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Short communication

Spatial relationships between alcohol-related road crashes and retail alcohol availability

Christopher Morrison[a,*], William R. Ponicki[b], Paul J. Gruenewald[b], Douglas J. Wiebe[a], Karen Smith[c]

[a] Department of Biostatistics and Epidemiology, Perelman School of Medicine, University of Pennsylvania, Blockley Hall, 423 Guardian Drive, Philadelphia, PA 19104, United States
[b] Prevention Research Center, Pacific Institute for Research & Evaluation, 180 Grand Avenue, Ste. 1200, Oakland, CA 94612, United States
[c] Research and Evaluation Department, Ambulance Victoria, 31 Joseph St, Blackburn North, Victoria 3130, Australia

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ABSTRACT

Background: This study examines spatial relationships between alcohol outlet density and the incidence of alcohol-related crashes. The few prior studies conducted in this area used relatively large spatial units; here we use highly resolved units from Melbourne, Australia (Statistical Area level 1 [SA1] units: mean land area = 0.5 km^2; SD = 2.2 km^2), in order to assess different micro-scale spatial relationships for on- and off-premise outlets.
Methods: Bayesian conditional autoregressive Poisson models were used to assess cross-sectional relationships of three-year counts of alcohol-related crashes (2010–2012) attended by Ambulance Victoria paramedics to densities of bars, restaurants, and off-premise outlets controlling for other land use, demographic and roadway characteristics.
Results: Alcohol-related crashes were not related to bar density within local SA1 units, but were positively related to bar density in adjacent SA1 units. Alcohol-related crashes were negatively related to off-premise outlet density in local SA1 units.
Conclusions: Examined in one metropolitan area using small spatial units, bar density is related to greater crash risk in surrounding areas. Observed negative relationships for off-premise outlets may be because the origins and destinations of alcohol-affected journeys are in distal locations relative to outlets.

1. Introduction

Approximately 20% of all fatal crashes worldwide are alcohol-related, amounting to over 250,000 deaths annually (WHO, 2011). Research over the last several decades has identified interventions that successfully reduce this global health burden, such as raising the minimum legal drinking age and conducting random roadside breath tests (Anderson et al., 2009). It is possible that reducing the physical availability of alcohol will have similar public health benefits. There is now substantial evidence that geographic areas with fewer alcohol outlets have lower incidence of other alcohol-related problems (e.g., assault, child abuse, crime; Campbell et al., 2009; Popova et al., 2009); however, there is comparatively little available evidence for road crashes. The current paper addresses this gap, investigating the geographic association between alcohol-related road crashes and the availability of alcohol through retail outlets within highly resolved spatial units.

The earliest studies to relate outlets to crashes used data aggregated within the very large spatial units of states (Colon, 1982; Colón and Cutter, 1983) and counties (Giacopassi and Winn, 1995; Jewell and Brown, 1995; Kelleher et al., 1996). Most found positive relationships, although some findings were negative or null. Recognising that larger spatial units increase the likelihood that results will be affected by aggregation bias (which attenuates parameter estimates toward null), recent studies have generally used smaller units, such as cities (McCarthy, 2003; Scribner et al., 1994), ZIP codes (Ponicki et al., 2013; Treno et al., 2007), or other custom units (Gruenewald and Johnson, 2010; Gruenewald et al., 1996), and have categorised outlets according to licence type. These studies consistently find on-premise outlets (e.g., bars, restaurants) to

* Corresponding author.
E-mail addresses: christopher.morrison@monash.edu, cneil@med.mail.upenn.edu (C. Morrison), bponicki@prev.org (W.R. Ponicki), paul@prev.org (P.J. Gruenewald), dwiebe@exchange.upenn.edu (D.J. Wiebe), Karen.Smith@ambulance.vic.gov.au (K. Smith).

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be positively related to crashes, but findings for off-premise outlets (e.g., liquor stores) are mixed.

To date, no published studies have examined these geographic relationships using spatial units smaller than California ZIP codes (mean = 158.7 km^2; SD = 295.0 km^2; Ponicki et al., 2013; Treno et al., 2007). This is problematic because on-premise and off-premise alcohol sales are likely to produce alcohol-related crashes in different locations, and studies using larger spatial units may not be able to disentangle the two. That is, an alcohol-impaired driver who departs from an on-premise outlet may crash somewhere between the outlet (origin) and another location (destination); whereas an alcohol-impaired driver who purchases alcohol at an off-premise outlet may crash somewhere between the place it is consumed (origin) and a third location (destination). The larger the spatial unit, the more likely it is that outlets, origins, destinations and crashes will be co-located within spatial units, washing out the distinct spatial signatures for on- and off-premise outlets while at the same time increasing the likelihood that effects will not be detectable due to aggregation bias.

For this study, we aggregated crash data and alcohol outlet data within Statistical Area level 1 (SA1) units from the city of Melbourne, Australia. These units have an average resident population of 415.3 (SD = 208.8) and cover a land area of 0.5 km^2 (SD = 2.2 km^2). In such small spatial units, we expected that greater density of on-premise outlets would be positively associated with alcohol-related crash rates in local and adjacent (i.e., spatially lagged) areas, but that there would be no detectable association for off-premise outlets.

2. Materials and methods

2.1. Sample

The spatial sample for this study was all SA1 units from the 2011 Australian Census with an internal centroid within the Australian Bureau of Statistics Major Cities region of Melbourne (n = 9214). We aggregated cross-sectional data from five sources within SA1 units: (i) alcohol-related road crashes from Ambulance Victoria (the sole emergency medical service provider in Melbourne) for 2010–2012, (ii) road crashes in which at least one person was injured from Victoria Police for 2010–2012, (iii) alcohol outlets from the Victorian Commission on Gambling and Liquor Regulation for 2011, (iv) 2011 roadway network and land use characteristics from VicMap, the state mapping authority, and (v) demographic characteristics from the 2011 Census.

2.2. Measures

The dependent measure was counts of alcohol-related crashes attended by Ambulance Victoria paramedics within each SA1 unit (Cox et al., 2013). We accessed reports for each patient within each case (a "casepatient"), then identified individual road crashes as all cases with one or more casepatients for which the paramedics assigned a case nature of motor vehicle collision, motorcycle collision, or bicycle collision. Cases were considered alcohol-related where paramedics indicated or queried that at least one casepatient had been drinking. We were not able to distinguish drivers from passengers. These data were provided to us geocoded to the SA1 unit.

The main independent measure of interest was the density of alcohol outlets within each SA1 (outlet counts denominated by SA1 land area). Outlets were categorized according to licence type as *bars* (general licences), *restaurants* (restaurant and café licences), and *off-premise outlets* (packaged licences). Outlet densities were calculated for adjacent SA1 areas by aggregating all SA1 units that share a boundary with the local SA1 unit. The mean distance between the centroid points of local and adjacent SA1 units was 0.63 km (SD = 0.54 km).

Other independent measures were the total length of roadways within each SA1 and the proportion by length that were highways or freeways (class code 0 or 1) and arterials or subarterials (class code 2 or 3), as well as the total count of intersections and the proportion that were "T" intersections (i.e., with three exits). Roadways representing SA1 boundaries were randomly assigned to one of the SA1 units they bordered. Population demographic characteristics were the median age of the resident SA1 population, the proportion that were male, and the proportion that spoke English at home. Socio-economic status was described using national deciles of the Index of Relative Social Advantage and Disadvantage (IRSAD), a composite measure published by the Australian Bureau of Statistics for which higher values indicate greater advantage. Commercial land use in local and adjacent SA1 units was the proportion of land area zoned for retail (zones B1Z, B2Z, B3Z, B4Z, B5Z) or capital city (CCZ1, CCZ2) use.

2.3. Statistical analyses

We assessed relationships between alcohol-related road crashes and alcohol outlet density in a Bayesian conditional autoregressive (CAR) Poisson model. Separating model errors into spatially unstructured noise and a spatially structured CAR random effect accounted for any loss of independence due to spatial autocorrelation (Waller and Gotway, 2004). We set non-informative prior distributions, and allowed the model to burn-in for 150,000 iterations before sampling 50,000 iterations to obtain posterior estimates. Spatial data management was performed using ArcGIS v.10.3 (ESRI, 2011), and the Bayesian spatial Poisson model was fitted using WinBUGS v1.4.3 (Lunn et al., 2000).

The expectancy for the Poisson model was a count of all Victoria Police injury crashes (n = 30,232) within each SA1. These data are publically available from VicRoads CrashStats, including latitude and longitude coordinates which we geocoded to SA1 units. 1453 SA1 units (15.8%) had no police-reported injury crashes; one additional crash was shared evenly between these units in order to avoid denominating the model by zero. By this approach, all injury crashes serve as an estimate of background crash risks due to road conditions, prevailing weather, traffic volume, driver behavior or other factors. This local variation is effectively constrained within a constant term, and parameter estimates for other independent variables describe the rate of alcohol-related crashes relative to this expected rate. We attempted a sensitivity analysis using all Ambulance Victoria injury crashes as the expectancy, but the very low number (n = 3572) produced a count of zero in the majority (75.3%) of SA1 units. An additional sensitivity analysis used the subset of Victoria Police injury crashes that occurred at night (6pm–6am everyday) and on weekends (4pm–6pm Fridays; 6am–8am and 2pm–6pm Saturdays; 6am–10am and 4pm–6pm Sundays), to account for traffic and background crash rates related to recreation around bars, restaurants and off-premise outlets rather than commuting.

3. Results

There were 1614 alcohol-related road crashes attended by Ambulance Victoria paramedics over the three years of the study. The characteristics of the 9214 SA1 units are described in Table 1.

Table 2 presents the results of the Bayesian spatial Poisson model. Compared to the rate of Victoria Police injury crashes, increased bar density of 10 outlets/km^2 within local SA1 units was unrelated to the rate of alcohol-related crashes (IRR = 1.00; 95%