicides accounted for over 75% of rural suicides during the 1979–1997 period, and Fiske and colleagues (2005) found that guns were used in 57% of rural California suicides. Parker and Rebhun (1995) showed that alcohol and interpersonal violence were linked in the United States, almost uniquely among nations. There is also a clear link in the United States between alcohol and the intrapersonal violence of suicide, with firearms as the method of choice and at higher

rates in rural than in urban areas. If bar densities, both local and lagged, are greater in rural zip code areas with higher suicide rates, does that mean that bars contribute to rural suicides? It is not difficult to imagine a scenario where a person, more likely white, male, older, and low income, drinks at a bar, proceeds home, and disinhibited by ethanol, uses his own firearm against himself. Whether such scenarios actually take place can only be tested by obtaining individual-level data that includes information on bar use and suicide, not data that are likely to be obtained easily or perhaps anytime soon, leaving only aggregate-level studies like the present one.

As noted in the introduction, suicide attempts are different in kind than completed suicides, and as seen in Table 2, differ sociodemographically from completed suicides. Suicide attempts are much more frequent, about 5 times as common as completed suicides (51,660 attempts and 10,719 completed suicides across the 6-study years), involve younger persons, and also blacks as well as whites. But in 2 important regards, suicide attempts resemble completed suicides. The rate of suicide attempts was greater in less populated and thus more likely rural areas, and suicide attempts were associated with greater bar densities. Thus, what has been said above about rurality and bars may well apply at least in part to suicide attempts as well as to completed suicide.

What is to be made of the negative correlation between suicide, both completed and attempted, and one type of alcohol outlet, restaurants? There are about 4.5 restaurants for each bar across the full 6 years of study data, and restaurants are more likely to be found in higher income urban and suburban areas. If the demographic effects of this study are valid, these are precisely the areas where suicides are least likely to occur and restaurants are bound to be negatively (locally) or unrelated (lagged) to suicides, both completed and attempted. What of the significant negative lagged off-premise effect on completed suicides? It seems unlikely that the presence of off-premise outlets in surrounding zip codes somehow reduces suicide rates in local zip codes. The effect is most likely a correlational artifact in the data. Consistent with this view is the failure to replicate the significance of this effect for suicide attempts.

There are clear policy implications arising from the findings reported here. The number of alcohol-related completed suicides and suicide attempts might decline if the number of bars were reduced, both rural and urban. Singh and Siahpush (2002) suggest that decreasing the number of firearms might reduce the rural suicide rate. Unfortunately, Second Amendment rights are as sacrosanct in rural America as in much of the rest of the country, so there is little likelihood that this intervention, quite probably the most effective, will ever be implemented. Fiske and colleagues (2005) found no relationship between completed suicide and numbers of physicians and mental health treatment providers at the county level. Singh and Siahpush, however, suggest that public health measures that target social integration, jobs, and services that provide social support might reduce the rural suicide rate. Fostering a greater sense of community in rural areas might reduce the isolation of rural life and lead to stronger communal bonds outside the immediate family and provide a sense of belonging to those living alone.

Study Generalizability

In order to assess the representativeness of the 581 stable zip code subsample and the generalizability of the panel model findings to all of California, supplementary cross-sectional analyses were carried out using data obtainable for the entire state only for the single year, 2000. Results from the panel models were then compared with results from the cross-sectional models for each outcome, suicide deaths, and attempts, by how well predictors from the respective panel and cross-sectional models matched on sign and significance. In general, the results of the panel models replicated well in the cross-sectional

models. The panel models are thus stable, their results reasonably consistent across panel and cross-sectional models, and therefore generalizable to the entire state of California.

Study Limitations

The major potential threat to these findings is that they result from ecological fallacy, inferring individual behavior from the broad population effects obtained from analysis of aggregate-level data. Is there some other feature of zip codes with large numbers of bars that is generating the observed relationship of bars to suicide? This question can only be answered with analysis of more refined cross-validating data at the individual level. While there appears to be a clear aggregate-level effect, care needs to be exercised in overinterpreting or imputing an individual-level mechanism to these results.

Hospital admissions are a potentially biased sample of the population because they oversample whites, who are more often insured, and older people who, by virtue of their greater need for medical care, are more frequently hospitalized. This potential source of bias would only affect the analysis of suicide attempts, however, because the data for completed suicide comes from a different source, the California Death Public Use Files, which is a relatively unbiased count of mortality. As noted in the Methods section, the Patient Discharge Data include only suicide attempts that involve admission to a hospital and exclude attempts that require only emergency room treatment and release, outpatient, or nonhospital residential recovery treatment. The number of attempts is probably undercounted because only the most serious attempts, those involving hospitalization, are included in the sample.

Despite these limitations, the current study is the best assessment available of the effects of outlet densities on suicide, both completed and attempted, over time in a large number of spatial units at a relatively local level of resolution. The most important finding was that although the number of suicides might be higher in urban areas, the rate of suicides was higher in rural areas. This draws attention to an easily overlooked problem in a society dominated by its urban centers, culture, and media. Rates of completed suicide were highest in rural America and were largely ignored because its victims were part of the vanishing landscape of rural American life.

Acknowledgments

REFERENCES

Abellera, J.; Conn, JM.; Annest, JL.; Kohn, M. How States are Collecting and Using Cause of Injury Data: 2004 Update to the 1997 Report. Council of State and Territorial Epidemiologists, Data Committee Injury Control and Emergency Health Services Section, American Public Health Association, and State and Territorial Injury Prevention Directors Association; Atlanta, GA: 2005.

Alaniz ML, Cartmill RS, Parker RN. Immigrants and violence: the importance of neighborhood context. Hisp J Behav Sci. 1998; 20:155–174.

Caces FW, Harford T. Time series analysis of alcohol consumption and suicide mortality in the United States, 1934-1987. J Stud Alcohol. 1998; 59:455–461. [PubMed: 9647428]

CACI Marketing Systems. Sourcebook America [CD-ROM]. 1996. 1997. 1998. 1999. 2000.

Centers for Disease Control and Prevention. Web-based injury statistics query and reporting system (WISQARS) [Online]. National Center for Injury Prevention and Control, CDC (producer); 2005. Available at: http://www.cdc.gov/injury/wisqars/index.html

Cherpital DJ, Borges LG, Wilcox HC. Acute alcohol use and suicidal behavior: a review of the literature. Alcohol Clin Exp Res. 2004; 28:18s–28s. [PubMed: 15166633]

Cohen DA, Bhosh-Distidar B, Scribner R, Miu A, Scott M, Robinson P, Farley TA, Bluthenthal RN, Brown-Taylor D. Alcohol outlets, gonorrhea, and the Los Angeles civil unrest: a longitudinal analysis. Soc Sci Med. 2006; 62:3062–3071. [PubMed: 16423436]

Duffy J, Kreitman N. Risk factors for suicide and undetermined death among in-patient alcoholics in Scotland. Addiction. 1993; 88:757–766. [PubMed: 8329967]

Durkheim, E. Suicide: A Study in Sociology. The Free Press; New York: 1997. 1897.

Environmental Systems Research Institute Inc. (ESRI) Business Information Solutions. Sourcebook America [CD-ROM]. 2001. 2002.

Fiske A, Gatx M, Hannell E. Rural suicide rates and availability of health care providers. J of Comm Psych. 2005; 33:537–543.

Freisthler B. A spatial analysis of social disorganization, alcohol access, and rates of child maltreatment in neighborhoods. Child Youth Serv Rev. 2004; 26:803–819.

Freisthler B, Midanik LT, Gruenewald PJ. Alcohol outlets and child physical abuse and neglect: applying routine activities theory to the study of child maltreatment. J Stud Alcohol Drugs. 2004; 65:586–592.

Gmel G, Rehm J, Ghazinouri A. Alcohol and suicide in Switzerland—an agregate-level analysis. Drug Alcohol. 1998; 17:27–37.

Goldsmith, SK.; Pellmar, TC.; Kleinman, AM.; Bunney, WE., editors. Reducing suicide: a national imperative. National Academy Press; Washington, DC: 2002.

Gorman DM, Speer PW, Gruenewald PJ, Labouvie EW. Spatial dynamics of alcohol availability, neighborhood structure and violent crime. J Stud Alcohol. 2001; 62:628–636. [PubMed: 11702802]

Greene, WH. Econometric Analysis. McMillan; New York: 1993.

Griffith, DA. Advanced Spatial Statistics. Kluwer Academic Publishers; Dordrecht, The Netherlands: 1988.

Gruenewald PJ, Johnson F, Treno AJ. Outlets, drinking and driving: a multilevel analysis of availability. J Stud Alcohol. 2002; 63:460–468. [PubMed: 12160105]

Gruenewald PJ, Millar AB, Treno AJ, Yang Z, Ponicki WR, Roeper P. The geography of availability and driving after drinking. Addiction. 1996; 91:967–983. [PubMed: 8688823]

Gruenewald PJ, Ponicki WR. The relationship of the retail availability of alcohol and alcohol sales to alcohol-related traffic crashes. Accid Anal Prev. 1995; 27:249–259. [PubMed: 7786392]

Gruenewald PJ, Ponicki WR, Mitchell PR. Suicide rates and alcohol consumption in the United States: 1970-1989. Addiction. 1995; 90:1063–1075. [PubMed: 7549775]

Gruenewald PJ, Remer L. Changes in outlet densities affect violence rates. Alcohol Clin Exp Res. 2006; 27:1184–1193. [PubMed: 16792566]

Harris EC, Barraclough B. Suicide as an outcome for mental disorders: a meta-analysis. Br J Med Psychol. 1997; 170:205–228.

Inskip HM, Harris EC, Baraclough B. Lifetime risk of suicide for affective disorder, alcoholism, and schizophrenia. Br J Med Psychol. 1998; 172:35–37.

Iritani BJ, Hallfors DD, Bauer DJ. Crystal methamphetamine use among young adults in the USA. Addiction. 2007; 102:1102–1113. [PubMed: 17567398]

Krug, EG.; Dahlberg, LL.; Mercy, JA.; Zwi, A.; Lozano, R., editors. World report on violence and health. World Health Organization; Geneva: 2004.

LaScala EA, Gruenewald PJ, Johnson F. Neighborhood characteristics of alcohol-related pedestrian injury collisions: a geostatistical analysis. Prev Sci. 2001; 2:123–134. [PubMed: 11523752]

Lipton R, Gruenewald PJ. The spatial dynamics of violence and alcohol outlets. J Stud Alcohol. 2002; 63:187–195. [PubMed: 12033695]

Makela P. Alcohol consumption and suicide mortality by age among Finnish men, 1950–1991. Addiction. 1996; 91:101–112. [PubMed: 8822018]

Meux EF. How many diagnoses and procedures? Discharge Data Review. 1993; 20:1.

Meux, EF.; Stith, SA.; Zach, A. Report of results from the OSHPS reabstracting project: an evaluation of the reliability of selected patient discharge data July through December 1988. Patient Discharge Data Section Office of Statewide Health Planning and Development; Sacramento, CA: December. 1990 1990. 35 pages plus appendices A–I

Murphy GE, Wetzel RD. The life risk of suicide in alcoholism. Arch Gen Psychiatry. 1990; 47:383–392. [PubMed: 2181963]

Norstrom T. Alcohol and suicide in Scandinavia. Br J Addict. 1988; 83:553–559. [PubMed: 3382813]

Norstrom T. Alcohol and suicide: a comparative analysis of France and Sweden. Addiction. 1995; 90:1463–1469. [PubMed: 8528031]

Openshaw, S. The Modifiable Areal Unit Problem. Geo Books; Norwich, UK: 1984.

Parker, RN.; Rebhun, LA. Alcohol and Homocide: A Deadly Combination of Two American Traditions. State University of New York Press; Albany: 1995.

Ponicki, WR.; Gruenewald, PJ. S^3: The Spatial Statistical System Users Guide, V5.2.. Prevention Research Center, Pacific Institute for Research and Evaluation, NIAAA Center Grant Number AA06282; Berkeley, CA: 2005.

Rossow I. Suicide, alcohol, and divorce: aspects of gender and family integration. Addiction. 1993; 88:1659–1665. [PubMed: 8130705]

Rossow I, Romelsjo E, Leifman H. Alcohol abuse and suicidal behavior in young and middle aged men: differentiating between attempted and completed suicide. Addiction. 1999; 94:119–1207.

Rush BR, Gliksman L, Brook R. Alcohol availability, alcohol consumption and alcohol-related damage. I. The distribution of consumption model. J Stud Alcohol. 1986; 47:1–10. [PubMed: 3485738]

Scribner RA, MacKinnon DF, Dwyer JH. Alcohol outlet density and motor vehicle crashes in Los Angeles County cities. J Stud Alcohol. 1994; 55:447–453. [PubMed: 7934052]

Scribner RA, MacKinnon DF, Dwyer JH. The risk of assaultive violence and alcohol availability in Los Angeles County. Am J Public Health. 1995; 85:335–340. [PubMed: 7892915]

Singh GK, Siahpush M. Increasing rural-urban gradients in US suicide mortality, 1970–1997. American J of Pub Health. 2002; 92:1161–1167.

Skog O-J. Alcohol and suicide in Denmark 1911-24 experience from a "natural experiment". Addiction. 1993; 88:1189–1193. [PubMed: 8241918]

Skog O-J, Elekes Z. Alcohol and the 1950-1990 Hungarian suicide trend—is there a causal connection? Acta Sociol. 1993; 36:33–46.

Skog O-J, Teixeira Z, Barrias J, Moreira R. Alcohol and suicide: the Portuguese experience. Addiction. 1995; 90:1053–1061. [PubMed: 7549774]

Stack S. Suicide: A 15-year review of the sociological literature. Part I: Cultural and economic factors. Suicide Life Threat Behav. 2000; 30:145–159. [PubMed: 10888055]

State of California Department of Health Services Center for Health Statistics. Death Public Use File 2000 [CD-ROM] 2001.

Treno AJ, Johnson FW, Remer L, Gruenewald PJ. The impact of outlet densities on alcohol-related crashes: a spatial panel approach. Accid Anal Prev. 2007; 39:894–901. [PubMed: 17275773]

Upton, GJG.; Fingleton, B. Spatial Data Analysis by Example, Vol. 1, Point Pattern and Qualitative Data. John Wiley & Sons; New York: 1985.

Upton, GJG.; Fingleton, B. Spatial Data Analysis by Example, Vol. 2, Categorical and Directional Data. John Wiley & Sons; New York: 1989.

U.S. Census Bureau. Census 2000 summary file 1. Census of population and housing, September, 2001 [DVD]. U.S. Department of Commerce, Economics, and Statistics Administration; Washington, DC:

Waller, LA.; Gotway, CA. Applied Spatial Statistics for Public Health Data. Wiley; NewYork: 2004.

Wasserman IM. The effects of war and alcohol consumption patterns on suicide: United States, 1910–1933. Soc Forces. 1989; 68:513–530.

Wilkinson KP, Israel GD. Suicide and rurality in urban society. Suicide and Life-Threatening Behavior. 1984; 14:187–199. [PubMed: 6334914]

Wolfram Research. Mathematica 4.2.0. Wolfram Research; Champaign, IL: 2002.

Yacoubian GS. Assessing environmental prevention strategies for reducing the prevalence of associated harms of methamphetamine use. J Drug Educ. 2007; 37:31–53. [PubMed: 17982934]

Table 1

Descriptive Statistics and Percent Change in Measures Over Time

Variable group	Variable name	Mean	SD	Minimum	Maximum	Percent change[a]	Range of percent change	
							Minimum	Maximum
Endogenous measure	Suicide deaths	2.98	2.58	0	17	9.95	−100.00	600.00
	Suicide attempts	14.77	12.52	0	106	15.42	−100.00	1200.00
Retail establishments	Total retail	149.27	121.68	0	716	4.23	−100.00	480.49
Alcohol outlets	Off-premise	24.69	18.13	0	135	−0.43	−100.00	300.00
	Restaurants	27.15	25.85	0	195	5.27	−100.00	600.00
	Bars	6.17	6.28	0	61	−3.98	−100.00	300.00
Population	Population age 15 + (×1000)	23.34	15.19	0	74	0.34	−36.77	61.27
Demographics	Household size	2.79	0.53	2	5	−1.69	−26.83	19.90
	Percentage male	50.09	2.70	43	81	0.20	−30.22	36.33
	Median household income (×1000)	41.28	15.14	11	124	31.79	−23.07	146.83
	Median age	34.71	5.58	21	68	3.02	−31.44	62.69
	Percent white	67.69	22.07	4	100	−3.29	−58.10	46.38
	Percent black	6.83	12.45	0	86	−3.89	−100.00	300.00
	Percent Hispanic	27.17	20.90	1	98	16.29	−91.12	205.00

[a] Average percent change within zip codes from 1995 to 2000.

Table 2

REM Panel Models for Suicide Deaths and Attempts

Spatial relationship	Model component	Variable	Deaths (n = 3,486)			Attempts (n = 3,486)		
			b	t	p[a]	b	t	p[a]
		Constant	−2273.780	−4.641	0.000	22.54	0.050	
		Time 1	−68.295	−1.832		48.528	2.046	0.041
		Time 2	−9.508	−0.248		83.496	3.302	0.001
		Time 3	−35.177	−0.902		5.324	0.201	
		Time 4	−103.813	−2.625	0.009	−64.534	−2.352	0.019
		Time 5	−117.602	−2.898	0.004	17.565	0.601	
Local effects	Retail establishments	Total retail	0.675	2.843	0.005	0.958	4.414	0.000
	Alcohol outlets	Off-premise	3.547	2.296	0.022	1.361	0.965	
		Restaurants	−3.348	−3.000	0.003	−2.205	−2.189	0.029
		Bars	7.600	2.418	0.016	8.157	2.890	0.004
	Demographics	Population age 15 + (×1000)	−7.594	−4.648	0.000	−3.791	−2.483	0.013
		Household size	−34.559	−0.665		−177.564	−3.382	0.001
		% Male	7.731	1.037		0.577	0.087	
		Median household income (×1000)	−10.028	−6.792	0.000	−4.721	−3.232	0.001
		Median age	13.248	2.591	0.010	−11.794	−2.428	0.015
		% White	2.792	2.127	0.034	2.974	2.187	0.029
		% Black	−4.647	−2.608	0.009	5.405	2.885	0.004
		% Hispanic	−7.274	−5.248	0.000	1.897	1.331	
Lagged effects	Retail establishments	Total retail	0.518	1.021		0.796	1.733	
	Alcohol outlets	Off-premise	−8.039	−2.922	0.004	−1.345	−0.528	
		Restaurants	−1.772	−0.778		−0.566	−0.271	
		Bars	15.990	2.220	0.026	−0.416	−0.063	
Spatial autocorrelation		ρs	0.026	1.312	0.190	0.156	8.394	0.000

REM, random effects models.

Nonsignificant effects have no entry.

[a] Two-tailed tests.