Acute Alcohol Consumption, Alcohol Outlets, and Gun Suicide

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Abstract

A case–control study of 149 intentionally self-inflicted gun injury cases (including completed gun suicides) and 302 population-based controls was conducted from 2003 to 2006 in a major US city. Two focal independent variables, acute alcohol consumption and alcohol outlet availability, were measured. Conditional logistic regression was adjusted for confounding variables. Gun suicide risk to individuals in areas of high alcohol outlet availability was less than the gun suicide risk they incurred from acute alcohol consumption, especially to excess. This corroborates prior work but also uncovers new information about the relationships between acute alcohol consumption, alcohol outlets, and gun suicide. Study limitations and implications are discussed.

Keywords

suicide; injury; alcohol; alcohol outlets; geography

INTRODUCTION

The majority of completed suicides involve guns (Branas, Nance, Elliott, Richmond, & Schwab, 2004; Singh & Siahpush, 2002) and over one third of these gun suicides involve alcohol (Smith, Branas, & Miller, 1999). Despite this, suicide prevention strategies that focus only on guns can be protracted with limited political support (Branas, 2006) and uncertain consequences (Kassirer, 1995; Teret & Wintemute, 1993; Wintemute, 1999; Zimring, 1991). Although the inappropriate use of a gun is necessary for the occurrence of intentionally self-inflicted gun injury (including completed suicide), there are other contributing but similarly modifiable factors that also warrant serious consideration. Many of these other factors have the advantage of being less politically confrontational than the guns themselves and, as such, may present more feasible opportunities for prevention.

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One such modifiable factor is alcohol. People may be at risk of intentionally self-inflicted gun injury (including completed suicide) soon after consuming alcohol (Brent, Perper, & Allman, 1987; Conn, Rudnick, & Lion, 1984; Humphry, 1991; Miller & Hemenway, 1999; Smith et al., 1999; Welte, Abel, & Wieczorek, 1988; Wintemute, Parham, Beaumont, Wright, & Drake, 1999). People may also be at risk of intentionally self-inflicted gun injury by being in environments where alcohol is highly available (Berman, Hull, & May, 2000; Escobedo & Ortiz, 2002; Johnson, Gruenewald, & Remer, 2009). Although both personal and environmental factors are important, prevention resources are often limited and communities interested in pursuing alcohol-related prevention strategies to reduce intentionally self-inflicted gun injury must often choose to target either alcohol consumption *or* environments that may promote alcohol consumption.

In order to assist these communities in gauging the relative value of different alcohol-related prevention strategies to reduce intentionally self-inflicted gun injury, we conducted a population-based case–control study of personal acute alcohol consumption, environmental alcohol outlet availability, and intentionally self-inflicted gun injury. We included both fatal and nonfatal outcomes and accounted for a variety of individual, situational, and environmental confounders.

METHODS

All data were obtained under approval from both the University of Pennsylvania and the Philadelphia Department of Public Health Institutional Review Boards. A federal certificate of confidentiality was also provided by the National Institutes of Health. All study subjects gave their informed consent prior to enrollment.

The study of acute alcohol consumption, alcohol outlets, and gun suicide has been very limited. We applied a case–control study design to determine the association between acute alcohol consumption, alcohol outlets, and intentionally self-inflicted gun injury. Our target population was determined to be residents of Philadelphia, prompting the use of population-based controls. The use of other types of non-population-based controls (dead controls, hospital-based controls, etc.) were considered, but would have likely biased any final odds ratio estimates toward the null (Wiebe & Branas, 2003; Wiebe, Branas, Berlin, & Morgenstern, 2004). We considered trial, cohort, and matched cohort designs, but for various reasons (ethical considerations, prohibitively long implementation time, limited generalizability, etc.), these were not pursued.

In applying the case-control design, we assumed that the resident population of Philadelphia risked shooting themselves at any location and at any time of day or night. Disease-based, "immunity" restrictions were not employed (unlike other situations where such restrictions might be appropriate, i.e., you must be in a car to risk being injured as an occupant during a crash). This is a common approach for case–control studies (Poole, 1986, 1987, 1999) and an acceptable assumption because guns are mobile and have the potential to be carried into practically any neighborhood street, home, or workplace environment (Branas, Elliott, Richmond, Culhane, & Wiebe, 2009). Any member of the general population has the potential to be exposed to guns and the bullets they discharge regardless of where they are or

what they are doing. As such, we reasonably chose not to exclude subjects as immune from hypothetically becoming cases because they were, for instance, at home during the night or at work in an office building during the day. Instead, we appropriately measured and controlled for locational and time-based situations that might have changed, but did not eliminate, the risk of shooting oneself.

Subject Identification and Matching

Intentionally self-inflicted gunshot injury cases caused by powder charge guns were identified as they occurred, from October 15, 2003, to April 16, 2006. The final six months of this period were limited to only gun suicides to insure that enough fatal cases were enrolled for sufficiently powered statistical analyses. Because they function differently from intentionally self-inflicted gun injuries and were beyond the scope of the relationship we sought to investigate, gun assaults, unintentional gun injuries, police-related shootings (an officer shooting someone or being shot), and gun injuries of undetermined intent were excluded. Individuals under 21 years of age were excluded because it was not legal for them to possess a gun in Philadelphia and, as such, the relationship we sought to investigate was functionally different enough to prompt a separate study of this age group. We excluded individuals who were not residents of Philadelphia as they were not part of our target population. We excluded individuals not described as black or white as they would have been a very small percentage of our subjects.

Data coordinators at the Philadelphia Police Department identified and enrolled new shooting cases as they occurred by reviewing an electronic incident tracking system and interviewing police officers, detectives, and medical examiners. Basic data for eligible cases were sent through wireless to the University of Pennsylvania, where study leaders forwarded them to a survey research firm for recruitment of a matched control. More detailed information for each enrolled case was later filled in using additional data from police, medical examiner, emergency medical services, and hospital data sources (Branas, Culhane, & Wiebe, 2008).

Population-based controls were drawn from the target population of interest that was thought to have given rise to the cases, namely all community-dwelling (i.e., not institutionalized, not incarcerated, etc.) Philadelphia residents (Wacholder, McLaughlin, Silverman, & Mandel, 1992). These population-based controls were a random sample of individuals at risk of being shot, who would have been identified as cases had they been shot in Philadelphia. Controls were selected independent of their geographical location but were in Philadelphia at the time the case subject to which they were matched shot himself/herself. The median number of days between the time a shooting occurred and the time a control interview was completed was two, with over three quarters of all control interviews being completed within four days of their matched shooting case. Controls were interviewed with as little delay as possible, greatly minimizing recall bias.

More specifically, controls were sampled from all of Philadelphia using random digit dialing (Waksberg, 1978; Weiner et al., 2007). The protocol allowed for controls who later were shot to remain eligible for inclusion in the study as cases (Rothman & Greenland, 1998). In the interest of time, multiple interviewers may have simultaneously begun and then

completed control interviews. This resulted in three cases that had more than two controls. These few additional controls were retained in final analyses. We also tested for the possibility that multiple telephone lines and age-, gender-, and race-eligible members of a household could lead to unequal probabilities of selection among the control subjects. Case weights equal to the inverse of the probability of selection were constructed, and weighted conditional logistic regression analyses were conducted in parallel with unweighted analyses. Little difference (<5%) was found between the weighted and the unweighted analyses; thus, unweighted analyses are reported.

We took several steps to maximize participation and avoid selection biases due to nonresponse (Harlow et al., 1993; Herzog & Rodgers, 1992; Koepsell, McGuire, Longstreth, Nelson, & van Belle, 1996; Weiner et al., 2007). Using standard formulae, the cooperation rate for our control survey was calculated to be 74.4%, and the response rate, 56.0% (Daves, 2006). These rates exceeded those for other surveys conducted at about the same time (Galea & Tracy, 2007) and were high enough to produce a reasonably representative sample of our target population (Groves, 2006; Keeter, Kennedy, Dimock, Best, & Craighill, 2006). Within the age, race, and gender categories on which we matched, our controls were also statistically similar to the general population of Philadelphia in terms of marital status, retirement, education, general health status, and smoking status within the age, gender, and race categories specified previously. They were however found to be unemployed significantly more often than the general population.

We used risk-set sampling, a common approach in case–control studies (Rothman & Greenland, 1998), to essentially pair-match our cases and controls on the date and time (within 30-minute periods, i.e., 10:30 pm–11:00 pm) of each shooting. We did this because the independent variables of interest we planned to analyze, including acute alcohol consumption and being near alcohol outlets, were often short lived, easy to adjust for in statistical models, and did not correspond with numerous unmeasured confounding factors the way the time of self-inflicted gun suicide did. Thus, the time of the shooting was highly relevant etiologically (Roberts, 1995), and many unmeasurable confounders related to time —hour of the day, day of the week, season of the year, etc.—were accounted for by this risk-set sampling approach.

Prior case–control work on gun injury (Kellermann et al., 1992), as well as other early injury case–control studies (Haddon, Valien, McCarroll, & Umberger, 1961), has pair-matched cases and controls on location, something that we purposely did not do because it would have likely produced bias toward the null due to overmatching (by increasing the number of case–control matches with noninformative, same exposures to outlets, thus increasing variability and reducing statistical significance) and because we also wanted to study the effects of location with respect to alcohol outlets (Branas et al., 2008).

We also adjusted for other certain basic factors that were thought to be appropriate for pair matching of our cases and controls based on conceptual confounder criteria and apriori justifications of statistical inefficiency (i.e., too few subjects for analysis in certain matched strata). When appropriate, pair matching is most practical using select nominal scale confounders and those with a large number of possible values per stratum (Rothman &

Greenland, 1998). In addition to time, our controls were thus matched to cases based on age group (21–24, 25–39, 40–64, and over 65 years old), gender, and race (black or white). Rather than adjust for them in our analysis, we pair-matched on these variables to avoid extremely sparse data in certain subgroups, given our prior knowledge that exceedingly different age, race, and gender distributions existed among self-inflicted shootings relative to the general population of Philadelphia. Based on early power calculations, two controls were matched to each shooting case.

Confounding and Subset Variables

Numerous variables are influential as confounders in the association between subject alcohol consumption, proximity to alcohol outlets, and intentionally self-inflicted gun injury. Confounding variables can be conceptually separated into individual and situational characteristics, both of which feed the eventual circumstances that result in intentionally self-inflicted gun injury. Based on previous work and theory, we measured and adjusted for many of these individual and situational characteristics (Table 1). Individual characteristics included age, race, gender, ethnicity, unemployment, education, and marital status. Situational characteristics included those specific to the subjects themselves at the time they were shot: whether they had consumed alcohol or were outdoors. We also accounted for situational characteristics specific to the neighborhood within which the shooting occurred: its alcohol outlet availability, racial and ethnic makeup, unemployment and income levels, and education (Gruenewald, 2007; Johnson et al., 2009; Kellermann et al., 1992; Livingston, Chikritzhs, & Room, 2007). The use of a risk-set sampling design accounted for many time-based confounders (Rothman & Greenland, 1998). Cases were also classified as either nonfatal or fatal intentionally self-inflicted gun injuries (i.e., completed gun suicides) to permit subset analyses. Sufficient numbers of fatal intentionally self-inflicted gun injuries were collected to conduct regression analyses; however, because of a very high fatality rate for cases, too few nonfatal intentionally self-inflicted gun injuries occurred over the study period, thus preventing regression analyses of this subset.

Data and Analyses

For cases, acute alcohol consumption at the time of the shooting was determined by blood alcohol concentrations from emergency departments and the morgue and, when these were not available, by police observation, which has been shown to be effective in distinguishing acutely intoxicated drinkers (Brick & Carpenter, 2001; Grossman et al., 1996; Moskowitz, Burns, & Ferguson, 1999; Soderstrom, Dailey, & Kerns, 1994; Stuster & Burns, 1998; van Wijngaarden, Cushing, Kerns, & Dischinger, 1995). For controls, acute alcohol consumption at the time of the shooting was determined via a series of questions that anchored recall and determined recency of drinking, rate of drinking, and number of drinks (defined as one bottle, can, or glass of beer; one glass of wine; one mixed drink; or one shot of liquor). Cases and controls were separated into no acute alcohol consumption, nonexcessive acute alcohol consumption (BAC [blood alcohol content] < 0.10 mg/dL or its gender-/height-/weight-adjusted drink equivalent), and excessive acute alcohol consumption (BAC 0.10 mg/dL or its gender-/height-/weight-adjusted drink equivalent) categories. Acute alcohol consumption was determined for 90.0% of cases and 99.7% of controls, and locations were obtained for 99.3% of cases and 95.9% of controls. Missing data were

imputed using multiple imputation by chained equations (Rubin, 1987; van Buuren, Boshuizen, & Knook, 1999).

All environmental data were linked to a given case subject according to his/her location when the shooting occurred, and for control subjects, according to where the he/she was located at the time his/her matched case subject was shot. We geographically coded subject locations to latitude and longitude points using intersections or blockfaces, and alcohol outlet locations to latitude and longitude points using actual addresses.

On-premise (such as bars and taverns) and off-premise (such as take-out establishments and delis) alcohol outlets were classified using liquor licenses and North American Industry Classification System (NAICS) codes obtained for each alcohol outlet in Philadelphia. On-premise alcohol outlets were, by definition, establishments where patrons were required to consume the alcohol they purchased at the establishment itself; off-premise alcohol outlets were establishments where patrons were required to consume the alcohol they purchased somewhere other than the establishment itself, usually a private residence.

The Pennsylvania Liquor Control Board (PLCB) regulates the beverage alcohol industry in Pennsylvania and issues beverage alcohol licenses for either on-premises retail sales of wine, liquor, or beer, or off-premises wholesale sales of malt beverages by the case and keg. The PLCB maintains an electronic list of all beverage alcohol licenses for Philadelphia and its contiguous counties, which is updated every day. To adequately account for turnovers in alcohol licenses, we acquired this list every six months for the duration of the study period. Alcohol outlets were identified by name, address, and license type.

By ordinance, the Philadelphia Department of Revenue collects a tax on sale of liquor, and malt and brewed beverages in the city of Philadelphia at a rate of 10%. Every sale at retail by any business or person holding a license or permit issued by the Commonwealth of Pennsylvania to sell or dispense liquor or malt and brewed beverages is subject to this tax. Exempt from the tax are state-operated liquor stores and malt beverage distributors, although these account for only about 6% of the alcohol outlets in Philadelphia (Liquor Sales Tax Regulations, Philadelphia city, code 19, section 1805). Access to NAICS codes for each alcohol outlet (liquor license holder) paying this alcohol tax in Philadelphia was obtained from the Department of Revenue for use in the study.

To corroborate our classifications, two pairs of field observers also visited a randomly selected group of 70 alcohol outlets from across Philadelphia on Thursday and Friday nights between 8 pm and 12 pm (midnight). Based on prior work (Graham & Homel, 1997; Graham, La Rocque, Yetman, Ross, & Guistra, 1980; Quigley, Leonard, & Collins, 2003; Wolfson et al., 1996), a structured data collection procedure was also developed and implemented to systematically observe alcohol outlet patrons, staff, drinking environments, and nearby areas. We did not conduct statistical analyses using this relatively small number of outlets, but were able to complete important and complementary qualitative assessments of alcohol outlets in better explaining our statistical findings. Other environmental factors were geographically coded using the latitude and longitude centroid and population-weighted centroid points of blocks, block groups, and tracts.

Case and control subjects were assigned measures of their cumulative exposure to environmental factors based on the points where the subjects were located and the point locations and magnitudes of the environmental factors surrounding them. The higher the measure, the greater the clustering and magnitude of environmental factors surrounding a subject's location. These environmental measures are discussed in greater detail elsewhere (Branas et al., 2009). Separate environmental measures were calculated for each subject and then compared between cases and their matched controls.

The environmental measures we used essentially assigned each subject his/her own unique neighborhood (Longley, Goodchild, Maguire, & Rhind, 2005) while directly accounting for spillover effects and the variability in neighboring areas (Geronimus, 2006; Holt, Steel, & Tranmer, 1996; Krieger et al., 2002; Openshaw, 1984; Scribner, 2000; Wong, 1991; Wrigley, 1995). These measures were calculated for alcohol outlets and all other environmental factors (Branas et al., 2009). Environmental measures for alcohol outlets were also separated into high and low availability using case and control subjects' median cut-points. For alcohol outlets, these categorical environmental measures were more readily interpretable in terms of main effects and also interaction terms with subjects' acute alcohol consumption.

We appropriately chose to adjust for unmatched confounding factors, such as age and location, using conditional logistic regression modeling to adjust for imbalances in these potential confounders between our case and control subject groups (Rothman & Greenland, 1998). Accordingly, individual- and environmental-level independent, potentially confounding variables were compared for cases and controls, followed by conditional logistic regression models (Breslow, 1996) of the focal independent variables—acute alcohol consumption and alcohol outlet availability—and the outcome of intentionally self-inflicted gun injury. Individual- and environmental-level confounders were selected for these conditional logistic analyses because they were of theoretical importance, could be measured within the scope of our study, had been used in prior studies (Cummings, Koepsell, Grossman, Savarino, & Thompson, 1997; Dahlberg, Ikeda, & Kresnow, 2004; Gruenewald, 2007; Johnson et al., 2009; Kellermann et al., 1992; Livingston et al., 2007; Nelson, Grant-Worley, Powell, Mercy, & Holtzman, 1996; Wiebe, 2003), and were sufficiently noncollinear with each other. Excessively collinear confounders were excluded by keeping variance inflation factors under 10 (Fox, 1991).

All regression models were adjusted for yearly age (because, even after matching on categorical age, there was still residual confounding due to the effect of continuous age within categories, as cases were slightly older than controls on average [Rothman & Greenland, 1998]) and all other confounders that were not excessively collinear. Robust sandwich estimators of variance were also specified (White, 1980) and the residuals from our regression models were not found to be statistically significant for spatial autocorrelation (using Moran's I and Geary's c co-efficients) (Getis, 2000; Gruenewald & Remer, 2006). Statistically significant findings were taken to be those with p-values less than .05 throughout our analyses, although we also report p-values of borderline significance, i.e., less than .10.

RESULTS

Study Participants

Over the study period, our research team was notified about 3,485 shootings of all types occurring in Philadelphia. This translated into an average of 4.77 ± 2.82 shootings per day, with a maximum of 21 shootings in a single day, and an average of 9 days a year that were shooting-free. From among all these shootings, 167 were intentionally self-inflicted (4.79%), 3,202 (91.88%) were assaults, 60 were unintentional (1.72%), 54 were legal interventions by law enforcement (1.55%), and two were of undetermined intent (0.06%). One intentionally self-inflicted gun injury occurred about every 5.5 days among Philadelphia residents.

From among the 167 intentionally self-inflicted gun injury case subjects who remained, 11 (6.59%) were under 21 years of age or of unknown age, three (1.80%) were nonresidents, and four (2.39%) were not described as being black or white, and were thus excluded. All 149 participants who remained were enrolled for the study's main analyses. The case fatality rate for these remaining participants was 91.89%. An age-, race-, and gender-matched group of 302 control participants were also concurrently identified and enrolled.

Cases and controls showed no statistically significant differences in terms of their age, race, and gender distributions. Cases and controls also showed no statistically significant differences in terms of the times of day, days of the week, and months of the year when their data were collected. Cases and controls were thus successfully matched on age, race, gender, and time.

In unadjusted statistical analyses, when compared with controls, shooting cases were more often Hispanic, more often unemployed, less educated, and less often married or with a partner. At the time of their shooting, cases were more often outdoors and in areas where fewer blacks, Hispanics, unemployed, lower-income, and college-educated individuals resided (Table 1).

Main Analytic Findings

In unadjusted statistical analyses of the study's focal independent variables, cases demonstrated significantly higher proportions of any acute alcohol consumption and excessive acute alcohol consumption and were significantly more often in areas of low alcohol outlet availability than controls ($p < .01$). Similar comparisons from unadjusted analyses were noted among gun suicides (Table 1).

Regression-adjusted statistical analyses of the study's focal independent variables showed that participants who had any level of acute alcohol consumption were 4.23 times as likely to intentionally shoot themselves compared with those who had no acute alcohol consumption ($p < .01$). Adjusted analyses also showed that this relationship became more pronounced for gun suicides (5.94 times, $p < .01$) and much more pronounced for excessive acute alcohol consumption (77.11 times, $p < .01$).

After statistical adjustment in our regression models, proximity to alcohol outlets overall (on- and off-premise) was largely unrelated to the risk of intentionally self-inflicted gun injury, although an elevated, but statistically nonsignificant, risk was noted in terms of proximity to off-premise alcohol outlets. Conversely, after adjustment in our regression models, subjects in areas of high on-premise alcohol outlet availability were at lower, but non-significant, risk of intentionally self-inflicted gun injury. Adjusted analyses also demonstrated that subjects in areas of high on-premise alcohol outlet availability were also at lower risk of gun suicide of borderline significance ($p < .10$) (Table 2). Testing of interaction terms through these regression-adjusted models indicated no consistent synergistic relationships between acute alcohol consumption and alcohol outlet availability; this lack of a finding was partly due to small numbers.

DISCUSSION

Acute alcohol consumption, especially to excess, was statistically associated with a significantly higher risk of intentionally self-inflicted gun injury and gun suicide in the urban area we studied. Alcohol outlet availability, on the other hand, did not appear to be statistically associated with a significantly higher risk of intentionally self-inflicted gun injury and gun suicide. Different types of alcohol outlets seemed to demonstrate opposing relationships—high on-premise alcohol outlet availability was associated with a lower risk of gun suicide of borderline significance, while high off-premise alcohol outlet availability was associated with an elevated, albeit non-significant, risk of gun suicide.

Although the majority of completed suicides involve guns (Branas, Nance et al., 2004; Singh & Siahpush, 2002) and over one third of these gun suicides involve alcohol (Smith et al., 1999), there has been comparatively little study of the alcohol–gun–suicide connection. The current study not only corroborates some aspects of prior work in this area but also uncovers new information about the relationships between acute alcohol consumption, alcohol outlets, and intentionally self-inflicted gun injury.

Alcohol Consumption and Gun Suicide

Consuming alcohol can lower inhibitions, increase confidence, and potentially release violent inclinations (David & Spyker, 1979; Romelsjo, 1995). Alcohol consumption may also lead to inaccurate assessments of future risks, causing individuals to act on fleeting, and sometimes violent, impulses (Gordis, 1997). In a similar way, individuals who take their own lives often do so in the face of a temporary crisis that they perceive as severe (Miller & Hemenway, 1999). Many, although not all, suicides are thus viewed as impulsive acts of violence. Suicides committed with guns, on the other hand, are almost uniformly viewed as acts of extremely traumatic violence, intolerable even to euthanasia advocates (Humphry, 1991).

An alcohol–gun–suicide connection has been posited by others (Miller & Hemenway, 1999). One study of adolescent suicide found that victims who used guns were nearly five times more likely to have been drinking alcohol than those who used other methods of suicide (Brent et al., 1987). Gun suicide victims often "brace" themselves with alcohol in anticipation of a painful or violent end (Conn et al., 1984; Humphry, 1991; Smith et al.,

1999; Welte et al., 1988; Wintemute et al., 1999). These individuals may be uncertain about killing themselves, making the risks they face temporary and the availability of alcohol and guns during these times especially important (Miller & Hemenway, 1999).

The existence of a gun is both a necessary and a sufficient cause required for the occurrence of gun suicide. Alcohol may in some cases be necessary for a gun suicide to occur, but it alone is not sufficient. The decision to consume alcohol can occur either before or after the decision has been made to attempt suicide with a gun and thus different intervention strategies might be pursued depending on the relative timing of these two decisions.

Our findings suggest a strong connection between acute alcohol consumption and intentionally self-inflicted gun injury and gun suicide. This alcohol–gun–suicide connection appears to be strongest for individuals who acutely consumed alcohol to excess, although small numbers of observations and large confidence intervals do not permit a more conclusive judgment with respect to excessive acute alcohol consumption. Acute alcohol consumption, and perhaps excessive acute alcohol consumption, may have made the impulsive and painful act of shooting oneself potentially easier and significantly more likely.

Although the inappropriate use of a gun is necessary for the completion of gun suicide, there are other contributing factors that have the advantage of being less politically confrontational than the guns themselves and, as such, may present more feasible opportunities for intervention. One such modifiable factor is alcohol. However, intervening on acute alcohol consumption, as a strategy to reduce gun suicide, is uncommon. Legislation that focuses on the intersection of alcohol and firearms at the state level might be considered an indirect attempt at interventions like this, although such legislation remains inconsistent. A recent study reported that only 20 states have laws that restrict possession and/or discharge of firearm by an acutely intoxicated person (Carr, Porat, Wiebe, & Branas, 2010). Other intervention strategies that address acute alcohol consumption and self-directed firearm use are also worth further consideration given our findings here.

Alcohol Outlets and Gun Suicide

Alcohol outlets, and the drinking environment more broadly, have largely not been part of the aforementioned posited alcohol–gun–suicide connection. Decades of prior ecological studies have shown that alcohol-related inter-personal violence is affected by the environmental context in which drinking occurs (Branas et al., 2009). However, not until relatively recently have studies been published that even consider the relationship between alcohol outlet density and suicide (Escobedo & Ortiz, 2002), much less have this relationship as their focus (Johnson et al., 2009).

In New Mexico, a county-level regression analysis showed that increasing alcohol outlet density was significantly related to increasing suicide rates (Escobedo & Ortiz, 2002). In California, a ZIP code-level longitudinal analysis demonstrated mixed findings with respect to alcohol outlets and completed suicides. Bar (on-premise) and off-premise alcohol outlet densities were positively and significantly associated with suicide rates, while restaurants serving alcohol were negatively and significantly associated with suicide rates (Johnson et al., 2009).Johnson et al. (2009) suggest that their findings may have as much to do with

general issues of rurality, such as social isolation, as they do with alcohol outlets. Nonetheless, both of these prior studies are important contributions and greatly advance our, as yet, nascent understanding of alcohol outlets and suicide.

It is very interesting to note that the mixed findings of the California study are somewhat mirrored in the results of our analysis. That is, we found that greater proximity to off-premise alcohol outlets was associated with greater, although nonsignificant, odds of gun suicide, while greater proximity to on-premise alcohol outlets was associated with lower odds of gun suicide of borderline significance. Although we did not separate out restaurants that serve alcohol for consumption on premise, it may be the case that our finding is driven by a preponderance of these restaurants among our on-premise alcohol outlets.

A number of conclusions relevant to these numerical findings can be made based on our field visits to alcohol outlets in Philadelphia. The off-premise outlets we visited were staffed by a very small number of servers who frequently worked from behind fortified walls of "bullet-proof" glass and only briefly interacted with patrons to distribute alcohol and small food items. Some off-premise staff were even equipped to sleep overnight at their businesses and avoid emerging from behind their protective barriers. These off-premise outlets were brightly lit, generally unattended spaces, where patrons appeared to have little connection, socially or otherwise, to servers or other patrons. If proximity to off-premise outlets had any relationship to the risk of intentionally self-inflicted gun injury, it may have been indirect; that is, areas where off-premise outlets were clustered may have also been areas with high levels of social isolation and anonymity, which in turn may have promoted suicide (Branas et al., 2009).

The on-premise outlets that we visited were in comparison highly monitored, socially connected spaces, even in what appeared to be highly chaotic neighborhoods. Unlike the lax monitoring of potentially at-risk patrons and the generally anti-social environment in off-premise outlets, on-premise alcohol outlets seemed to provide nonalcoholic goods and services to their patrons as well as a certain social connectivity that may have, in some ways, reduced feelings of isolation and enhanced the kind of face-to-face guardianship that can be used to potentially identify ideators and suppress short-lived suicidal impulses (Branas, Richmond, & Schwab, 2004; Duberstein et al., 2004; Heath, 2007). Based on the limited findings we report here, this idea is, at present, only hypothetical and speculative. However, future empirical consideration might be given to testing the ability of servers to recognize potentially suicidal individuals within bars and taverns and refer them to mental health services. The possibility of this intervention has merit for future study given its low cost, community-level reach, and successes with server training programs for related phenomena —preventing aggression (Graham, Bernards, Osgood, Homel, & Purcell, 2005), fetal alcohol syndrome (Dresser, Starling, Woodall, Stanghetta, & May, 2011), and problem drinking (McKnight, 1991).

Study Limitations

In extending the work of prior analyses that have been entirely ecological in design, we conducted a case–control study that used the individual as its unit of analysis. Given that we also brought ecological data into our case–control analyses, our study had the advantage of

being able to compare individual- and environmental-level influences. This gets past some of the aggregation biases that have been discussed in prior analyses (Johnson et al., 2009) and may explain some differences in findings between our study and prior work. However, our study was not sufficiently powered, statistically, to draw reasonable inferences about the synergistic relationships between acute alcohol consumption by our individual study participants and the availability of alcohol outlets in the environment around these individuals. Future studies of alcohol out-lets and intentionally self-inflicted injury should consider planning to test such alcohol consumption–alcohol outlet interaction effects.

A number of other study limitations also deserve discussion. Our control population was more unemployed than the target population of Philadelphians that it was to intended to represent. Although we did account for employment status in our regression models and our control population was found to be representative of Philadelphians for five other indicators, having a preponderance of unemployment among our controls may mildly erode our study's generalizability. Our controls being more unemployed than the general population also makes the unemployment difference between cases and controls less than what it truly might have been (i.e., 9.6% unemployed among controls may have actually been lower if we had fielded a more representative population sample of controls). This may have reduced the true association between unemployment and self-inflicted gun injury, which would have been higher. Therefore, if we assume that unemployment was underadjusted for as a positive confounder (i.e., its inclusion in our models correctly inflated, but not enough, the unadjusted odds ratio estimate between alcohol and self-inflicted gun injury), then our reported results are, if anything, underestimates of the relation between alcohol and self-inflicted gun injury and our final interpretations are likely conservative but should remain unchanged.

It is also worth noting that our findings are possibly not generalizable to nonurban areas whose gun injury risks can be significantly different than those of urban centers such as Philadelphia (Branas, Nance et al., 2004). Certain other variables that may have confounded the association between acute alcohol consumption, alcohol outlets, and intentionally self-inflicted gun injury may have been omitted in our analysis. These omitted confounders noticeably included depression and other psychopathologies, for which we were not able to collect data. Given that this was not a randomized trial, the possibility of bias from unmeasured confounding, inherent in all observational study designs (including the case–control design), was present. We have endeavored to control for this bias by carefully selecting and including numerous confounding variables. Even with the possibility of unmeasured confounding however, the case–control design used here improves upon prior ecological study designs that infer individual-level risks from aggregations of individuals (and thus potentially experience greater unmeasured confounding).

We did not enroll non-gun suicides and cannot judge the associations between acute alcohol consumption, alcohol outlets, and the risks of intentionally self-inflicted injury with a gun compared with other means. Although these would have been useful comparisons to make, collection of non-gun intentionally self-inflicted injury information was not pursued because it was seen as a considerably more challenging data collection endeavor given that shootings were much better defined and monitored by the police and medical systems in Philadelphia.

Finally, we did not account for the potential of reverse causation between alcohol and intentionally self-inflicted injury. This may have posed a problem in that people who were at risk of intentionally self-inflicted gun injury may have also consumed alcohol or been in proximity to alcohol outlets because of their pre-existing risk. Although the list of confounders we included may have served to reduce some of the problems posed by reverse causation, future case–control studies might consider instrumental variables techniques to explore the effects of reverse causation.

CONCLUSION

This study finds that the gun suicide risk to individuals who are in areas of high alcohol outlet availability is less than the gun suicide risk they incur from acute alcohol consumption, especially to excess. Although off-premise alcohol outlet availability did not appear to be statistically associated with a significantly higher risk of intentionally self-inflicted gun injury and gun suicide, being in an area of high on-premise alcohol outlet availability was associated with a lower risk of gun suicide of borderline statistical significance. The current study not only corroborates some aspects of prior ecological work but also uncovers new information about the relationships between acute alcohol consumption, alcohol outlets, and intentionally self-inflicted gun injury. Cities should consider addressing alcohol-related factors as modifiable and politically feasible approaches to reducing intentionally self-inflicted gun injury and gun suicide.

Acknowledgments

Biographies

Charles C. Branas, Ph.D., is an Associate Professor of Epidemiology and the Director of the Cartographic Modeling Laboratory at the University of Pennsylvania. He has also held numerous other university appointments, including as a former Penn fellow at the University Office of the Provost. Dr. Branas works to improve health and healthcare, and is recognized for his efforts to reduce violence and enhance emergency care. Much of his work incorporates human geography and spatial interactions. His studies have taken him to various places, including the neighborhoods of Philadelphia, rural counties across the US, and most recently, cities and small towns in Guatemala. Dr. Branas sits on various boards and scientific panels at the National Institutes of Health, the Centers for Disease Control, the American Trauma Society, and the American Public Health Association, and is a past president of the Society for Advancement of Violence and Injury Research.

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Thomas R. Ten Have, Ph.D., MPH, was a Professor of Biostatistics at the University of Pennsylvania. Dr. Ten Have passed away in May 2011 and will be greatly missed by his colleagues and many mentees. Dr. Ten Have's research interests represented the intersection of causal statistical methods and behavioral interventions. He collaborated on trials involving the prevention of suicide; the treatment of substance abuse, anxiety, and depression; and the disparities in screening and treatment of mental health disorders in colored participants. The eldest son of missionaries, he was raised in Korea, Malaysia, and Nepal, before his family moved to Michigan. Dr. Ten Have focused on accounting and algebra in junior college, prior to entering the undergraduate business program at the University of Michigan in Ann Arbor. Of the entire business curriculum, he found himself most interested in data analysis and management. A serendipitous perusal of a pamphlet on statistics that he found in the university counseling office changed the course of his career. He received his MPH and Ph.D. in biostatistics at the University of Michigan and became an associate professor at the Center for Biostatistics and Epidemiology at Pennsylvania State University. In 1997, Dr. Ten Have joined the University of Pennsylvania. In addition to his world-class research and teaching, Dr. Ten Have served as a member of the American Statistical Association, the Institute of Mathematical Statistics, the International Biometrics Society, the Society for Epidemiological Research, and the American Public Health Association. In 1999, he was named a fellow of the American Statistical Association.

Douglas J. Wiebe, Ph.D., is an Assistant Professor at the Department of Biostatistics and Epidemiology at the University of Pennsylvania. He holds secondary appointments in the Department of Emergency Medicine and in the Department of Surgery/Division of Trauma at the University of Pennsylvania, and is a visiting scholar at the Department of Geography at the University of Cambridge, England. Dr. Wiebe's research addresses environmental risk factors for injury and disease, the impact of daily routines on health-related behavior, and the collection and modeling of data with both spatial and temporal components. He serves on study sections for the National Institutes of Health, the National Science Foundation, and the Social Science and Humanities Research Council of Canada.

GLOSSARY

Case–control study	It is a type of epidemiological observational study in which persons with a disease (or other outcome variable) of interest and a control group of persons from a defined target population without the disease are selected for comparison in terms of factors to which they were exposed.
Suicide	The act of intentionally taking one's own life or, alternatively, death caused by self-directed injurious behavior (Goldsmith, Pellmar, Kleinman, & Bunney, 2002).
Suicide attempt	A non fatal, self-directed, potentially injurious behavior with any intent to die as a result of the behavior. A suicide attempt may or may not result in injury (Goldsmith, Pellmar, Kleinman, & Bunney, 2002).

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TABLE 1

Unadjusted analyses of cases and controls in terms of situational and individual characteristics

| | | All intentionally self-inflicted gun injuries | | Gun suicides | |
		Cases	Controls	Cases	Controls
Situational characteristics	*Acute alcohol consumption* (%)				
	None	69.1	89.1	69.0	90.9
	Nonexcessive	12.2	10.6	11.1	8.7
	Excessive	18.8	0.3	19.9	0.3
	Alcohol outlet availability (%)				
	Low	54.7	47.7	54.1	47.7
	High	45.3	52.3	45.9	52.3
	Low on-premise	54.1	48.1	54.1	48.0
	High on-premise	45.9	52.0	45.9	52.0
	Low off-premise	48.7	51.6	47.3	50.9
	High off-premise	51.4	48.4	52.7	49.1
	Being outdoors (%)	16.2	5.8	15.8	5.9
	Surrounding area				
	Blacks (mean: 1,000 people/mile)	12.8	15.8	12.5	15.6
	Hispanics (mean: 1,000 people/mile)	2.9	3.7	3.1	3.6
	Unemployment (mean: 1,000 people/mile)	1.6	1.7	1.7	1.7
	Income (mean: million dollars/mile)	602.4	656.3	611.5	649.4
	College educated (mean: 1,000 people/mile)	2.9	3.5	3.0	3.4
Individual characteristics	Age (mean, years)	48.1	47.5	48.5	47.9
	Black (%)	37.8	37.4	36.3	36.6
	Male (%)	87.2	86.4	87.7	86.9
	Hispanic (%)	6.9	3.3	6.9	3.0
	Unemployed (%)	13.4	9.6	14.0	9.2
	Education (mean, yrs)	12.0	12.7	12.0	12.7
	Married or with a partner (%)	36.3	59.7	33.4	60.5

TABLE 2

Regression-adjusted analyses of the associations between acute alcohol consumption, alcohol outlet availability, and intentionally self-inflicted gun injury

		All intentionally self-inflicted gun injuries	Gun suicides
Acute alcohol consumption	None	1.00	1.00
	Any	4.23 [2.25–7.98]***	5.94 [2.91–12.14]***
	None	1.00	1.00
	Non-excessive	1.83 [0.81–4.13]	2.54 [1.07–6.00]**
	Excessive	77.11 [8.76–678.38]***	85.75 [10.04–732.27]***
Alcohol outlet availability	Low	1.00	1.00
	High	0.77 [0.44–1.27]	0.62 [0.36–1.07]*
	Low on-premise	1.00	1.00
	High on-premise	0.76 [0.44–1.31]	0.62 [0.36–1.07]*
	Low off-premise	1.00	1.00
	High off-premise	1.57 [0.84–2.92]	1.33 [0.70–2.56]

Note: Models adjusted for all characteristics listed in Table 1. Adjusted odds ratios and 95% confidence intervals (in square brackets), with *p*-values indicated as

*
 p < .10,

**
  p < .05, and

***
  p < .01.