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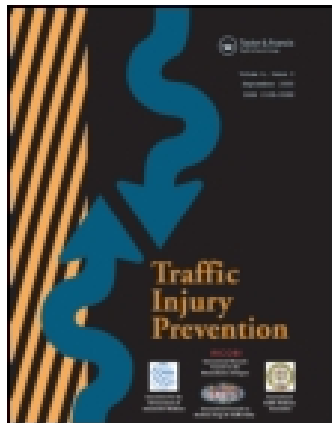
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Traffic Crashes and Alcohol Outlets in a Brazilian State Capital

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Objective: Restricting alcohol outlets is being considered as a measure for preventing alcohol-related crashes. However, in many developing countries, alcohol availability is not regulated and its influence on motor vehicle traffic crashes is unknown. This study explores the association between traffic crashes and alcohol outlets in a Brazilian city.

Method: Data were geocoded and exploratory analysis was conducted using the kernel density estimator. Two generalized additive models (GAMs) were implemented to predict the factors associated with alcohol-related crashes.

Results: For 78 percent of the 3840 traffic crashes where the driver was a victim, there was at least one bar located within a 300-m radius. The median distances between an outlet were 124.4 and 130.7 m for a non-alcohol- and alcohol-related crashes, respectively ($P = .13$). The GAMs did not make evident any significant association between the outlet locations and alcohol-related crashes: the presence of at least one outlet was associated with alcohol-related crashes with an odds ratio (OR) of 0.94 (95% confidence interval [CI] = 0.75–1.17). Alcohol crashes are more likely to be observed among males (OR = 1.58; 95% CI = 1.21–2.06), young drivers vs. those aged 50 years+ (OR = 3.4; 95% CI = 1.79–6.43), and crashes with fatalities (OR = 1.73; 95% CI = 0.98–3.04).

Conclusions: Density of alcohol outlets was high all over the city and both alcohol- and non-alcohol-related crashes occurred near an outlet. The study helps to better understand the relationship between alcohol availability and traffic crashes in a middle-income country where licensing/zoning is absent and suggests that measures for restricting the physical availability of alcohol are necessary, even though further studies are still needed.

Keywords: traffic accidents, low- and middle-income countries, alcohol availability, alcohol outlets, generalized additive model (GAM)

Introduction

Motor vehicle traffic crashes are a key public health problem in both high- and low/middle-income countries. It is estimated that alcohol use is associated with almost 30 percent of traffic deaths in high-income countries (e.g., the United States; National Highway Traffic Safety Administration 2005) and up to 70 percent of those occurring among drivers from low/middle-income countries (Peden et al. 2004). In Brazil, where positive blood alcohol concentration ranges from 20 percent in non-

fatally injured victims (De Boni et al. 2011) to 50 percent in those fatally injured (de Carvalho Ponce et al. 2011; Modelli et al. 2008; Stampe et al. 2010), preventing traffic crashes represent a challenge for the next decades (Reichenheim et al. 2011).

The association between the density of alcohol outlets and alcohol-related crashes has been assessed since the late 1970s (Colon 1982; Colon and Cutter 1983), and since the mid-1990s, most studies have explored the association between outlet density and alcohol-related crash risk in the context of small areas, such as neighborhoods and census tracts (Grue-newald et al. 1996; Theall et al. 2009; van Oers and Garretsen 1993). This scale of analysis seems to be related to the improvement in local databases, the progressive sophistication of geoprocessing techniques/spatial statistics in recent years, as well as the relevance of local data for policy making and evaluation

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of public policies related to the physical availability of alcohol (Babor et al. 2010; Stockwell and Gruenewald 2004). Despite substantial methodological advances, studies have generated contradictory findings. Most studies have pointed to a positive but modest association between outlet density and crashes (Gruenewald and Johnson 2010; Toomey et al. 2012; Treno et al. 2007), but there are negative findings as well (Meliker et al. 2004; Theall et al. 2009). The underlying causes of the observed association remain to be fully clarified, as discussed in Gruenewald's (2007) and Livingston et al.'s (2007) reviews.

Even though the international literature has documented the association between outlet density and different alcohol-related harms in developed countries (Campbell et al. 2009; Popova et al. 2009), very little research has focused on low- and middle-income countries. In the latter, legislation on alcohol availability is relatively new—as in the case of Brazil—and/or still faces serious difficulties in terms of approval and/or enforcement (Caetano and Laranjeira 2006). Alcohol availability is high in Brazil (Laranjeira and Hinkly 2002) and has been associated with homicides. Homicide rates have been found to be considerably reduced in one Brazilian city (Diadema) after the implementation of a local legislation restricting outlet opening hours (the authors estimated that this specific measure may be associated with 9 lives saved/month or a 44 percent reduction in the homicide rate per year; Duailibi et al. 2007). However, no previous study evaluated the putative association between alcohol outlet density and alcohol-related crashes.

Considering the contradictory findings on the association between traffic crashes and alcohol outlet density, the scarcity of scientific evidence on alcohol availability in low- and middle-income countries, as well as the high rates of deaths from traffic crashes in Brazil, this study assessed the association between alcohol outlets and crashes (both in general and with a focus on alcohol-related crashes) using geoprocessing techniques and spatial analysis.

Method

The study was conducted in the city of Porto Alegre, the southernmost Brazilian state capital (with an adult population of approximately 1,100,000 inhabitants as of 2010).

Alcohol Outlets

Data on alcohol outlets were obtained from the Municipal Secretariat of Industry and Commerce (SMIC), which is responsible for licensing and classifying every commercial activity in the city. There is no license system or government monopoly to sell alcoholic beverages in Brazil, as is the case of many other countries. Therefore, we selected places where people go to drink on the premises (*bar-chopp* [bar/pub serving draft beer], *bar-café*, restaurants, bowling alleys, nightclubs, and convenience stores) and excluded places where people usually buy and take the alcoholic beverages out but do not drink alcohol on the premises (e.g., supermarkets and mini-markets).

In 2008, 2027 outlets were registered in the databases, but 513 were actually duplicates (i.e., a single outlet registered by the SMIC twice). The registers were geocoded using ArchView 3.1 (ESRI Inc., USA) and included the addresses supplied by the SMIC and the digital street address map provided by the municipality. We successfully geocoded 908 premises using automatic procedures, with an additional 560 registers manually geocoded, and fixed obvious mistakes/incomplete information such as wrong/misspelled street names. At the end of the geoprocessing procedures, 1468 outlets were successfully geocoded (corresponding to 96.96% of the registered outlets).

Traffic Crashes

Data were provided by the Public Company of Transport and Circulation (EPTC). EPTC is the municipal company in charge of monitoring traffic circulation, applying fines, and supervising the enforcement of traffic legislation. One must observe, however, that EPTC is not a police division and is not entitled to arrest traffic law offenders.

We obtained data relative to the period of January 1 to December 31, 2009. The data set contained information on the street name and number, date, weather conditions, type of vehicle, victims (fatalities and nonfatal injuries), type of traffic crash, and the crash record issued by the police department, as well as basic information about the victims themselves, such as age and gender. For the sake of the analyses presented in the current article, we selected crashes in which the driver was injured.

In 2009, there were 22,945 traffic crashes in Porto Alegre; 7648 involved an injury, and 4456 of those injured were drivers. We successfully geocoded 4202 (94.3%) of those crashes and excluded the drivers of bicycles and *carroças* (rustic wagons pulled by horses; $n = 262$). Because most of the Brazilian data sets do not have data on blood alcohol concentration (BAC), traffic crashes were then classified into 2 categories: (1) alcohol-related crashes represented by a surrogate indicator—nighttime crashes with an injured driver (fatal or nonfatal) taking place between 8 p.m. and 4 a.m.—and (2) non-alcohol-related crashes, defined as every other crash. In 2009, alcohol-related crashes corresponded to 938 events and non-alcohol-related crashes to 3002 events.

Analysis

Frequencies of alcohol- and non-alcohol-related crashes taking place on different segments of the urban network (larger and smaller avenues and streets, as well as on roads that cross the city) were tabulated. Chi-square tests were performed to compare the proportion of both types of traffic events at different urban segments. In a subsequent step, all locations were ranked according to the decreasing proportion of crashes and grouped according to the quartiles of their distribution.

Exploratory analyses used the kernel density estimator (KDE) with the aim of identifying alcohol outlets and alcohol-related crash and non-alcohol-related crash clustering (“hot”) areas. The most important parameter that affects the outcome of the KDE is bandwidth (radius; Bailey and Gatrell 1995), but

the limited number of studies that have made evident parameters associated with road crash density measurements make the process of policy making too subjective and a matter of debate (Anderson 2009). For the sake of the present study we tested different bandwidths.

Finally, we implemented two generalized additive models (GAMs), considering alcohol-related crash as the outcome. A generalized additive model “is an extension of a generalized linear model with a linear predictor involving a sum of smooth functions of covariates” (Wood 2006, p. 121; Hastie and Tibshirani 1990). In the models presented in this article, the spatial distribution of crashes was a smoothed function of the geographical coordinates of each crash. Gender, age, weekend (yes/no), fatality (yes/no), motorcycle (yes/no), and public transport (yes/no) were entered as covariates in both models, which also included a variable related to bars locations. In the first model, this variable was defined as “any bar located within a radius of 300 m of the crash” (yes/no), whereas in the second we used the Euclidian distance to the nearest bar. Different software programs were used to performing data analysis including Terraview version 4.1 (INPE, Tecgraf PUC-Rio and FUNCATE, Brazil), ArcView version 3.1 (ESRI Inc., USA), and R version 2.12 (R Foundation for Statistical Computing, Austria).

Results

Alcohol-related crashes corresponded to 23.8 percent of all traffic crashes in 2009. Most events (63.4%) occurred in avenues, with decreasing proportions for streets (30.3%) and highways (5.3%). No statistically significant association was found between the type of road where the event took place (i.e., avenue, street, or highway) and alcohol- or non-alcohol-related crashes. With regard to the distribution throughout the different categories of roads, we observed that the first quartile (i.e., roads with the highest proportion of crashes) included 9 roads. The second quartile included 30 roads, the third one included 76 roads, and the last one included 257 roads. No statistically significant difference between the distribution of roads and the presence of alcohol was made evident by different analyses. Figure 1 depicts Porto Alegre land use, urban and rural areas, as well as the distribution of roads with a higher/lower proportion of traffic crashes.

Kernel maps with alcohol outlets and alcohol- and non-alcohol-related crash hot spots are shown in Figure 2.

In 78 percent of the events analyzed in our study, there was a bar located within the 300-m radius and in 93.5 percent there was a bar within a radius of 700 m. No significant association was found between alcohol-related crashes and the presence/absence of bars within radii of either 300 or 700 m in bivariate analyses ($P = .26$ and $P = .17$, respectively). Overall, the median distance between a traffic crash and the nearest bar was found to be 125 m, with median distances of 124.45 m (minimum 0 m and maximum 2680.3 m) for non-alcohol-related crashes and 130.7 m (minimum 0 m and maximum 2297.32 m) for alcohol-related crashes ($P = .13$).

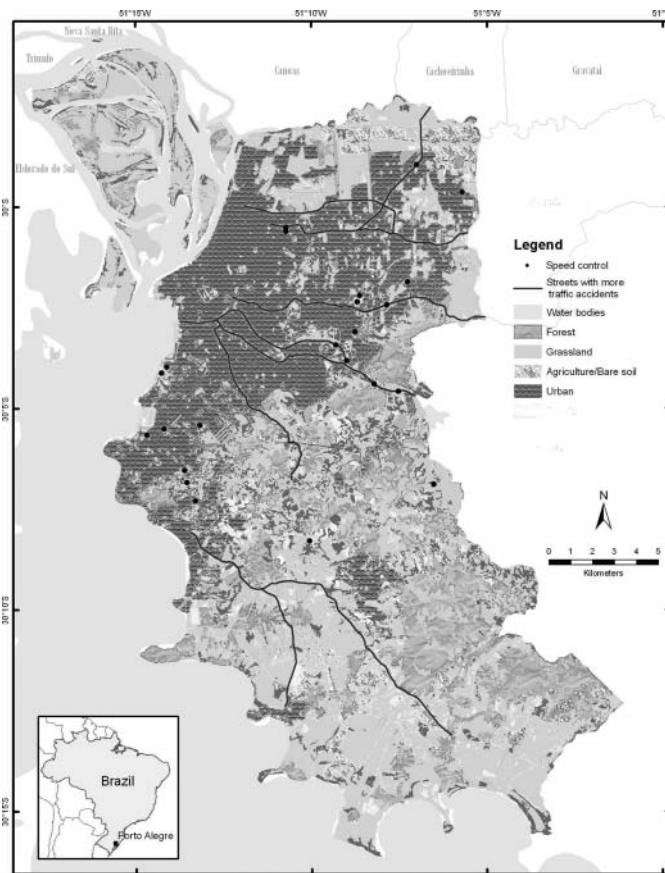


Fig. 1. Porto Alegre land use and urbanization.

The two GAMs did not make evident any significant association between the location of bars and alcohol-related crashes, despite documenting a significant increase in the chance of being involved in an alcohol-related event among males, younger drivers (aged less than 50 years old), crashes involving at least one fatality, and crashes taking place in the weekends (Table I). The spatial component of the GAM can be visualized as a risk map for alcohol-related crashes in Figure 3.

Discussion

This is the first study to evaluate the putative association between traffic crashes and alcohol outlets in a low/middle-income town. Such studies are pivotal because low- and middle-income countries show high rates of mortality due to traffic events and usually have few regulations concerning the purchase of alcoholic beverages. Our findings did not make evident any statistically significant association between outlet density and alcohol-related crashes in the city of Porto Alegre, which is in accordance with one of the few studies that is not ecological in its design, carried out by Meliker et al. (2004).

Outlet density was found to be so high in Porto Alegre that either alcohol-related crashes or non-alcohol-related crashes or, quite frankly, any event taking place in the city would be invariably located close to at least one bar. This unusually

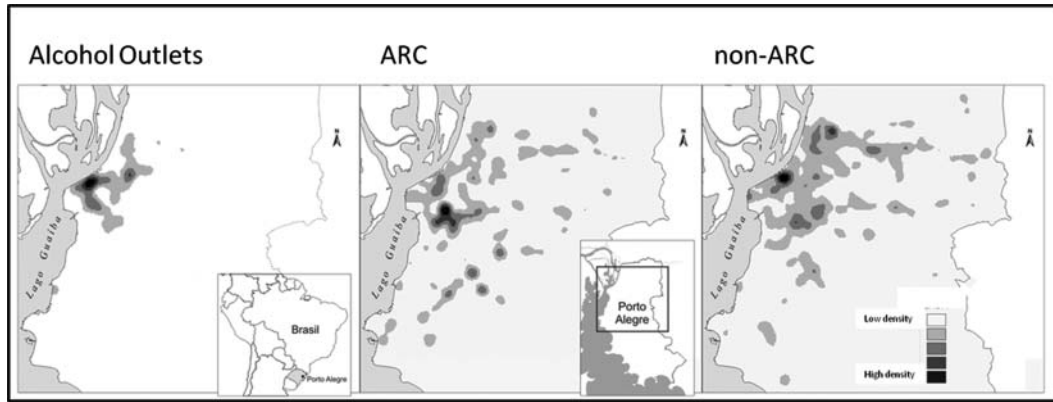


Fig. 2. Kernel density maps for alcohol outlets, alcohol-related traffic crashes (ARC), and non-alcohol-related traffic crashes (non-ARC).

high outlet density is by no means exclusive of the city of Porto Alegre and has been documented by previous Brazilian studies, carried out in other urban settings, such as Sao Paulo (Laranjeira and Hinkly 2002) and Vitoria, the capital city of the southeastern state of Espirito Santo (Basilio and Garcia 2006). Such previous studies, as well as the present one, demonstrate that Brazil has a vigorous, poorly regulated alcohol market. The Brazilian market is substantially different from mature markets (the vast majority of which are located in high-income countries), where the vast majority of studies assessing the putative association of alcohol outlet density and alcohol-related harms have been carried out (Babor et al. 2003).

The outlet kernel map identified three hot spots (Figure 2). These areas are relatively close to each other but have different characteristics. It may be hypothesized that individuals who drink in different areas of the city might have distinct demographic characteristics and patterns of alcohol use. The proper

identification of specific patterns of alcohol use—for example, binge drinking, which is strongly associated with driving under the influence (Duncan 1997; Escobedo et al. 1995; Kim et al. 2010; Valencia-Martin et al. 2008) and is highly prevalent in Brazil (Pechansky et al. 2009)—should be pursued by additional studies.

The high-density alcohol-related crash area is located in a region where important avenues intersect (Figure 1), and the GAMs (Figure 2) showed that ARC has higher odds in the central area of the city. This finding may be explained by the fact that individuals from different areas of the city eventually go to the main leisure areas, drink alcoholic beverages, and then drive their cars back home, as suggested by the amenity effect, originally proposed by Livingston et al. (2007). However, in order for a traffic crash to occur, additional factors must be in place. Gruenewald and Johnson (2010) showed that the effect of alcohol outlets may be modulated by the relative flow of vehicles across specific roads. Depending on the

Table 1. Generalized additive models for predicting factors associated with alcohol-related crashes in Porto Alegre, 2009

	N (%)	OR unadjusted	Model 1		Model 2	
			OR (95% CI)	P	OR (95% CI)	P
Male	3475 (88)	1.16 (0.91–1.48)	1.58 (1.21–2.06)	<.001	1.58 (1.21–2.06)	<.001
Age						
Up to 21	549 (13.9)	1.83 (1.03–3.49)	3.4 (1.79–6.43)	<.001	3.4 (1.79–6.42)	<.001
21–25	778 (19.7)	1.38 (0.77–2.61)	2.65 (1.41–4.98)	.002	2.65 (1.41–4.98)	.002
25–30	861 (21.8)	1.46 (0.83–2.77)	2.68 (1.43–5.01)	.002	2.67 (1.43–4.99)	.002
30–40	786 (19.9)	1.31 (0.74–2.48)	2.3 (1.23–4.31)	.009	2.3 (1.23–4.31)	.009
40–50	484 (12.3)	1.38 (0.76–2.64)	2.1 (1.10–3.96)	.023	2.08 (1.10–3.94)	.024
50–60	233 (5.9)	1.38 (0.73–2.73)	1.62 (0.89–3.18)	.160	1.61 (0.82–3.16)	.165
>60	78 (1.9)	1	1		1	
Any motorcycle	2814 (71.4)	0.49 (0.42–0.57)	0.41 (0.34–0.49)	<.001	0.41 (0.34–0.49)	<.001
Public transport	231 (5.9)	0.62 (0.42–0.87)	0.55 (0.37–0.81)	<.001	0.55 (0.37–0.81)	.002
Fatality	60 (1.5)	1.88 (1.09–3.17)	1.73 (0.98–3.04)	.059	1.73 (0.98–3.04)	.056
Weekend	1728 (43.8)	1.93 (1.67–2.24)	1.69 (1.45–1.98)	<.001	1.69 (1.45–1.98)	<.001
Alcohol outlet within 300 m	3076 (78.1)	0.90 (0.76–1.08)	0.94 (0.75–1.17)	.472	—	—
Alcohol outlet distance	—	—	—	—	1.00 (0.99–1.01)	.302
$S(x,y)^a$.032		.016

^aSee Figure 3.

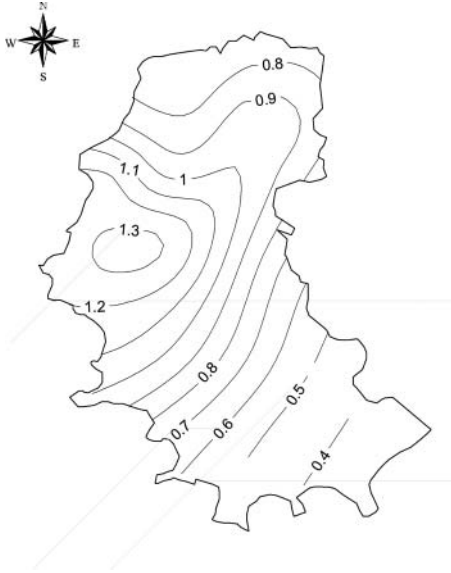


Fig. 3. Spatial odds ratio estimated by the generalized additive models. Lines indicate that the OR is higher in the center of the city.

intensity of the flow, an increase of 10 percent in alcohol outlet density may be associated with a 0 to 150 percent increase in the number of alcohol-related crashes.

Other findings from the 2 models using GAM corroborated findings from previous studies, such as the greater involvement of men (compared to women) in alcohol-related crashes; the greater severity of alcohol-related crashes (versus non-alcohol-related), as shown by a higher number of casualties (Hingson and Winter 2003; Zador et al. 2000); as well as the clustering of alcohol-related crashes on weekends (de Carvalho Ponce et al. 2011). In addition, with respect to the age of the drivers involved in the traffic crashes, our data found a concentration of such events among younger drivers (vs. older ones; odds ratio [OR] = 3.28; Bingham and Shope 2007; Chou et al. 2006; Quinlan et al. 2005). However, unlike international studies, such increased risks affect not only youth but middle-aged individuals, up to 50 years old, when a steep decline in the OR was observed. Such a unique finding may be associated with drinking patterns that are characteristic of the Brazilian context, where binge drinking is prevalent not only among youth but among adults aged 30 to 40 years old (Laranjeira et al. 2010).

The presence of motorcycles in the accidents under analysis was an important confounding factor, controlled for in the GAM. Data from our models showed that the presence of a motorcycle in a crash was found to be a protective factor, lowering the odds of alcohol-related crashes. This inverse association might be explained by the different characteristics of car and motorcycle drivers, as well as by the presence of commercial motorcycle drivers or “motoboy,” who seem to have different patterns of alcohol and drug use (Andrade and Jorge 2000; Breitenbach et al. 2011; Kieling et al. 2011; Santos et al. 2008).

Limitations of this study include the inaccuracy of the available databases and the use of a surrogate measure for the key

variable characterizing alcohol-related crashes. Compared to data collected in emergency rooms from developed countries (as reported by the DRUID (Driving Under the Influence of Drugs, Alcohol and Medicines) project in Europe, for example), and compared to data collected in Porto Alegre (De Boni et al. 2011), the surrogate measure used in this article may have underestimated alcohol use among drivers. However, there is no consensus in the literature about the best surrogate for alcohol-related crashes, especially when considering nonfatal injuries. Voas et al. (2009) considered single-vehicle nighttime crashes occurring late at night as a useful proxy, even though the authors considered as nonfatal crashes those in which only damage to property took place. Considering the Brazilian data, we supposed that single-vehicle nighttime crashes might underestimate even more the alcohol-related crashes in the city. We performed additional analyses using this variable as the outcome (data not shown), and the new findings did not differ from the original ones by any substantial means, with the exception of higher confidence intervals and a more pronounced association with fatally injured victims. However, BAC is not included in the official Brazilian data sets, with the exception of coroners’ reports, and the use of a proxy was the only possible way to estimate the association of traffic crashes and alcohol outlets using secondary data. The generalization of our findings to other Brazilian urban areas should be viewed with caution. Despite such similarities, Porto Alegre has, of course, a specific geography; a given design of its network of highways, avenues, and streets; and its own combination of cars, motorcycles, trucks, vans, and pedestrians, in and across different areas and ways.

Finally, it is important to note that Brazilian legislation has recently incorporated a zero-tolerance approach to drinking and driving. This change represents a fundamental, but still isolated, measure in any concerted effort aiming to reduce the number of crashes in the country. Without a proper zoning of alcohol outlets and a comprehensive preventive program promoting safer driving as a permanent educational goal, any single piece of legislation will fall short of the profound impact that such initiatives must have in order to reduce morbidity and mortality much below currently unacceptable levels.

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