Disaggregating relationships between off-premise alcohol outlets and trauma

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The Foundation for Alcohol Research and Education (FARE) is an independent, not-for-profit organisation working to stop the harm caused by alcohol.

Alcohol harm in Australia is significant. More than 5,500 lives are lost every year and more than 157,000 people are hospitalised making alcohol one of our nation's greatest preventative health challenges.

For over a decade, FARE has been working with communities, governments, health professionals and police across the country to stop alcohol harms by supporting world-leading research, raising public awareness and advocating for changes to alcohol policy.

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FARE is guided by the World Health Organization's *Global Strategy to Reduce the Harmful Use of Alcohol*[1] for stopping alcohol harms through population-based strategies, problem directed policies, and direct interventions.

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The Monash University wide research income was over $300 million in 2014. In 2014 Monash University secured over $60 million of ARC and $69 million of NHMRC funding, of which majority was awarded to the Faculty of Medicine, Nursing and Health Sciences (FMNHS).

The University's primary research goal into the next decade is to achieve significant research benefits for the various communities we engage with and serve, through the provision of research that is excellent, relevant, and has an impact. Monash University's emphasis in the Research Strategic Plan (2011-2015) is a six pillar research strategy focusing on talent enhancement, building interdisciplinary teams, research training, providing world class infrastructure, professionalising research, and translating research to deliver impact, which is particularly relevant to this research proposal.

The Monash University School of Public Health and Preventive Medicine provides a strong research environment with $40 million of our budget derived from research, with over $17 million of this from NHMRC/ARC funding in 2014. The research within the School has led to over 700 peer-reviewed articles during 2013. The School initiates and manages large epidemiological studies, including multicentre clinical trials, clinical registries and cohort studies.

[1] World Health Organization (2010). *Global strategy to reduce the harmful use of alcohol.* Geneva: World Health Organization.

About Ambulance Victoria

Ambulance Victoria (AV) is the Victorian Government enterprise charged with the state-wide role of ensuring that the people of Victoria receive the most appropriate response to personal and community medical emergencies, and medical transport. It is a critical link in Victoria's healthcare and emergency management systems.

Ambulance Victoria operates across the state, with major administrative centres in Melbourne and Ballarat. It employs approximately 3,000 career paramedics supported by approximately 1,000 volunteers. Air ambulance services are provided by 4 fixed wing and 5 helicopter aircraft delivering fast access for rural communities to major specialist facilities in the metropolitan region. Ambulance Victoria also provides adult medical retrieval services staffed by medical personnel and utilise advanced telehealth systems.

In servicing the community, Ambulance Victoria is supported by other organisations, including AV auxiliaries, the Emergency Services Telecommunications Authority (ESTA), Victoria Police, Country Fire Authority (CFA), Metropolitan Fire Brigade (MFB), and health care providers.

Ambulance Victoria aims to improve the health of the community by delivering innovative, high-quality ambulance services. Research is integral to Ambulance Victoria achieving its vision for better health in the community.

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Contents

Summary

This study examines the associations between alcohol sold through off-premise outlets, such as liquor stores, in Australia and the incidence of traumatic injury in surrounding areas.

Prior studies suggest that areas with greater concentrations of liquor outlets have more trauma cases; however few have attempted to disaggregate these relationships by outlet characteristics.

Two independent observers assessed alcohol price (based on the price of the cheapest bottle of wine) and the volume of alcohol available for sale (paces of shelf space) in 295 liquor outlets in Melbourne, Victoria. These outlets were randomly selected using a geographic sample frame. We also differentiated between outlet types in this study, examining both liquor chains and independent stores.

Consistent with economies of scale, we found that larger liquor outlets and chains sold cheaper alcohol than their independent counterparts. Cheaper outlets were also located in disadvantaged areas. Importantly, chains have cheaper alcohol available than independent outlets, and this relationship could not be explained by land and structure rents or other features of the alcohol market (for example, cheaper outlets are located in disadvantaged areas).

We then constructed spatial models assessing counts of ambulance attendances for intentional injuries (such as assault, stabbing and shooting) and unintentional injuries (fall, crush, and strike by an object).

Intentional and unintentional traumatic injuries occurred more commonly in areas with greater concentrations of off-premise alcohol outlets. These relationships extended to areas adjacent to where the outlets were located.

Chain outlets contributed most substantially to trauma risk, with each additional chain outlet associated with a 35.3 per cent increase in intentional injuries and a 22 per cent increase in unintentional injuries in the local SA1 area. Chains sold cheaper alcohol than independent stores, so this might partly explain their greater harmful effect.

Stores in disadvantaged areas have cheaper alcohol, so any harms related to cheap alcohol disproportionately affect disadvantaged people.

These findings suggest that limiting the exposure of local populations to off-premise alcohol outlets, particularly chain outlets, may reduce the incidence of trauma in neighbourhoods.

Introduction

Trauma places a substantial burden on global health, contributing to around 1.4 per cent of all deaths and 2 per cent of years of life lost (Shield, Gmel, Patra, & Rehm, 2012). From a prevention perspective, accidents and injuries have multiple contributing factors towards which intervention might be directed; and alcohol consistently ranks high among these potential causes. Both in Australia and worldwide, 17 to 18 per cent of traumatic deaths can be attributed to its consumption (Begg, Vos, Barker, Stanley, & Lopez, 2008; Shield et al., 2012). Thus, strategies seeking to reduce alcohol-related trauma could potentially have a substantial public health impact.

Limiting the availability of alcohol in communities is one approach which has received strong support in the research literature, as a greater concentration of outlets licensed to sell alcohol in an area is positively related to the incidence of trauma (Campbell et al., 2009).

In this study we contribute to this research area by examining the way in which outlets licensed to sell alcohol for off-premise consumption ("off-premise outlets") are associated with trauma occurring in nearby areas. We then disaggregate these relationships based on relevant outlet characteristics.

Current evidence

In the last two decades a number of studies have related the density of off-premise outlets in a geographic area to traumatic injury and to increased alcohol consumption (Campbell et al., 2009).

Most studies were cross-sectional and were conducted in the United States. For example, greater density of off-premise outlets predicted more robberies and assaults in neighbourhoods of Minneapolis, but not rape or all violent crimes (Toomey et al., 2012). Other studies have found similar associations between outlet density and youth violence (Alaniz, Cartmill, & Parker, 1998), violent crime (Gorman, Li, & Horel, 2005), child abuse (Freisthler, Midanik, & Gruenewald, 2004), and intimate partner violence (Roman & Reid, 2012; Toomey et al., 2012). Elsewhere, greater off-premise outlet density predicted greater per capita alcohol sales in British Columbia (Stockwell et al., 2009).

Time-series studies, in which cross-sections are combined to capture changes in exposures and outcomes within the same geographic regions over time, provide a higher level of evidence than cross-sectional studies because they allow researchers to observe temporality (Finkel, 1995). These studies have generally supported the findings of the cross-sectional studies. For example, greater outlet density preceded more hospital assault cases in California zip codes over a six year period (Gruenewald & Remer, 2006). Similar positive longitudinal associations have been reported between changes in off-premise outlet density and police reported night-time assault (Livingston, 2008), alcohol-attributable hospital admissions (Stockwell et al., 2013), domestic violence (Livingston, 2011), and alcohol consumption (Gruenewald, Ponicki, & Holder, 1993).

Using a different analytic approach, Treno and colleagues (2001) combined person-level survey data with spatially aggregated data, finding off-premise outlet density within a 2km buffer around respondents' residences was related to all-cause incidence of accidents and injuries. Other authors have used similar approaches to relate exposure to greater outlet density to the risk of assault with a gun (Branas, Elliott, Richmond, Culhane, & Wiebe, 2009) and increased alcohol consumption (Chen, Grube, & Gruenewald, 2010; Halonen et al., 2013; Iritani et al., 2013; Kavanagh et al., 2011; Scribner, Cohen, & Fisher, 2000).

In contrast, other studies contain inconclusive findings (for instance Lipton & Gruenewald, 2002; Livingston, 2008), and many more combine off-premise and on-premise outlets, such as bars and restaurants, into a single category (Gorman, Speer, Gruenewald, Labouvie, 2001; Scribner, McKinnon, & Dwyer, 1995). On-premise outlets are strongly associated with trauma (Campbell, et al, 2009), so this construction precludes assessment of the separate relationships for each outlet type. Nevertheless, this literature suggests off-premise outlets may be associated with trauma in nearby areas and for nearby residents, and that these relationships may be mediated by the residents' own alcohol consumption.

Disaggregating outlet density measures

Despite their collective strengths, these prior studies share a key limitation: the common outlet density metric assumes uniformity of effects for outlets on outcomes of interest. This is because data are aggregated within spatial areas (such as postcodes or Census regions) and exposure to outlets is measured using counts of licensed addresses denominated by some areal measure such as land area or total roadway length. The estimated relationships therefore describe the average relationship for outlets; however not all outlets are alike.

Due to economies of scale, retail stores selling equivalent commodities (such as alcohol) differ in a predictable manner (Treno et al., 2013). Larger stores and chains maintain profits through low margins and high sales volumes. Unable to compete on price, smaller and independent stores are forced to appeal to potential customers by alternate means (for instance, product range, service, ambiance). After accounting for differences in land and structure rents, larger stores selling cheaper products will need to sell greater volumes of lower cost alcohol to be profitable (Aoyama, Murphy, & Hanson, 2011).

Availability theory suggests lower total costs (including financial and convenience costs) lead individuals to consume greater quantities of alcohol (Stockwell & Gruenewald, 2004). By that mechanism, greater density of larger and chain outlets with lower prices may reduce the total cost of alcohol for local populations, leading to greater consumption within neighbourhoods. Greater consumption is itself associated with more traumatic injury (Gruenewald et al., 1993; Stockwell & Gruenewald, 2004). Thus, it is possible that larger and chain outlets selling cheaper alcohol products will contribute to greater incidence of trauma than smaller and independent outlets selling more expensive products.

Studies using simple density measures assess aggregate relationships between off-premise outlets and trauma. However, alternate approaches are required if one wishes to disaggregate these relationships based on outlet characteristics.

One study in Local Government Areas (LGAs) of Western Australia found assault incidence was independently related to the total volume of alcohol sales after controlling for outlet density (Liang & Chikritzhs, 2011). Another series of studies from Canada focused on the minimum drink price and gradual privatisation of off-premise sales after 1988 (Macdonald et al., 2012; Stockwell et al., 2013; Stockwell et al., 2011; Treno et al., 2013). Researchers mailed questionnaires to 98 private liquor stores and 199 government controlled liquor stores in British Columbia (Macdonald et al., 2012; Treno et al., 2013). The study found that private stores sold alcohol more expensively than government stores, but were open longer hours (Macdonald et al., 2012). In another British Columbia study, researchers assessed longitudinal relationships between the establishment of private stores and alcohol-related mortality (Stockwell et al., 2011), and between minimum drink price and alcohol-attributable hospital admissions (Stockwell et al., 2013). Overall outlet density and the proportion of outlets that were private predicted mortality, and higher minimum drink price predicted fewer hospital admissions.

Combined, these studies are consistent with the hypothesis that lower total costs of alcohol lead to more alcohol-related problems, and that this relationship is mediated by greater consumption among local populations.

Study aims

The aim of this study was to assess the relationships between off-premise alcohol outlets and trauma in surrounding areas, and then to disaggregate these relationships according to theoretically relevant outlet characteristics (including the price and volume of alcohol available for sale, and the differences between chain and independent businesses).

In order to do so, we used premise assessments to typologise a spatial sample of off-premise liquor outlets in Melbourne, Victoria.

First, we tested the proposition that these features would be related within outlets, using linear regression to control for indicators of the local alcohol market, including indicators of land and structure rents[2].

We then related ambulance attended trauma cases to outlet characteristics in Bayesian spatial models, hypothesising:

- greater outlet density would be related to greater incidence of trauma
- larger and chain outlets selling cheaper alcohol would contribute most substantially to trauma risk.

[2] The results for this outlet-level analysis have been accepted for publication in *Drug and Alcohol Review* (Morrison, Ponicki, & Smith, In press)

Method

Sample frame

In order to investigate the spatial relationships between off-premise outlets and the incidence of trauma, we required a spatial sample frame.

Using the 2011 Census, we defined the study area as all Statistical Area level 2 (SA2) regions with an internal centroid within the Australian Bureau of Statistics (ABS) Major Cities of Australia region of Melbourne. The Major Cities are defined according to the proximity of Census units to five classes of service centre (ABS, 2013a).

This approach produced a surface with one doughnut hole (Mornington) and one island which was not connected to any other SA2 units (Melton West). We included Mornington and excluded Melton West to produce a study area with 256 SA2 units on a contiguous surface (known as a convex hull).

SA2 are the second smallest spatial resolution at which the ABS releases Census data units, with a mean population of 9,414.4 (SD = 6548.6) nationwide. Wholly nested within SA2 units, SA1 units are the smallest available resolution (mean population = 392.4; SD = 195.7).

Off-premise outlet density and income are key elements of this study, so to ensure that we were able to compare areas with low income to those with high income, and those with low outlet density to those with high density, we stratified SA2 units based on these attributes.

Defining off-premise outlets density as the number of outlets in the SA2 denominated by the land area, and income as the median household income, we dichotomised the 256 SA2 units at the study area medians. This procedure yielded four cells (strata) containing roughly equal numbers of SA2 units.

We then randomly selected SA2 units from within each stratum. We were concerned that our sample would include outlets that were predominantly located in high density inner city areas, so we over sampled the low density areas at a ratio of 2:1. Our final spatial sample was 62 SA2 units, including 20 low density-low income, 21 low density-high income units, 11 high density-low income units, and 10 high density-high income units. In all, these units had a total population of 869,095 and contained 2,119 SA1 units and 260 addresses with Packaged Liquor licences.

Premise assessments

We obtained a list of all licensed alcohol outlets in Victoria from the Victorian Commission for Gambling and Liquor Regulation (VCGLR, 2014). Using the latitude and longitude coordinates included in those data, we constructed maps of the outlet locations within Melbourne. Included outlets were those located within the selected SA2 regions.

Two research assistants conducted premise assessments in all included off-premise outlets. Each observation took approximately five minutes, during which time the assistants independently collected information on the price, volume and operating characteristics of the outlets. This component of the study received approval from the Monash University Human Research Ethics Committee as a low risk application, given that all data collected were publically accessible and did not pertain to staff or customers.

During data collection, the research assistants reported finding outlets in the field that were not in their lists. We identified that these were establishments with General liquor licences, which are bars and restaurants that are permitted to sell alcohol for off-premise consumption. There were 197 such establishments within the 62 randomly selected SA2 units. As the purpose of the study was to assess off-premise outlets, we required that venues with General licences must have a separate room dedicated to off-premise sales in order to be included in the study.

Virtual assessments can be reliable for identifying large objects (like footpaths or park benches), but may be an imprecise tool for assessing fine detail (such as cigarette butts) (Chudyk, Winters, Gorman, McKay, & Ashe, 2014; Mooney et al., 2014). Therefore, we used Google Street View to exclude 112 General licence outlets that clearly did not have liquor stores or facilities for drive-through sales attached to the outlet (for instance, restaurants located in shopping strips). The remaining 85 were added to the outlet list. Research assistants indicated that 50 of these did not meet the inclusion criteria, and the remaining 35 were included in the sample.

The final sample was 295 off-premise outlets nested in the 62 SA2 regions of Melbourne, Victoria.

Outlet-level variables

Variables of interest from the premise assessment described the price, volume of alcohol available for sale, and the operating characteristics of the outlets.

Price was measured according to the cheapest 750ml bottle of wine, the cheapest six pack of 375ml cans or bottles of beer, and the cheapest 24 pack of 375ml cans or bottles of beer (a 'slab'). *Volume* was the number of paces of shelf space dedicated to alcohol sales (measured by walking along every shelf in the outlet) and an estimate of the floor area (length by width). Other *operating characteristics* of interest in this analysis were the presence of a walk-in fridge and drive-through sales.

We also differentiated between independent and chain liquor outlets, identifying chains as those for which the licencee held more than one licence in the state. Some outlets used a different operating name than the licence name, so where the research assistants believed an outlet to be a chain, they indicated as such and recorded the business name. These were cross-checked against other business names in the state and supplemented by web searches.

SA1 units described the neighbourhoods in which the outlets were located. National decile scores for the Index of Relative Socio-economic Advantage and Disadvantage (IRSAD) described relative advantage (ABS, 2013b). For outlets adjacent to each selected outlet we calculated the average alcohol volume, average price for the cheapest bottle of wine, and a dummy variable indicating whether any were chains. We determined adjacency using Thiessen polygons, a procedure in which polygons are constructed around points (outlets) such that every area inside the polygon is closest to its corresponding point.

Spatial unit variables

For the spatial analysis we characterised the average off-premise outlet within SA1 units by taking the mean of the price and volume measures. Census 2011 data for Statistical Area level 1 (SA1) units characterised neighbourhoods of Melbourne by: population density, median household income, median age, the proportion of residents who were Australian born, and the proportion of residents who were current students.

Ambulance Victoria (AV) case patient records provided the outcome data to test our hypotheses (Cox, Martin, Somaia, & Smith, 2013). AV paramedics record patient data in the field using VACIS, an electronic clinical information system. Patient data include the latitude and longitude of the event location, and are stored securely in a data warehouse. AV provided records for all trauma cases attended in Victoria between 1 July 2012 and 30 June 2014. Geographic data were spatially masked within SA1 census regions. Based on our review of the literature, the main outcome of interest was non-fatal *intentional injuries* (Campbell et al., 2009; Gruenewald & Remer, 2006; Livingston, 2008), which we defined as all cases in which AV paramedics indicated the mechanism of injury was assault, stabbing or shooting. We also included *unintentional injuries* as those cases with a mechanism of fall, crush, or where the patient was struck by an object. Other traumatic injuries which may be related to off-premise outlet density (including intimate partner violence and child abuse; Freisthler et al., 2004; Livingston, 2011) could not be determined from these data. Counts of intentional and unintentional injuries were calculated within SA1 units. We received separate approval from Monash University Human Research Ethics Committee to use these prehospital data.

Statistical analysis

We tested the inter-observer reliability of the outlet level measures using Cohen's kappa for binary variables and Pearson's correlation coefficient for continuous variables. We then conducted our analysis in two stages. Using the outlet level data, we examined whether chains and larger outlets sold cheaper alcohol (independent of local alcohol market and population characteristics) in linear models. We then used SA1 areas as the unit of analysis in spatial models for counts of trauma cases.

First, to determine whether outlet volume and type were independently related to price, a linear regression model examined the cheapest price for a bottle of wine (logged) in each outlet according to that outlets' own characteristics, the characteristics of adjacent outlets, and characteristics of the SA1 unit in which the outlet was located that we considered could be related to demand for cheaper alcohol (socio-economic advantage, population density, median age, Australian born, current students). The dependent measure was normally distributed after log transformation, and the model accounted for sample weights. Spatial autocorrelation (that is, the geographic clustering of similar values) of model residuals was very low (Moran's I = 0.072), indicating adjustment for this potential source of type I error was not required (Waller & Gotway, 2004). Likelihood ratio tests suggested hierarchical structures nesting outlets SA2 units did not improve model fit ($p > 0.999$).

Second, to examine relationships between outlet characteristics and traumatic injury incidence, we used hierarchical Bayesian spatial Poisson models with SA1 units nested within SA2 units. The dependent measures were counts of ambulance-attended intentional (Model 1) and unintentional injuries (Model 2).

We constructed two variants of each model. In the first (a) the independent measure was the count of off-premise outlets, and in the second (b), we separated off-premise outlets into the assessed dimensions: counts of chain outlets, counts of independent outlets, the average cheapest wine price for off-premise outlets within the SA1 units, and the proportion of outlets with drive-through facilities (as customers of these outlets may travel further after purchasing alcohol). We did not include the average shelf-paces within spatial units, as this measure was highly correlated with outlet counts ($r = 0.998$). Constraining the estimated effect for land area to 1.00 meant count measures could be interpreted as densities. Models controlled for on-premise outlets (counts of bars and restaurants) and demographic and zoning characteristics (resident population, median household income, proportion of land area zoned for retail use) that may have been related to the incidence of intentional and unintentional injuries. As effects may spill across the boundaries of SA1 units, we also accounted for the characteristics of adjacent spatial areas. In addition to the random effect for the SA2 units in which the SA1 units were nested, these Bayesian spatial models included a conditional autoregressive (CAR) random effect which controlled for the loss of unit independence due to spatially auto correlated model residuals and accounted for the small area problem (Waller & Gotway, 2004). The CAR term also controlled for over-dispersion of the outcome models, which otherwise violates the assumption of Poisson models that the mean is equal to the variance (Lord, Washington, & Ivan, 2005). This Bayesian approach produces a median estimate and a 95 per cent credible interval, which can be interpreted similar to a 95 per cent confidence interval in a regular regression model.

Results

Outlet-level data

Among the 295 off-premise outlets, 80 (27.2%) were independently operated and 215 (72.9%) were chains (see Table 1).

Data for the cheapest price of beer were incomplete, as 39 (13.2%) outlets did not sell six packs and 60 (20.3%) outlets did not sell 24 pack slabs. All but two of the outlets examined sold wine, and the mean price of the cheapest 750ml bottle was A$5.54 (SD = $2.87).

Outlets had between 3.5 and 1,047.5 alcohol shelf-paces (mean = 112.5; SD = 130.7), and this measure correlated very highly with the estimated floor area (r = 0.900).

Measures characterising the price (cheapest wine) and volume (alcohol shelf-paces) of alcohol in the 295 outlets had very high inter-observer reliability (r ≥ 0.928).

Table 1. Characteristics of off-premise outlets (n = 295)

	Reliability	n	%	Mean	SD	Min	Max
Licence type							
Packaged liquor		260	88.14				
General		35	11.90				
Business type							
Independent		80	27.21				
Chain		215	72.90				
Operating characteristics							
Drive through	κ = 0.840	36	12.24				
Walk-in fridge	κ = 0.731	198	67.12				
Outlet dimensions							
Cheapest wine (A$)	r = 0.973			5.54	2.87	2.40	29.00
Shelf-paces	r = 0.928			114.09	133.40	3.50	1,047.50

Nb. Tables 1 and 2 have been reproduced from the original manuscript accepted for publication in Drug and Alcohol Review (Morrison, Ponicki, & Smith, in press)

In the linear model (Table 2), chain outlets and alcohol shelf-paces were independently associated with cheapest wine price. Specifically, chains had a 0.40 unit decrease in logged price compared to independent outlets (*b* = -0.392, 95% confidence interval: -0.513, -0.271; p < 0.001). A one unit increase in logged paces of shelf-paces was associated with 0.095 unit decrease in logged price (*b* = -0.095, 95% confidence interval: -0.185, -0.006; p = 0.037). Additionally, outlets in disadvantaged areas had cheaper wine prices, and outlets adjacent to chains were cheaper than those not adjacent to chains. Greater distance to the nearest packaged outlet was associated with more expensive wine, whereas a greater proportion of students was associated with cheaper wine.

Table 2. Multivariable linear regression model for the price of the cheapest 750ml bottle of wine (natural log, ln), with adjustment for sample weights (n = 295).*

	b	(95%	CI)	p-value
Outlet characteristics				
Shelf-paces (ln)	**-0.095**	**(-0.185,**	**-0.006)**	**0.037**
Chain	**-0.392**	**(-0.513,**	**-0.271)**	**< 0.001**
General licence	0.050	(-0.130,	0.230)	0.584
Drive-through	0.101	(-0.040,	0.242)	0.158
Walk-in fridge	0.092	(-0.025,	0.210)	0.122
Characteristics of adjacent outlets				
Mean shelf-paces (ln)	-0.021	(-0.105,	0.063)	0.628
Mean cheapest wine price (ln)	0.005	(-0.179,	0.190)	0.954
Distance to nearest off-premise outlet (1 km)	**0.047**	**(0.008,**	**0.085)**	**0.018**
Any chain	**-0.233**	**(-0.450,**	**-0.016)**	**0.035**
Neighbourhood characteristics				
Socio-economic advantage** (decile)	**0.021**	**(0.002,**	**0.040)**	**0.030**
Population density (1000/km2)	0.008	(-0.017,	0.033)	0.526
Median age (10 years)	-0.017	(-0.060,	0.027)	0.449
Australian born (10%)	-0.015	(-0.044,	0.013)	0.281
Current students (10%)	**-0.079**	**(-0.148,**	**-0.011)**	**0.023**
Constant	**2.655**	**(1.919,**	**3.392)**	**< 0.001**
Model R^2	*0.361*			
Spatial autocorrelation of model residuals (Moran's I)	*0.072*			

* Bolded estimates have p < 0.05

**Index of Relative Socio-economic Advantage and Disadvantage (IRSAD)

Spatial unit data

Ambulance Victoria paramedics attended 3,089 intentional injuries (mean = 1.46; SD = 4.41) and 19,129 unintentional injuries (mean = 9.03; SD = 11.80) in the 2,119 SA1 units during the three years from mid-2011 to mid-2014.

On average, SA1 areas contained 0.139 off-premise outlets, comprised of 0.038 independent outlets and 0.092 chain outlets; and areas had a mean volume of 11.6 alcohol shelf-paces.

Other SA1 level characteristics are described in Table 3.

Table 3. Characteristics of all 2119 SA1 regions included in the study area

	Mean	SD	Min	Max
Outcomes				
Intentional injuries	1.458	4.414	0.000	135.000
Unintentional injuries	9.027	11.796	0.000	169.000
Off premise				
Total outlets	0.130	0.447	0.000	4.000
Independent outlets	0.038	0.216	0.000	3.000
Chain outlets	0.092	0.362	0.000	3.000
Mean cheapest wine (A$)	5.725	0.707	2.700	19.495
Drive through (proportion of total)	0.129	0.098	0.000	1.000
Shelf paces	11.835	54.307	0.000	1,047.500
On premise				
Bars	0.107	0.569	0.000	11.000
Restaurants	0.253	1.077	0.000	18.000
SA1 characteristics				
Age (median)	37.470	6.720	12.000	82.000
Australian born (%)	66.915	15.515	0.000	100.000
Median household income	73,827.150	27,222.020	0.000	260,715.000
Retail zone (%)	2.740	8.947	0.000	96.996
Population	410.218	202.823	3.000	3,042.000
Adjacent SA1 characteristics				
Off premise				
Total outlets	0.792	1.143	0.000	7.000
Independent outlets	0.208	0.563	0.000	6.000
Chain outlets	0.584	0.922	0.000	5.000
Mean cheapest wine (A$)	5.336	0.721	2.700	5.725
Drive through (proportion of total)	0.137	0.198	0.000	1.000
Shelf paces	53.866	98.787	0.000	791.000
On premise				
Bars	0.641	2.062	0.000	28.000
Restaurants	1.530	3.412	0.000	42.000
SA1 characteristics				
Age (median)	37.232	4.782	22.200	66.424
Australian born (%)	63.353	14.162	0.000	100.000
Median household income	75,503.600	19,932.100	24,831.340	137,366.100
Population density	2.173	1.626	0.002	12.058

The hierarchical Bayesian conditional autoregressive Poisson models are presented in Table 4.

In Models 1a and 2a, the total count of off-premise outlets was positively related to the incidence of intentional and unintentional injuries.

Disaggregating by outlet characteristics, in Model 1b, an increase of one chain outlet was associated with a 35.3 per cent increase in intentional injury (IRR = 1.35; 95% CI: 1.11, 1.64).

In Model 2b, chains also predicted the occurrence of unintentional injuries: one additional outlet was associated with 22.0 per cent greater incidence (IRR = 1.22; 95% CI: 1.08, 1.38).

In all four models, relationships in adjacent SA1 areas were mostly similar to those in local SA1 areas. Global Moran's I for the four models was very high (≥ 0.828), suggesting that had we not accounted for spatially auto correlated residuals, false positive findings were very likely.

Table 4. Bayesian hierarchical Poisson models predicting injury events in SA1 units (k = 2119)

	Intentional injuries						Unintentional injuries					
	Model 1a			Model 1b			Model 2a			Model 2b		
	2.5%	Median	97.5%	2.5%	Median	97.5%	2.5%	Median	97.5%	2.5%	Median	97.5%
Local SA1 characteristics												
Off premise												
Total outlets	**1.189**	**1.380**	**1.597**				**1.063**	**1.178**	**1.303**			
Independent outlets				0.866	1.209	1.684				0.793	0.984	1.221
Chain outlets				**1.112**	**1.353**	**1.638**				**1.077**	**1.220**	**1.382**
Least wine price (ln)				0.252	0.524	1.012				0.632	0.885	1.257
Drive through (proportion)				0.520	1.015	1.895				0.596	0.890	1.345
On premise												
Bars	0.997	1.134	1.285	**1.020**	**1.160**	**1.325**	0.913	1.001	1.102	0.919	1.008	1.108
Restaurants	0.939	1.012	1.092	0.948	1.021	1.101	0.981	1.031	1.080	0.989	1.038	1.092
SA1 characteristics												
Area (expectancy)		1.000			1.000			1.000			1.000	
Age (median)	**0.703**	**0.807**	**0.919**	**0.715**	**0.817**	**0.926**	**1.378**	**1.482**	**1.596**	**1.364**	**1.471**	**1.589**
Australian born (10%)	**0.738**	**0.805**	**0.878**	**0.744**	**0.806**	**0.887**	**0.859**	**0.909**	**0.955**	**0.862**	**0.909**	**0.962**
Median household income ($10,000)	**0.895**	**0.928**	**0.962**	**0.902**	**0.934**	**0.969**	**0.955**	**0.975**	**0.996**	**0.956**	**0.977**	**0.997**
Retail zone (%)	**1.010**	**1.103**	**1.203**	**1.010**	**1.102**	**1.200**	0.996	1.053	1.114	0.994	1.050	1.111
Population (1,000)	**1.521**	**2.118**	**2.921**	**1.482**	**2.024**	**2.795**	**2.514**	**3.093**	**3.819**	**2.446**	**3.034**	**3.740**
Adjacent SA1 characteristics												
Off premise												
Total outlets	**1.001**	**1.084**	**1.176**				0.999	1.053	1.108			
Independent outlets				0.874	1.040	1.239				0.866	0.965	1.075
Chain outlets				0.970	1.070	1.182				**1.002**	**1.064**	**1.130**
Least wine price (ln)				0.390	0.712	1.241				0.652	0.869	1.261
Drive through (proportion)				0.494	0.742	1.113				0.634	0.809	1.033
On premise												
Bars	**1.038**	**1.103**	**1.170**	**1.042**	**1.112**	**1.182**	0.944	0.984	1.027	0.951	0.991	1.032
Restaurants	0.942	0.977	1.015	0.938	0.974	1.011	0.986	1.010	1.034	0.989	1.012	1.035
SA1 characteristics												
Age (median)	0.610	0.802	1.011	0.630	0.801	1.045	0.750	0.888	1.092	0.751	0.880	1.021
Australian born (10%)	**1.019**	**1.188**	**1.413**	0.998	1.194	1.377	0.974	1.092	1.249	0.964	1.092	1.189
Median household income ($10,000)	**0.671**	**0.732**	**0.797**	**0.670**	**0.728**	**0.794**	**0.787**	**0.832**	**0.877**	**0.790**	**0.829**	**0.874**
Population	**1.054**	**1.140**	**1.228**	**1.061**	**1.145**	**1.230**	**1.105**	**1.159**	**1.216**	**1.108**	**1.162**	**1.221**
Global Moran's I for CAR		0.842			0.838			0.828			0.831	
Proportion of variance explained by:												
SA2 random effect	0.000	0.001	0.063	0.000	0.001	0.064	0.000	0.008	0.099	0.000	0.006	0.082
CAR random effect	0.379	0.592	0.770	0.339	0.566	0.756	0.385	0.553	0.682	0.401	0.539	0.658

Interpretation

This study demonstrates that intentional and unintentional traumatic injuries occur more commonly in areas with greater concentrations of off-premise alcohol outlets, and that chain outlets contribute most substantially to trauma risk. These relationships may extend to areas adjacent to where the outlets are located. Importantly, chains also have cheaper alcohol available than independent outlets, and this relationships could not be explained by land and structure rents or other features of the alcohol market (for example, cheaper outlets are located in disadvantaged areas).

There are a number of theoretical mechanisms which may explain our results. Availability theory suggests that greater outlet density leads to greater consumption among local residents, which in turn leads to greater risk of injury (Stockwell & Gruenewald, 2004). In addition to selling cheaper alcohol, chains also have more sales promotions than independent outlets (Jones, Barrie, Robinson, Allsop, & Chikritzhs, 2012). If they sell more alcohol than similarly sized independent outlets, then the relationship between chains and trauma may be mediated by total consumption.

Alternatively, off-premise outlets, and particularly chains, may attract people who are at greater risk for trauma (McCord, Ratcliffe, Garcia, & Taylor, 2007). Outlets themselves may also be attracted to areas with greater social disorganisation; defined as the "inability of a community structure to realize the common values of its residents and maintain effective social controls" (Sampson & Groves, 1989, p. 777). It is clear that problems such as traumatic injury occur more frequently in "disorganized" neighbourhoods (Sampson et al., 1997), and it is also possible that chains are attracted to these areas to a greater degree than independent outlets.

Some prior studies have linked off-premise outlets and intentional injuries (Alaniz et al., 1998; Branas et al., 2009; Campbell et al., 2009; Freisthler et al., 2004; Livingston, 2008, 2011), but to our knowledge none have identified a relationship between off-premise outlets and unintentional injuries.

One study included this mechanism of injury with aggregate counts of all-cause hospitalisations (Stockwell et al., 2013), suggesting a relationship was possible. Comparing trauma types, differences that emerged between areas that had more intentional injuries (more bars, younger residents) and those that had more unintentional injuries (older residents) were consistent with findings from previous spatial and person-level analyses (Campbell et al., 2009; Cox, Morrison, Cameron, & Smith, 2014), however there were also notable similarities in their associations with off-premise outlets.

Both intentional and unintentional injuries were more frequent in areas with greater off-premise outlet density, and effects for both trauma types were strongest for chain outlets. Relative effect sizes were comparable: point estimates suggests each additional chain outlet is associated with a 35.3 per cent increase in intentional injuries and a 22 per cent increase in unintentional injuries in the local SA1 area.

However, chain outlets may place a greater overall burden on public health through unintentional injury than intentional injury due to substantially greater cumulative incidence of the former. After linear interpolation, each additional chain outlet was associated with 0.28 additional intentional injuries compared to 1.09 additional unintentional injuries per year. The focus on intentional injury in this literature may be misplaced (Alaniz et al., 1998; Branas et al., 2009; Campbell et al., 2009; Freisthler et al., 2004; Livingston, 2008, 2011).

This study highlights several areas that would benefit from further research. The possible mechanisms by which a greater density of off-premise outlets, and particularly chain outlets, might be related to greater incidence of traumatic injury could be clarified by coupling time-series outlet-level data with time-series person-level data characterising individual alcohol consumption. Such a construction would enable explicit examination of the longitudinal effect of drinking as a mediator between outlets and trauma, and would confirm the direction of the associations we report here.

Additionally, a key limitation of this study is that shelf paces and the cheapest bottle of wine have not been validated for use as proxies for the price and volume of alcohol sales. To our knowledge, no sales data are publically available at sufficiently high resolution to examine their relationship to trauma occurrence as we have done here, though future studies could attempt to do so using sales receipts for a sample of outlets.

In sum, we found that intentional and unintentional injuries occurred more frequently in areas with greater densities of off-premise outlets. Chains contributed most substantially to this increased risk. These findings would appear to support reducing off-premise outlet density, particularly chain outlet density, as a strategy to reduce trauma and improve the public's health.

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