Alcohol sale status and homicide victimization in Kentucky, 2005-2012: Is there a spatial association?

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Abstract

To date, the association between the alcohol sale status of decedents' residence and alcohol-related homicide victimization have not been studied as far as we know. The current study aims to: i) determine whether homicide victims who were residents of *wet* counties had higher odds of testing positive for alcohol than their counterparts in *moist* or *dry* counties after adjusting for confounders; ii) determine whether homicides and alcohol-related homicides tend to cluster spatially; iii) determine whether the aforementioned associations exist only in highly-populated counties. A multilevel logistic regression analysis was used to analyze the data on homicide victims in the Kentucky Violent Death Reporting System from 2005 to 2012. Spatial statistics were used to determine the spatial autocorrelation in rates of homicides and alcohol-related homicides. Overall, 944 homicide victims were included. The male to female ratio was 3:1. About 32.8% of homicide victims tested positive for alcohol. About 33.0% of homicide decedents who were residents in *wet* counties tested positive for alcohol compared to 32.5% of their counterparts in *moist/dry* counties. Residence in *wet* counties was associated with a statistically insignificant increase in the unadjusted odds ratio (OR) of alcohol-related homicide victimization (OR=1.20, 95% CI=0.81-1.77) as well as the adjusted odds (aOR=1.33, 95% CI=0.83-2.12). There was no association between population size and alcohol-related homicide rate.

Introduction

Homicide is among the top ten leading causes of death in adults in the United States (Logan *et al.*, 2011; Centers for Disease Control and Prevention, 2014) and alcohol consumption together with homicide victimization is a major public health problem (Grucza *et al.*, 2012). Prior studies of homicide victimization and alcohol show that alcohol was present in about 50% of homicide victims (Darke, 2010; Kuhns and Maguire, 2012). Among the various causes of violent deaths that occurred In the state of Kentucky between 2005 and 2010 (Walsh *et al.*, 2009), homicide was the second most common (22%). Several countries have implemented policies limiting alcohol use to reduce alcohol-related harms, such as suicide, homicide, other violent crimes and vehicle accidents. Such policies included banning alcohol sales, limiting number of alcohol outlets (Branas *et al.*, 2011; Parker *et al.*, 2011; Jennings *et al.*, 2014; Giesbrecht *et al.*, 2015), applying high alcohol taxes (Zeoli and Webster, 2010), limiting hours of alcohol sales (Duailibi *et al.*, 2007; Malaga *et al.*, 2012), limiting days of alcohol sales (Middleton *et al.*, 2010; Heaton, 2012), setting a maximum blood alcohol level when driving (Grucza *et al.*, 2012) and limiting age when drinking is allowed (Grucza *et al.*, 2012). Results from studies on the effect of the aforementioned policies on reducing homicide victimization are conflicting. For example, one of the earliest policies restricting alcohol in the United States is the constitutional prohibition of alcohol in 1920 (Asbridge and Weerasinghe, 2009). A study on the effect of the enactment of this policy employed an interrupted time series of 11,018 homicide victims and offenders in Chicago between 1870 and 1930 found no change in the alcohol-related homicide rates, a 21% increase in total homicides and an 11% increase in the non-alcohol-related homicides (Asbridge and Weerasinghe, 2009). They attributed the absence of change in alcohol-related homicide rates to underestimation, or possibly that the prohibition was not sufficiently enforced to effectively stop people from drinking. The rise in total and non-alcohol-related homicides was explained by a possible black market, organized crime and the existence of a subculture of violence at that time (Asbridge and Weerasinghe, 2009). Several questions remain unanswered in that study due to lack of data. For example, did the prohibition impact the economy by increasing the unemployment rate and poverty lead to violence? Alternatively, was the prohibition associated with the emergence of other substance-

abuse activities leading to violence? On the other hand, a prior study of alcohol availability and homicides found that an increase in alcohol sales was associated with an increase of homicides rates in men only, which suggests that both alcohol and violence are more common in men (Ray *et al.*, 2008). Similarly, another study of the association between the number of on-premise violent crimes in Kansas showed that a 10% increase in drinking establishments was associated with a 3.7% to 4.1% increase in violent crime suggesting that alcohol might act as a catalyst for violent behaviours (Anderson *et al.*, 2014). A major limitation of the prior studies is the *ecologic fallacy*, which means that results cannot be generalized to individuals.

Kentucky has diverse and continuously changing alcohol laws that result in an intermingled combination of *wet* counties (32), *moist* (49) and *dry* ones (39). Dry counties are counties that prohibit all sale of alcoholic beverages, wet counties those that permit full retail sales of alcohol under state license whereas moist counties are those with a wet city in a dry county or which only allow sale of alcohol at select sites, such as historic sites. The classification is not strict and moist cities can be in dry counties and vice versa (Department of Alcoholic Beverage Control, 2015). To date, there is no study of the association between the alcohol sale status of decedents' residence and homicide victims testing positive for alcohol in Kentucky. In this study, we used the term *alcohol-related homicide* to refer to victims testing positive for alcohol, not perpetrators. The current study aims to determine: i) whether homicide victims who are residents of wet counties have higher odds of testing positive for alcohol *post mortem* than homicide victims who are residents of moist/dry counties, after adjusting for confounding factors; ii) whether there is spatial autocorrelation among homicide and/or alcohol-related homicide rates in wet counties; and iii) whether the association between alcohol sale status of a decedents' residence and being an alcohol-related homicide victim exists primarily in counties with high populations.

Materials and Methods

Data source

Data on violent deaths for the period 2005 to 2012 were extracted from the Kentucky Violent Death Reporting System (KVDRS), a passive surveillance system that provides a detailed account of violent deaths that have occurred in Kentucky since 2005. The KVDRS combines data from death certificates, coroner/medical examiner reports, police reports, crime laboratory reports and toxicology reports. More information about KVDRS and how it collects data can be found in our previous work (Khaleel *et al.*, 2016). We identified homicide decedents from the KVDRS by the final way of death assigned by the data abstractors.

The exposure variable

The primary exposure variable was the alcohol sale status of the county in which homicide victims lived. For the purpose of this study, this variable was coded as a binary variable (wet *vs* moist/dry). Decedent's county of residence was abstracted from the KVDRS and matched to the wet, moist, dry county list released by the Department of Alcoholic Beverage Control in 2015; earlier versions of the list were not easily accessible. The classification of Kentucky counties into wet, moist and dry can be found in our previous work (Khaleel *et al.*, 2016). Briefly, counties were considered

dry if alcohol sales were prohibited; moist if alcohol sales were limited to certain places, such as historic places and golf courses; and wet if alcohol sales were allowed without limits.

The outcome variable

The *post mortem* level of blood alcohol of homicide victims was defined as a binary variable (positive, negative). Homicides were considered alcohol-related if the *post mortem* blood alcohol content was higher than 0.0% (Kaplan *et al.*, 2014; Giesbrecht *et al.*, 2015). Those who were not tested or were tested with an undetermined result were excluded from the multilevel regression analysis; however, they were mapped and examined to determine spatial randomness. If found to be spatially random; no specific spatial pattern was identified.

Confounders and effect modifiers

Sociodemographic variables included sex (male, female); age group (≤21, 21-30, 31-40, 41-50, 51-60, ≥61 years); race (Caucasian, African American/all others/unspecified); and educational level (8th grade, 9-12th grade, high school grade, above high school grade). Other potentially confounding factors, as suggested by the literature, included presence of mental illness (yes, no); substance-abuse problem (yes, no); intimate partner problem (yes, no); argument before homicide (yes, no); marital status (married, never married/single, widowed, divorced/separated); and type of weapon (firearm, poisoning, hanging, sharp objects, all others, unspecified/unknown). However, none of these potential confounders were statistically significant with either the exposure or the outcome and were therefore not included in the final analysis.

Each county's population was classified as either ≤35,000, 35,001-100,000 or >100,000. In addition, Appalachian or non-Appalachian residence of homicide victims was also included as a binary variable. Counties in Appalachia (in the eastern part of Kentucky) were identified using the Appalachian Regional Commission's classification (2015). Further details are mentioned in our previous work (Khaleel *et al.*, 2016). A composite binary variable was created to indicate the presence of substances other than alcohol in the blood. That is, if the *post mortem* blood was positive for any of the following drugs (amphetamine, antidepressant, benzodiazepines, cocaine, marijuana, anticonvulsants, muscle relaxant, opiate, barbiturates, antipsychotic), the presence of *other drugs* was considered positive. If the *post mortem* blood test was negative for all of them, it was considered negative. Although some of these drugs have legitimate medical uses, it was impossible to determine whether this was the case for most homicides.

Statistical analysis

We used frequencies and percentages in univariate analysis to describe the variables. In the bivariate analysis, the chi square test was used to find possible associations. Factors were considered confounders if they were associated with both exposure and outcome in the bivariate analysis. If their one-sided P-value was less than 0.05 they were included in the fully saturated model. The unadjusted and adjusted odds ratios (ORs) and the 95% confidence intervals were used to examine the association between alcohol sale status of the area and being an alcohol related homicide victim. To control for the county effects, a multilevel logistic regression model was used to assess which risk factors were significantly associated with being an alcohol-related homicide victim. The final model was adjusted for education level, sex and population. These factors were selected to remain in the final model if they had a P-value less than 0.0001 in

the fully saturated model for homicides. Testing for interaction by population size was not statistically possible due to limited events related to the confounding factors and was therefore removed from the final model. PROC GLIMMIX (SAS/STAT, 2014), which performs estimation and statistical inference for generalized linear mixed models was used to fit the multilevel logistic regression model with binary distribution, log link function and the residence county as a random intercept. For mapping and spatial analysis, crude rates of homicides in each county were calculated by dividing the total number of homicides by the 2010 population and multiplying by 100,000. Rates of alcohol-related homicides were calculated by dividing the number of homicide victims who tested positive for alcohol by the total number of the tested decedents and multiplying by 100. Spatial autocorrelation analysis of the rates of alcohol-related homicides was done using Global Moran's I. Briefly, the value of Global Moran's I varies between -1 and 1. A higher positive Moran's I indicates that similar values tend to cluster together, while a negative value implies that similar values are dispersed. When Moran's I is near 0, there is no significant spatial clustering or dispersion of values. For this analysis, inverse distance between county centroids was selected as the conceptualization of spatial relationships among counties, implying that neighbouring counties had a larger influence on the computation for a target county than counties that were situated far away. P-values lower than 0.05 were considered statistically significant. A map based on local Moran's I or the local indicators of spatial autocorrelation (LISA) was used to assess whether homicides and alcohol-related homicides were spatially clustered within wet counties. The Local Moran's I was used as an indication whether or not to reject the null hypothesis of no clustering in high or low rates, feature by feature; in effect, whether the apparent similarity (a spatial clustering of either high or low values) or dissimilarity (a spatial outlier) is more pronounced than one would expect in a random dis-

tribution. A high positive z-score for a feature indicates that the surrounding features have similar values (either high values displayed as High-High for a statistically significant cluster of high values, or low values given as Low-Low for a statistically significant cluster of low values). A low, negative z-score for a feature indicates a statistically significant spatial data outlier, *i.e.* a high-value feature surrounded by features with low values (High-Low) or a low value surrounded by high values (Low-High outlier). All statistical tests were one sided with a significance level of 0.05. All data were analyzed using SAS, version 9.4. Maps, cluster analysis and spatial statistics were done using ArcGIS 10.3 (ESRI, Redlands, CA, USA).

Results

Table 1 shows that 60.6% of the 944 homicides that occurred between 2005 and 2012 in Kentucky, occurred in wet counties. A high percentage of homicide victims who were residents of wet counties were less than 30 years old (48.8%), black (48.6%), male (79.6%), had a 9th-12th grade educational attainment (58.6%), never married/single (62.2%) and not residents in Appalachia (93.3%) (results not shown). Regarding stress-related covariates, a higher percentage of homicide victims in wet counties had an argument before the incident (26.9%), had mental health problems (1.0%), substance-abuse problems (3.5%), had *other drugs* in their blood at the time of the incident (53.5%) or died by firearm (73.8%). Finally, a high percentage of homicide victims who were residents of wet counties were also residents of counties with populations higher than 100,000, in contrast to those who were residents of moist/dry counties, where the populations were less than 35,000 residents (data not shown).

Table 2 shows the unadjusted OR, adjusted OR, and 95% confidence interval for the association between residence in wet coun-

Table 1. Frequency and percentages of homicide victims by decedent's residence alcohol sale status in Kentucky from 2005 to 2012.

Characteristic	Total		Wet		Moist/Dry		P-value
	N 944	% 100	N 572	% 60.6	N 372	% 39.4	
Education Level							<0.0001
8th grade	156	16.5	68	11.9	88	23.7	
9th-12th	492	52.1	335	58.6	157	42.2	
High School Grade	209	22.1	114	19.9	95	25.5	
Above High School	87	9.2	55	9.6	32	8.6	
Sex							<0.0001
Male	708	75.0	455	79.6	253	68.0	
Female	236	25.0	117	20.5	119	32.0	
Population of residence county							<0.0001
≤35,000	316	33.5	65	11.4	251	67.5	
35,000-100,000	179	19.0	82	14.3	97	26.1	
>100,000	449	47.6	425	74.3	24	6.5	

Table 2. The unadjusted and adjusted odds ratio and 95% confidence interval of the association between residence in wet counties and being an alcohol-related homicide victim.

	Alcohol related		Alcohol unrelated		Unadjusted OR, 95% CI	Adjusted OR, 95% CI*	P-value (one sided)
	N	%	N	%			
Homicides (n=944)	310	32.8	634	67.2	-	-	-
Wet (n=572)	189	33.0	383	67.0	1.20 (0.81-1.77)	1.33 (0.83-2.12)	0.11
Moist/Dry (n=372)	121	32.5	251	67.5	Ref°	Ref°	

OR, odds ratio. *The final model for homicides was adjusted for education level, sex and population. The fully saturated model for homicides included age, education level, sex and population. °The reference category, *i.e.* the group with which the first category was compared.

ties and being an alcohol-related homicide victim. The descriptive statistics showed that 33.0% of homicide victims from wet counties were positive for alcohol *post mortem* compared to 32.5% of those from dry counties. In addition, residence in wet counties was associated with a statistically insignificant 20% increase in the unadjusted OR of a homicide victim having consumed alcohol (OR=1.20, 95%CI=0.81-1.77). Adjusting for education level sex, and population did not change the effect estimate significantly.

Homicide rates by county were spatially autocorrelated (Moran's I=0.26, P-value≤0.0001) (map not shown). The LISA map in Figure 1 shows a large high- rate cluster among several rural counties adjacent to, or within, Kentucky's Appalachian region – three wet, five dry, and one moist county. Other areas of

concern included rural Cumberland County (dry) in southern Kentucky and urban Louisville-Jefferson County (wet). There were no homicides reported in six (5%) of Kentucky's 120 counties: Boone, Campbell, Carroll, Green, Laurel and Trimble, which was due to excluding cases because they lacked values regarding one or more of the confounding factors.

In contrast, there was only very slight, and statistically insignificant, spatial autocorrelation among alcohol-related homicide rates (Moran's I=0.1, P-value=0.07), (map not shown). Furthermore, the LISA map in Figure 2 shows only a few scattered high-rate clusters - two in a wet, two in a moist and one in a dry county.
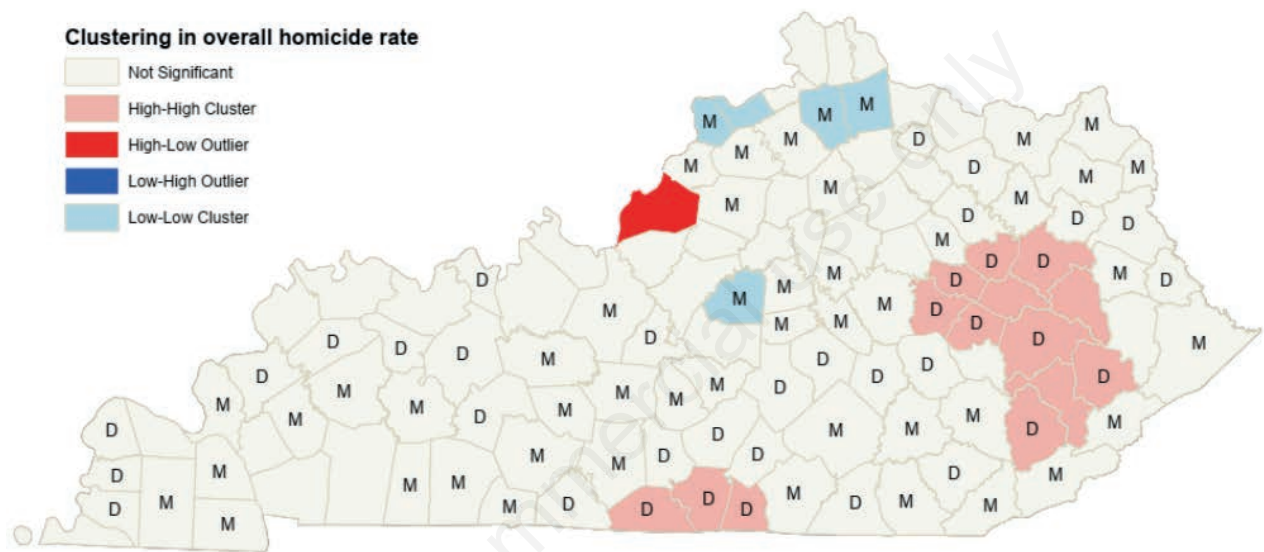

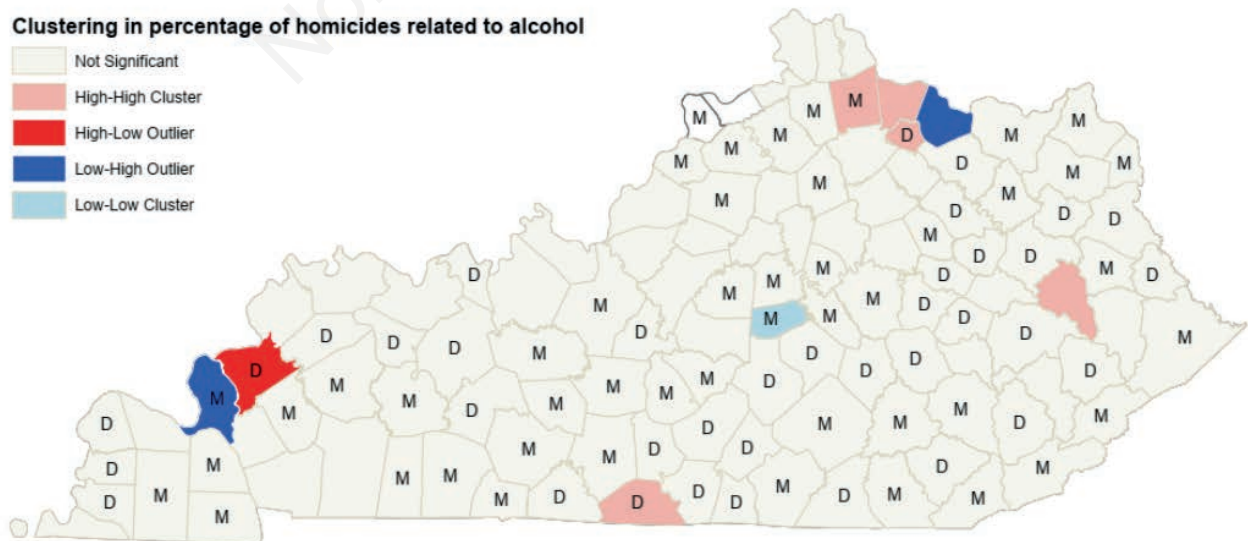**Figure 1. Cluster and outlier analysis of homicide rates in Kentucky, 2005-2012.**

Figure 2. Cluster and outlier analysis of alcohol-related homicide rates in Kentucky, 2005-2012.

Discussion and Conclusions

The aim of the current study was to find out if there are increased odds for a resident in a wet county of becoming a homicide victim after having consumed alcohol, which makes this investigation the first to focus on the association between local alcohol sales status and alcohol-related homicides. Our research adds to the current literature by studying the association between residency in wet counties and becoming an alcohol-related homicide victim, while adjusting for individual factors and counties using multilevel modelling (Gmel et al, 2016). We used spatial statistics to examine spatial autocorrelation of alcohol-related homicide rates in Kentucky (Gmel *et al.*, 2016) with the underlying hypothesis that living in wet areas where alcohol sales are allowed on and off premises may create an environment that encourages drinking and therefore promotes associated harmful activities (Livingston *et al.*, 2007).

In this study, alcohol was present in 32.8% of all homicide victims investigated. The percentage of homicide victims who were found to reside in wet counties and were positive for alcohol (33.0%) was similar to the percentage of homicide victims residing in moist/dry counties and who were also positive for alcohol (32.5%). These percentages were similar to those in other studies on the role of alcohol in homicide victimization (Kuhns *et al.*, 2011; Chermack *et al.*, 2012). We also found a 33% increase in the odds of being an alcohol-related homicide victim among residents of wet counties compared to residents of moist/dry counties (aOR=1.33, 95%CI=0.83-2.12) after adjusting for education level, sex and population; however, the association was not statistically significant. We also found that the odds of homicide victims having consumed alcohol increased with education from the 8th grade.

Results from spatial analysis did not provide evidence of spatial autocorrelation among county-level rates of alcohol-related homicides. However, results from the spatial analysis were not adjusted for potential confounders, such as sex and educational level. In addition, the spatial analysis was not adjusted for county-level factors, such as unemployment and economic status. Furthermore, the spatial analysis showed clustering of high homicide rates in the Appalachian region as well as clustering of alcohol-related homicides in counties in this region and nearby counties, which consist of a mixture of wet, moist, and dry counties. Again, results from the spatial analysis were not adjusted for confounders. However, these findings combined might indicate that residents of wet counties might be exposed to the negative social effects of alcohol reflected in high homicide rates. In addition, clusters in dry counties may suggest that the alcohol restriction policy is not achieving what it was meant to achieve. In fact, it may suggest that banning of alcohol may have resulted in other legal or illegal ways of obtaining alcohol and therefore resulting in increased odds of alcohol-related victimization. Alternatively, it would be relatively easy for people in dry counties to obtain alcohol by travelling to neighbouring wet counties, which could explain the low level of statistical significance.

There are no prior studies of the homicide victims investigated here with which to compare our findings of the association between alcohol sales and being an alcohol-related homicide. However, results from our study add to the existing literature of aggregate alcohol consumption and homicide rates (Mann *et al.*, 2006; Pridemore and Chamlin, 2006; Norstrom *et al.*, 2010; Ramstedt, 2011; Wolf *et al.*, 2014), alcohol sales and homicides rates (Norstrom, 2011a; 2011b), of density of alcohol outlets and

youth homicides (Parker *et al.*, 2011) and of extended hours of sales and consumption of alcohol with increasing homicide rates (Sanchez *et al.*, 2011). Alcohol promotes violent behaviour through increasing the tendency for misunderstandings in personal interactions (Weizmann-Henelius *et al.*, 2012; Anderson *et al.*, 2014). Alcohol availability may create an environment that cultivates alcohol consumption and violence (Zinkiewicz *et al.*, 2016).

There is a global consensus that alcohol consumption is a major public health problem leading to preventable morbidity and mortality (Rehm *et al.*, 2007; Weizmann-Henelius *et al.*, 2012). Estimates predicted that every 0.35 litre increase in the per capita total alcohol consumption for the period 1994-2002, should result in an approximately a 9% increase in alcohol-related mortality, 1% increase in accidents, 4% increase in homicide and 3% increase in assaults (Andreasson *et al.*, 2006). A recent study in New Zealand that used geographically weighted regression to examine the relationship between alcohol outlet density and violence, as measured by police activity, found that each additional bar or nightclub that opened was associated with nearly 5.3 additional violent events per year, and one additional licensed club was associated with 0.8 additional violent events per year (Cameron *et al.*, 2015). Results from other studies report comparable findings (McKinney *et al.*, 2009; Anderson *et al.*, 2014; Jennings *et al.*, 2014; Hobday *et al.*, 2015).

Spatial analysis in our study showed clustering of homicides in the Appalachian region suggesting the need for violence prevention programs that focus not only on alcohol, but also in context with other homicides risk factors in this region related to economic, geographic and unique cultural considerations.

Findings from this study could inform social agencies, research institutes, law enforcement, violence surveillance systems, the media and public health programs to plan prevention programs to reduce homicides in general and alcohol-related homicides in particular. Agencies that might include our findings in curriculum development and outreach activities include, but are not limited to, the Alcohol Policy Information System, the National Institute on Alcohol Abuse and Alcoholism and the Kentucky Department for Alcoholic Beverage Control. There is a need for better collaboration between policy makers, advocates, researchers, law enforcement and public health professionals to create planned multifaceted interventions (based on ecological and community level models) aimed at reducing alcohol-related events in communities (DiClemente *et al*., 2009). Evidence from the previous publications, and the current study, suggests that alcohol consumption policy prevention measures need to go beyond the individual intervention level and reach the community level as alcohol misuse and abuse is complex and therefore requires multifaceted interventions (Allamani, 2012). Interventions that aim to enhance the socioeconomic status of deprived communities include reduced access to firearms; increased police presence or surveillance in neighbourhoods with high rates of violent activities; control of drug use and trade activities; better access to, and availability of, counselling for couples and families; and reduced access to drugs and alcohol. The public also needs also to be educated about times and places of strong criminal activities. Most importantly, there is a need to improve the socioeconomic status of the Appalachian communities by increasing access to education and providing job opportunities.

This study has several strengths. To our knowledge, it is the first study of the association between residence sale status and being an alcohol-related homicide victim in Kentucky, while its

use of multilevel modelling permitted to adjust for county- as well as individual-level confounders, such as education level and gender. The multilevel approach overcomes the ecologic fallacy that is a major limitation of prior studies. Furthermore, the use of spatial analysis, albeit unadjusted, helped to identify the situation of homicide clusters, which necessitates further investigation into those areas to identify possible prevention strategies being sensitive to regional differences (*i.e.* the Appalachian area).

This study has also several limitations, *e.g.*, approximately 48% of all violent deaths lacked data with regard to either residence alcohol sale status, blood alcohol content or other variables which made it necessary to exclude them from the study. This may have resulted in a non-differential bias possibly reducing estimates towards the null. Secondly, although we assumed that the restriction of alcohol in dry counties might have led to illegal alcohol consumption among decedents, there was no information about the type of alcohol consumed to validate this assumption. Thirdly, residual confounding might exist in the spatial analyses because they were not adjusted for individual level confounders, such as gender and educational level, nor county level confounders, such as unemployment rate, gun sales and economic growth. Fourthly, wet/moist/dry status might have changed in some counties during the study period, which might have led to non-differential misclassification of the counties and underestimated the measure of the association. That is, the measurement error in the dependent variable would increase the standard errors on the regression coefficient, leading to potential Type II errors (failing to reject the null when it should be rejected), which could be another explanation for the insignificant findings. Lastly, another important limitation of the KVDRS data is that the answer *No* to the questions in the Coroner Investigation Reporting form does not necessarily mean that this information is negative; rather, it could mean that something is not known because the information is extracted from the decedent's relative, who may or may not have accurate information about the decedent. Furthermore, there was no specific variable describing why blood samples were not tested for alcohol. It would have been useful to know why those decedents were not tested. It is possible they were not tested because there was clear evidence at the death scene that these decedents were consuming alcohol, or perhaps because the decedent's body was decomposed which made testing impossible.

We recommend a comparison study of homicide survivors to determine the effects of alcohol on the lethality of violence. In addition, we emphasize the need for accurate data collection at the incident scene to minimize data loss. Furthermore, we recommend a multifaceted approach, rather than just focusing on alcohol prohibition, for the prevention of alcohol-related homicides.

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