ADDICTION
SSA SOCIETY FOR THE STUDY OF ADDICTION
RESEARCH REPORT
doi:10.1111/add.13637

A momentary exposures analysis of proximity to alcohol outlets and risk for assault

Christopher N. Morrison[1,2], Beidi Dong[1], Charles C. Branas[1], Therese S. Richmond[3] & Douglas J. Wiebe[1]

Department of Biostatistics and Epidemiology, Perelman School of Medicine, Penn Injury Science Center, University of Pennsylvania, Philadelphia, PA, USA,[1] Department of Epidemiology and Preventive Medicine, Monash University, Melbourne, VIC, Australia[2] and Department of Biobehavioral Health Sciences, School of Nursing, Penn Injury Science Center, University of Pennsylvania, Philadelphia, PA, USA[3]

ABSTRACT

Aims This study estimated, with high spatial and temporal specificity, individuals' risk of being assaulted relative to their momentary proximity to alcohol outlets during daily activities. **Design** Case–control study. **Setting** Philadelphia, PA, USA. **Participants** Cases were 194 non-gun assault victims and 135 gun assault victims aged between 10 and 24 years. Age-matched controls (n = 274) were selected using random-digit dialing. **Measurements** Participants described minute-by-minute movements (i.e. activity paths) during the course of the day of the assault (cases) or a recent randomly selected day within 3 days of interview (controls). The dependent measure was being an assault case compared with a non-assault control. The main independent measures were participants' momentary proximity to alcohol outlets. The units of analysis were 10-minute segments beginning at 4:00 a.m. **Findings** Proximity to bars and restaurants was associated with decreased odds of non-gun assault before 1 p.m. [e.g. 7 a.m. to 9:59 a.m.: odds ratio (OR) = 0.78; 95% confidence interval (CI) = 0.64, 0.94; P = 0.008], and increased odds after 7 p.m. (e.g. 1 a.m. to 3:59 a.m.: OR = 1.96; 95% CI = 1.24, 3.09; P = 0.004). Proximity to beer stores was associated with increased odds before 1 p.m. (e.g. 7 a.m. to 9:59 a.m.: OR = 2.34; 95% CI = 1.58, 3.46; $P < 0.001$) and from 4 p.m. to 6:59 p.m. (OR = 1.50; 95% CI = 1.14, 1.96; P = 0.004), but decreased odds after 7 p.m. (e.g. 1 a.m. to 3:59 a.m.: OR = 0.28; 95% CI = 0.12, 0.63; P = 0.002). Proximity to alcohol outlets was mostly unrelated to risks for gun assault. **Conclusions** Individuals in areas with greater densities of bars and restaurants and beer stores appear to be at increased risk for non-gun assault at times when these outlets are likely to be patronized most heavily.

Keywords Alcohol outlets, assault, case–control, firearm, gun, individual, outlet density, violence.

Correspondence to: Christopher N. Morrison, Department of Biostatistics and Epidemiology, Perelman School of Medicine, Penn Injury Science Center, University of Pennsylvania, Blockley Hall, 423 Guardian Drive, Philadelphia, PA 19104, USA. E-mail: cneil@mail.med.upenn.edu
Submitted 14 March 2016; initial review completed 15 June 2016; final version accepted 27 September 2016

INTRODUCTION

Ecological studies suggest that assaults occur with greater frequency in areas with greater concentrations of alcohol outlets [1,2]. Evidence is available across geographical locations, at different spatial scales and in both cross-sectional and longitudinal studies [3–7], and results are consistent with theories regarding the physical availability of alcohol, its consumption, and related problems within populations [8–10]. Collectively, these studies support the strong claim that reducing aggregate densities of alcohol outlets will reduce aggregate incidence of assault in populations [11].

Whether these ecological relationships apply to individuals is unclear. Very few studies assess individuals' risks of being assaulted relative to local densities of alcohol outlets (i.e. their 'physical exposure' to alcohol outlets). Those that are available provide mixed results [12–15]. There are clear methodological and theoretical explanations for these inconclusive findings. First, imprecise assessment of physical exposure (e.g. counts of outlets within distance buffers around participants' homes) may lead to measurement error. Secondly, routine activities theory [16] suggests that most criminal acts require convergence in space and time of motivated offenders, suitable targets and the absence of capable guardians [16]. Because human activity is constrained by biological and social factors, relative densities of offenders, victims and guardians are likely to vary over time at specific places [17]. Thus, individuals' risk

of being assaulted relative to local alcohol outlet density may not be uniform throughout the day. To address these key methodological and theoretical limitations, this study assesses whether individuals are at increased risk of being assaulted when they are located physically in areas with more alcohol outlets, and whether risks differ by time of day.

Individual-level studies

Three systematic reviews [1,2,18] identify very few individual-level studies that relate alcohol outlets to assault risk. Two studies [13,14] describe cross-sectional analyses of survey data in which physical exposure to alcohol outlets was calculated by combining the spatial locations of participants' homes with spatial locations of alcohol outlets. Using data from a sample of residents aged 18–65 years from Los Angeles and Southern Louisiana, Theall *et al.* [13] calculated the count of outlets within a 1-mile buffer of respondents' homes and the distance to the nearest outlet. Experiencing violence (defined as hearing or witnessing violence or being assaulted) was related positively to off-premise outlet counts, but all-cause injury risk was not. Similarly, using data from a telephone survey of residents aged ≥ 18 years in two states, Treno *et al.* [14] found counts of both on- and off-premise outlets within a 2-km buffer around respondents' residences were related to all-cause injury risk.

Other studies have used similar approaches to relate alcohol outlet density to outcomes other than assault, including alcohol-related aggression [19], driving after drinking [20], alcohol consumption, e.g. [21–23] and mortality [24]. For example, in a multi-level cross-sectional analysis of students from eight colleges, Weitzman *et al.* [25] found that on-campus residence at a college with greater proximity to alcohol outlets was associated with more problems related to students' drinking. Nevertheless, these studies of individuals may be affected by measurement error. Because people move routinely through space over time, static measures such as the number of alcohol outlets around a person's home may not reflect their actual physical exposure to outlets [26,27].

Advances in study methods

In recent years, there have been substantial advances in methods used to assess physical exposure to neighborhood features in the areas where study participants spend time (known as 'activity spaces') [28]. Using survey methods [29–35] or Global Positioning Tracking (GPS) tracking [36,37] to approximate participants' routine movements, physical exposures are measured within polygons that capture each person's unique activity space. This approach provides greater spatial specificity compared to measures based on home location alone [36,37].

Two individual-level studies from our group have used a variant of activity spaces ('activity paths') to examine relationships between assault risks and physical exposure to alcohol outlets with high spatial and temporal specificity. The first [12] was a case–control study of adults comparing the neighborhoods in which cases were assaulted with a gun to the neighborhoods in which controls were located at the same time of day. Aggregated over the course of the day, risks for gun violence were higher when participants were located in areas with more off-premise outlets. The second [15] combined interviewer prompts with live electronic data collection using a Geographic Information System (GIS) to capture the activity paths of adolescents and young adults over a single day. The study was both a case–control and a case-cross-over study of non-gun and gun assaults, comparing both momentary proximity to alcohol outlets and other neighborhood features between cases and controls (case–control) and within cases (case-cross-over). Aggregated over the course of the day, there was no detectable association between assault risk and momentary proximity to alcohol outlets (i.e. combining on-premise, off-premise outlets and other neighborhood features in a factor scale).

Study aims

The aim of this study was to assess whether and how physical exposure to alcohol outlets (time spent nearby alcohol outlets) is related to assault risk for individuals, and whether relationships differed across times of day. To do so we conducted a secondary analysis of data from our GIS-assisted case–control study [15]. Guided by routine activities theory, we hypothesized that individuals' risk of being assaulted would be greatest when they were in greater proximity to alcohol outlets at times when the outlets were patronized most heavily and would be most likely to attract or generate motivated offenders (e.g. at night for bars and restaurants) [38].

METHODS

Study design

The Space–Time Adolescent Risk Study (STARS) was a case–control study conducted among young people aged 10–24 years in Philadelphia, PA, USA.

Study sample

Eligible cases were patients aged 10–24 presenting to the emergency departments of the Hospital of the University of Pennsylvania or the Children's Hospital of Philadelphia for treatment of a non-gun assault ($n = 194$) or gun assault

(n = 135) injury. Eligible non-gun assaults were patients admitted for treatment of a traumatic injury which they self-reported was inflicted intentionally by another person with or without a non-gun weapon; gun assaults were patients admitted for treatment of a traumatic injury which they self-reported was inflicted by another person with a gun. Age-matched controls (n = 274) were selected using random-digit dialing among residents of the 12 ZIP-code catchment area for the hospitals (response rate: 57.1%). The required sample size for this study was calculated for analyses examining aggregate relationships between assault risk and physical exposure to all alcohol outlets over participants' entire days. Because this secondary analysis disaggregates by time of day and alcohol outlet type, results may be biased towards null.

Data collection

The materials and methods for STARS have been described in detail previously [15]. Briefly, a trained interviewer administered a GIS-assisted survey to cases and controls in the hospital, at the research office or in participants' homes. The survey assessed demographics, general health and perceptions of their residential neighborhood. Participants described chronologically their minute-by-minute locations and activities for the day of the assault (cases) or a randomly selected day from among the 3 days prior to the interview (controls). Interviewers sat side-by-side with participants while looking at a shared computer screen. Data were entered into a custom GIS-based software package that collected the latitude and longitude coordinates and time of participants' movements. For each point in time at which their activities or location changed, participants described their current activities (free text), whether an adult family member was present (dichotomous), whether a peer was present (dichotomous), mode of transport (on foot, in vehicle, or other) and whether they were in possession of alcohol (dichotomous). We also identified weekend hours (from sunset on Friday to 11:59 p.m. Sunday) and times when participants were at home.

Measures of proximity to alcohol outlets

For the current study, we divided each participant's 1-day data into 10-minute segments beginning at 4:00 a.m. (e.g. 4:00–4:09 a.m.). The latitude and longitude at the start of each segment described participants' geographical locations for the following 10 minutes (Fig. 1a). In total, there were 10 808 segments for the non-gun cases, 8989 segments for the gun assault cases and 24 077 segments for the controls. We then estimated spatially and temporally specific proximity to alcohol outlets and other neighborhood features for each segment.

The main independent variable was proximity to alcohol outlets. The Pennsylvania Liquor Control Board issues three classes of retail alcohol license relevant to this study. Restaurant licenses permit beer, wine and liquor sales for on-premise consumption (hereafter, 'bars and restaurants'). Eating-place licenses permit the sale of beer for on-premise consumption with a meal and for off-premise consumption, provided that sales are not in single containers ('beer stores'). Off-premise sales of wine and liquor are limited to government monopoly off-premise outlets located throughout the state ('liquor stores'). To construct raster layers describing continuous densities of the city's 427 bars and restaurants, 1056 beer stores and 634 liquor stores, we smoothed these data spatially using kernel density estimation (Fig. 1b,c,d). We then joined these raster data spatially to the points representing the beginning of each 10-minute segment. Given the high spatial precision of our data, we considered this a better approach than taking values aggregated within arbitrary administrative units (e.g. Census block groups). The three resulting variables describing proximity to alcohol outlets were heavily positively skewed ($0.89 \leq$ skewness ≤ 6.25). We calculated their natural logarithm to reduce the likelihood that the extreme high values would influence results inordinately.

Other independent measures

We collected key demographic characteristics and behavioral indicators that could be related both to participants' physical exposure to alcohol outlets and to risk for assault, and may therefore confound relationships (e.g. whether they had ever carried a gun).

Neighborhood characteristics may also be related both to assault risk and to alcohol outlet density. Data to describe 26 neighborhood characteristics were obtained from four sources:

- Census 2010 data described demographic characteristics for the local resident population within Census block groups;
- tax parcel data from Philadelphia described land use;
- the 2008 Southeastern Pennsylvania Household Survey [39] described local population characteristics;
- and participant responses described perceptions of local areas.

Similar to the approach for alcohol outlets, these spatially referenced data were converted to raster layers using kernel density estimation for point data and inverse distance weighting based on the centroids of polygon data. In a factor analysis, 23 characteristics loaded onto five factors: (i) neighborhood connectedness, (ii) income, (iii) vacancy, vandalism, violence, (iv) emergency services and (v) race/ethnicity. The composition of these scales is described

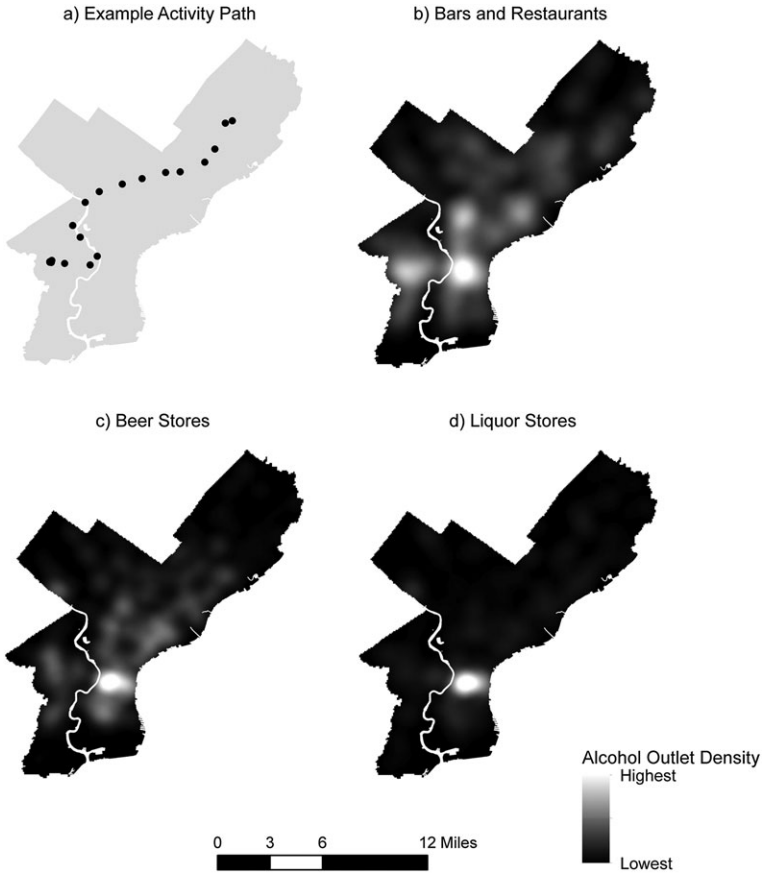

Figure 1 Spatial data management

in a previous paper [15]. The three variables not captured in the factor scales but included as independent variables in the current analysis were commercial land use (to account for the possibility that alcohol outlets mark for physical exposure to retail areas), population density (possibly representing guardianship) and the density of middle/high schools (also representing guardianship).

Statistical analyses

The units of analysis were the ten-minute segments nested within eight uniformly defined 3-hour time phases (e.g. 4 a.m.–6:59 a.m.). Two conditional logistic regression models estimated the (i) overall odds of non-gun assault compared to controls or (ii) the overall odds of gun assault compared to controls. Both models included a fixed-effect for the time phase, such that exposures for cases were compared to controls within the same 3-hour period. This approach controlled partially for the possibility that segments were autocorrelated within participants. All independent variables describing physical exposure to alcohol outlets, neighborhood conditions and other behavioral and temporal characteristics were included in both models. Analyses included all segments for the controls, but only the final observation before the assault for cases. Gun assault cases were dropped from the non-gun assault model, and non-gun cases were dropped from the gun assault model. This procedure produced an overall estimate (i.e. aggregated over the whole day) of the odds ratio and 95% confidence interval for non-gun and gun assault per unit increase in physical exposure to alcohol outlets.

We then conducted separate logistic regression models within each time phase, dropping cases whose assault event occurred outside the 3-hour window. We thus produced time-of-day specific estimates for the relationships between proximity to alcohol outlets and the odds of assault. Given that proximity to alcohol outlets was calculated from the kernel density estimate then log-transformed, individual parameter estimates are not easily interpretable, but the direction of the association and comparison within outlet types across day phases is informative.

Spatial data management was performed using ArcGIS version 10.1 [40]. Parameters for the regression models were estimated using Stata version 14 [41].

Specification tests

We conducted several specification tests to reduce the likelihood that observed relationships were artefacts of model construction. First, after comparing individual-level participant characteristics for cases versus controls using Student's *t*-test for continuous measures and χ^2 tests for

categorical measures, we adjusted our main-effects analyses for variables where the groups differed systematically. Secondly, a correlation matrix for the logged alcohol outlet variables demonstrates that these measures were moderately collinear (Table 1). After removing systematically one and then two of the alcohol outlet variables, we repeated the conditional logistic regression and the logistic regression models. Finally, we then tested alternate time-phases (e.g. 2-hour periods, 4-hour periods), and stratified the analyses further by age ($<$ or ≥ 18).

RESULTS

Participant characteristics are presented in Table 2. Non-gun and gun cases were systematically different compared to controls based on age, sex, race/ethnicity and some indicators of risk (e.g. 28.2% gun assault cases had ever carried a gun versus 16.0% controls).

Counts of non-gun and gun assaults within time phases are presented in Table 3. The low incidence (≤ 2 cases) of gun assaults during the 7 a.m.–10:59 a.m. phase and of both assault types during the 4 a.m.–6:59 a.m. phase prevented estimation of relationships during these periods. Results of the conditional logistic regression models are presented in Table 4. Greater liquor store density was related to increased odds of non-gun assault. There was no relationship for bars and restaurants or for beer stores. Being in an area with lower neighborhood connectedness, higher income and more vacancy, vandalism and violence was associated with increased odds of non-gun assault. Being on foot, away from home, possessing alcohol and being younger were also related to increased odds. By contrast, the gun assault analysis shows a negative relationship with greater proximity to liquor stores. There was no association for bars and restaurants or beer stores.

Figure 2 shows the odds ratios and 95% confidence intervals for the associations between non-gun and gun assaults and densities of bars and restaurants, beer stores and liquor stores (adjusted for the same covariates as the overall analyses). Results are presented within the 3-hour time strata. From 7 a.m. to 12:59 p.m., greater proximity to bars was associated with decreased odds of non-gun assault (e.g. 7 a.m. to 9:59 a.m.: odds ratio (OR) = 0.78; 95% confidence interval (CI) = 0.64, 0.94; $P = 0.008$). From 1 p.m. to 6:59 p.m. there was no association, but from 7 p.m. to 3:59 a.m., relationships were positive (e.g. 1 a.m. to 3:59 a.m.: OR = 1.96; 95% CI = 1.24, 3.09; $P = 0.004$). Point estimates increase steadily throughout the day. By comparison, the trend for the odds of non-gun assault related to proximity to beer stores was approximately reversed. Relationships were positive in the morning and early afternoon (e.g. 7 a.m. to 9:59 a.m.: OR = 2.34; 95% CI = 1.58, 3.46; $P < 0.001$), mixed between 1 p.m. and 6:59 p.m. and negative thereafter (e.g. 1 a.m. to 3:59 a.m.: OR = 0.28; 95% CI = 0.12, 0.63; $P = 0.002$). Proximity to liquor stores was related positively to non-gun assault only between 10 p.m. and 12:59 a.m (e.g. OR = 1.60; 95% CI = 1.13, 2.27; $P = 0.008$). As in the overall analysis, proximity to alcohol outlets was mostly unrelated to gun assaults within time strata, with a few isolated exceptions (e.g. relationships were positive for bars and restaurants between 4 p.m. and 6:59 p.m.; OR = 2.43; 95% CI = 1.57, 3.77; $P < 0.001$).

Results of the specification tests were substantively similar to the results of the main-effects models reported here. Adjusting for the individual-level variables on which cases were systematically different from controls (Table 2) did not materially affect results.

DISCUSSION

This study provides evidence that increased risk for non-gun assault is specific to the time and place of physical exposure to alcohol outlets for adolescents and young adults, and that relationships differ by time of day. Being in a neighborhood with a greater concentration of bars and restaurants was associated with increased assault risk in evening and night-time hours (after 7 p.m.), peaking between 1 a.m. and 3:59 a.m., whereas being in a neighborhood with greater concentration of beer stores was associated with increased assault risk during daytime hours (7 a.m.–12:59 p.m. and 4 p.m.–6:59 pm). Proximity to alcohol outlets was mainly unrelated to risks for gun assaults.

The findings for non-gun assaults are consistent with our expectations based on routine activities theory [16]. The times of day at which study participants (representing suitable targets) were exposed to more bars and restaurants and were at greatest risk for assault corresponds with the peak times for these establishments (i.e. most probably their busiest times and patron intoxication at its greatest). Alcohol consumption is related to increased aggression [42], and people who exhibit more aggression and hostility

Table 1 Correlation between alcohol outlet exposure variables (natural logarithm) for 10-minute segments.

	ln (bars and restaurants)	*ln (beer stores)*	*ln (liquor stores)*
ln(bars and restaurants)	1.000		
ln(beer stores)	0.565	1.000	
ln(liquor stores)	0.272	0.387	1.000

Table 2 Participant characteristics.

	Non-gun assaults (n = 194)	*Gun assaults (n = 135)*	*Controls (n = 274)*
Age [mean (SD)]	15.9 [0.3]*	19.5 [0.3]*	17.8 [0.2]
Male	175 (90.2)*	123 (91.1)*	274 (100.0)
Race/ethnicity			
Black (%)	170 (87.6)*	122 (90.4)*	268 (97.8)
White (%)	15 (7.7)*	1 (0.7)*	3 (1.1)
Hispanic (%)	3 (1.6)*	1 (0.7)*	0 (0.0)
Grades received in school			
As and Bs	93 (48)	43 (34.1)	123 (45.1)
Bs and Cs	106 (56.0)	78 (61.9)	153 (56.0)
Cs and Ds	32 (25.4)	32 (25.4)	58 (21.3)
Ds and Fs	12 (6.2)	10 (7.9)	19 (7.0)
Wear seatbelt most of time or always (%)			
Never	19 (9.8)	21 (16.7)	33 (12.1)
Rarely	19 (10.0)	22 (17.5)	34 (12.5)
Sometimes	64 (33.0)	46 (36.5)	90 (33.1)
Most of the time	32 (16.5)	18 (14.3)	52 (19.1)
Always	60 (31.0)	19 (15.1)	63 (23.2)
Ever choose path based on safety (%)	80 (75.5)	69 (71.1)	120 (74.1)
Change direction because route seems unsafe (%)	*		
Daily	65 (34.0)	40 (32.5)	95 (35.2)
Weekly	33 (17.3)	29 (23.6)	74 (27.4)
Monthly	45 (23.6)	23 (18.7)	53 (19.6)
Never	48 (17. 8)	31 (25.2)	48 (17.8)
Ever been jumped (%)	137 (71.0)	69 (55.2)	154 (56.4)
Ever in fistfight (%)	184 (95.3)	118 (93.7)	250 (91.6)
Know someone in jail or prison (%)	88 (83.8)	83 (84.7)	140 (87.5)
Ever been in jail or prison (%)	13 (37.1)	41 (53.3)*	26 (29.2)
Ever been on juvenile probation (%)	40 (20.7)	67 (53.2)*	48 (17.6)
Ever been shot (%)	7 (3.6)	20 (15.8)*	11 (4.0)
Ever carried a weapon (%)	50 (25.8)	60 (47.6)	107 (39.2)
Ever carried a gun (%)	19 (9.8)	38 (28.1)*	44 (16.0)
Could get a gun (%)	69 (35.9)*	66 (53.2)	158 (58.3)
Drank alcohol in past 30 days (%)	39 (20.1)*	46 (36.5)	90 (33.6)
Smoked marijuana in past 30 days (%)	35 (18.1)	50 (39.7)*	62 (23.2)
Ever sold drugs (%)	30 (15.7)	33 (26.4)*	45 (16.5)
Neighborhood environment scale [mean (SD)]	0.52 [0.2]	0.51 [0.2]	0.49 [0.2]
Things I have seen and heard scale [mean (SD)]	0.48 [0.2]	0.59 [0.2]*	0.51 [0.2]
Generalized self-efficacy [mean (SD)]	0.80 [0.1]*	0.84 [0.1]	0.84 [0.1]

*Characteristics for cases differ compared to controls, $P < 0.05$, assessed using Student's *t*-test for continuous measures, and χ^2 tests for trend for categorical measures. Characteristics for this sample reported previously in Wiebe *et al*. [15]. SD = standard deviation.

Table 3 Time of day at which assault events occurred.

Event time	*Non-gun assaults*	*Gun assaults*
7 a.m.–9:59 a.m.	21	2
10 a.m.–12:59 p.m.	21	10
1 p.m.–3:59 p.m.	52	11
4 p.m.–6:59 p.m.	31	19
7 p.m.–9:59 p.m.	32	41
10 p.m.–12:59 a.m.	22	37
1 a.m. – 3:59 a.m.	15	14
4 a.m.–6:59 a.m.	0	1
Total	194	135

prefer to drink in bars [19,43]; therefore, it is possible that during later hours, bars and restaurants may either generate violence, attract people more likely to perpetrate violence or both [44,45]. Either mechanism will lead to the presence of more motivated offenders in the local area. Finally, there may be fewer capable guardians later at night [16,46]. Thus, the three theoretical conditions for producing increased risks for assault are met.

Similarly, beer stores are more active during the day, operating typically between 9 a.m. and approximately 7 p.m.–10 p.m. in Philadelphia [17]. Meetings between suitable targets and motivated offenders proximate to these outlets are therefore more likely during daytime hours. The

Table 4 Conditional logistic regression model for odds of being assaulted (10-minute segments nested within 3-hour time of day phases).

	Non-gun assaults			*Gun assaults*		
	OR	*(95%CI)*	*P-value*	*OR*	*(95%CI)*	*P-value*
Alcohol outlets						
Restaurant licenses (ln)	1.103	(0.985, 1.236)	0.090	1.105	(0.978, 1.249)	0.109
Beer stores (ln)	0.966	(0.750, 1.243)	0.786	0.959	(0.774, 1.189)	0.705
Liquor stores (ln)	**1.136**	**(1.103, 1.170)**	**<0.001**	**0.723**	**(0.622, 0.841)**	**<0.001**
Neighborhood characteristics						
Neighborhood connectedness (factor scale)	**0.826**	**(0.726, 0.939)**	**0.004**	**0.741**	**(0.699, 0.786)**	**<0.001**
Income (factor scale)	**1.197**	**(1.040, 1.378)**	**0.012**	1.095	(0.815, 1.469)	0.548
Vacancy, vandalism, violence (factor scale)	**1.672**	**(1.318, 2.122)**	**<0.001**	**2.644**	**(1.681, 4.160)**	**<0.001**
Emergency services (factor scale)	1.013	(0.680, 1.510)	0.949	**1.217**	**(1.108, 1.336)**	**<0.001**
Race/ethnicity (factor scale)	1.142	(0.982, 1.328)	0.085	**0.856**	**(0.743, 0.988)**	**0.033**
Commercial zone (Z-score)	0.862	(0.701, 1.060)	0.160	0.864	(0.627, 1.189)	0.369
Population density (Z-score)	0.963	(0.746, 1.244)	0.772	0.885	(0.741, 1.057)	0.177
School density (Z-score)	0.977	(0.753, 1.267)	0.860	0.910	(0.691, 1.200)	0.506
Individual and momentary characteristics						
Age (1-year increase)	**0.794**	**(0.705, 0.895)**	**<0.001**	**1.124**	**(1.080, 1.170)**	**<0.001**
Weekend	0.718	(0.277, 1.859)	0.495	0.972	(0.603, 1.566)	0.907
At home	**0.345**	**(0.222, 0.535)**	**<0.001**	**0.546**	**(0.347, 0.860)**	**0.009**
With adult family member	1.127	(0.647, 1.965)	0.673	1.261	(0.558, 2.852)	0.577
With peer	0.873	(0.456, 1.669)	0.680	1.251	(0.702, 2.232)	0.447
In vehicle (ref)						
On foot	**4.613**	**(2.222, 9.575)**	**<0.001**	**17.913**	**(5.593, 57.378)**	**<0.001**
Other transport	1.359	(0.428, 4.308)	0.603	**7.153**	**(2.885, 17.736)**	**<0.001**
Possess alcohol	**2.898**	**(1.365, 6.152)**	**0.006**	0.592	(0.211, 1.658)	0.318

Bolded estimates are significant at $P < 0.05$.

reduced odds of assault while near bars in the morning and beer stores at night may be due to fewer motivated offenders near these establishments when they are closed [12]. The potentially attractive or generative effects of government liquor stores for motivated offenders may be mitigated by real or perceived increased guardianship. The mainly null findings for gun assaults suggest that proximity to alcohol outlets is not a major contributor to these comparatively rare and potentially more serious events among adolescents and young adults.

Our results may explain the mixed findings reported in previous individual-level studies, including our own. Prior survey studies used relatively imprecise measures of physical exposure to alcohol outlets [13,14]. Our own previous analyses estimated overall relationships between momentary proximity to outlets and assault risk aggregated across times of day or included alcohol outlets in a composite measure with additional neighborhood variables [12,15]. We also previously used non-comparable samples (adults versus adolescents and young adults). In contrast, the approach we took to the current analysis enabled us to assess relationships with high spatial and temporal specificity across different times of day. Disentangling relationships between individuals who move through time and space and outlets that attract or generate different risks over time may require such an approach. Comparing results of our overall analyses with results of our stratified analyses illustrates this point clearly (Fig. 2). Parameter estimates for the conditional logistic regression models aggregated out the distinct signatures evident within the time strata. In that light, results of individual-level studies that do not provide this high degree of precision should be interpreted very cautiously.

Despite the many strengths of our design, there are some limitations. First, selecting non-gun and gun assault cases within Philadelphia produced a sample of mainly black young men from lower-income areas. We were not able to examine relationships for women, older people or for people from other racial/ethnic groups. Neighborhood exposures for these groups or for people from higher-income areas may be associated with assault risk in different ways. Secondly, available alcohol outlet data enabled us to disaggregate alcohol outlets into only three types. Bars and restaurants were considered as like units, but activities and alcohol use in these establishments differ [38]; relationships to assault risk are likely to differ. Thirdly, cases and controls may not be exchangeable on all characteristics related to assault risk. Adjusting for individual-level characteristics that we knew differed between cases and controls did not materially affect our results, but some confounding from unmeasured variables may have occurred. Finally, perpetrating an assault is a very strong predictor

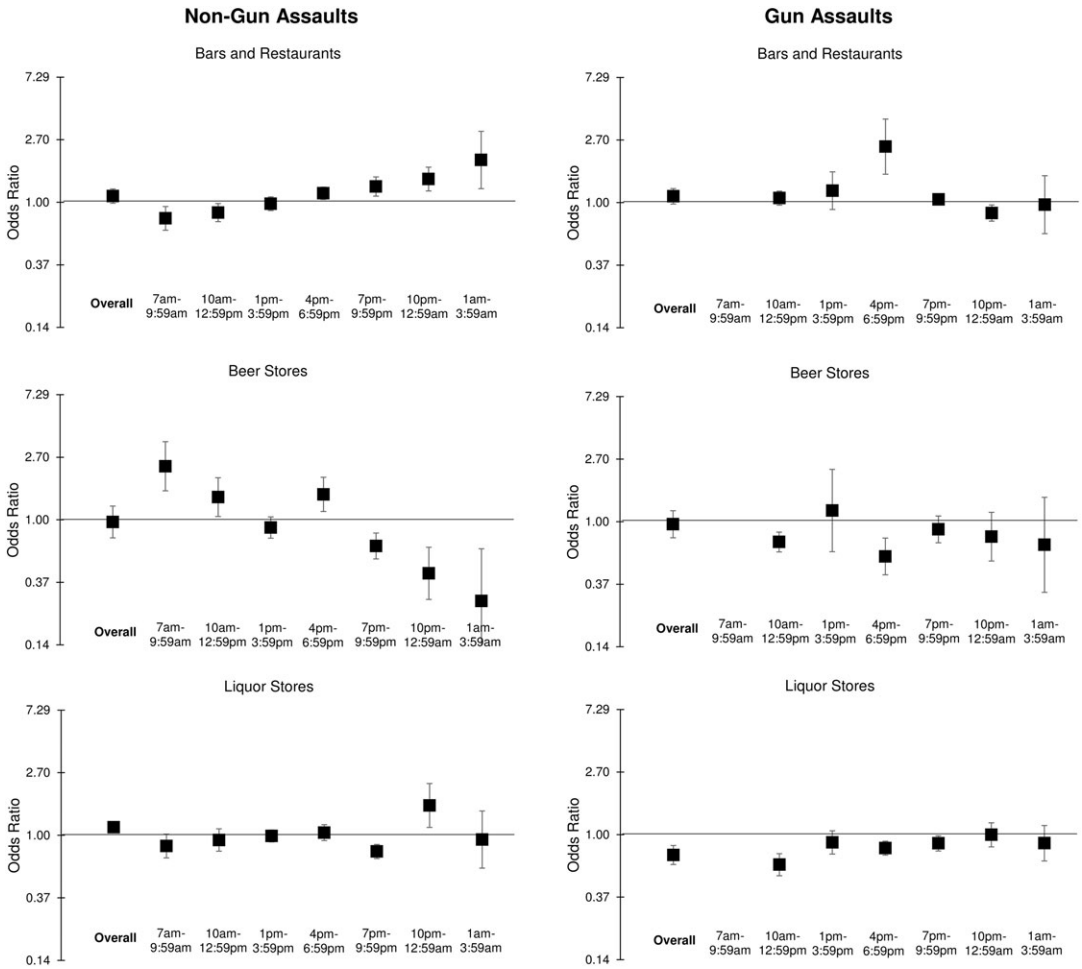

Figure 2 Parameter estimates for logistic regression models assessing odds of assault, stratified by time-of-day phases

of being assaulted [47]. If offenders were systematically more likely to be physically exposed to alcohol outlets, results may be biased.

This study represents an important advance in the collective understanding of relationships between physical exposure to alcohol outlets and assault risks for individuals. Risks for non-gun assault increase when individuals are in neighborhoods with more bars and restaurants during evening and night-time hours, and when they are in areas with more beer stores during daytime hours. These results complement the findings presented in numerous ecological studies that identify relationships between aggregate concentrations of alcohol outlets and aggregate incidence of non-gun assault [1,2], and may help to explain the mixed findings contained in the few prior individual-level studies [12–15]. Although analyses should be replicated in other geographical areas with different population groups, these findings provide evidence that avoiding areas with high outlet density at times when the outlets are most heavily patronized may decrease risks for non-gun assault for individuals. Reducing densities of alcohol outlets within neighborhoods may have similar effects.

Declaration of interests

None.

Acknowledgements

This work was supported by National Institute of Alcohol Abuse and Alcoholism (NIAAA) Research Grant R01AA014944. Dr. Morrison was supported by the Penn Injury Science Center through a grant from the National Center for Injury Control and Prevention at the Centers for Disease Control and Prevention (R49 CE002474).

References

1. Popova S., Giesbrecht N., Bekmuradov D., Patra J. Hours and days of sale and density of alcohol outlets: impacts on alcohol consumption and damage: a systematic review. *Alcohol Alcohol* 2009; **44**: 500–16.
2. Campbell C. A., Hahn R. A., Elder R., Brewer R., Chattopadhyay S., Hahn R. A. *et al.* The effectiveness of limiting alcohol outlet density as a means of reducing excessive alcohol consumption and alcohol-related harms. *Am J Prev Med* 2009; **37**: 556–69.

3. Gruenewald P. J., Remer L. Changes in outlet densities affect violence rates. *Alcohol Clin Exp Res* 2006; **30**: 1184–93.
4. Livingston M. A longitudinal analysis of alcohol outlet density and assault. *Alcohol Clin Exp Res* 2008; **32**: 1074–9.
5. Livingston M. Alcohol outlet density and assault: a spatial analysis. *Addiction* 2008; **103**: 619–28.
6. Mair C., Gruenewald P., Ponicki W., Remer L. Varying impacts of alcohol outlet densities on violent assaults: explaining differences across neighborhoods. *J Stud Alcohol Drugs* 2013; **74**: 50–8.
7. Scribner R. A., MacKinnon D. P., Dwyer J. H. The risk of assaultive violence and alcohol availability in Los Angeles County. *Am J Public Health* 1995; **85**: 335–40.
8. Gruenewald P. J. The spatial ecology of alcohol problems: niche theory and assortative drinking. *Addiction* 2007; **102**: 870–8.
9. Babor T., Caetano R., Casswell S., Edwards G., Giesbrecht N., Graham K. *et al. Alcohol: No Ordinary Commodity: Research and Public Policy*, 2nd edn. Oxford, UK: Oxford University Press; 2010.
10. Stockwell T., Gruenewald P. J. Controls on the physical availability of alcohol. In: Heather N., Stockwell T., editors. *The Essential Handbook of Treatment and Prevention of Alcohol Problems*. New York: John Wiley; 2004, pp. 213–34.
11. Anderson P., Chisholm D., Fuhr D. C. Effectiveness and cost-effectiveness of policies and programmes to reduce the harm caused by alcohol. *Lancet* 2009; **373**: 2234–46.
12. Branas C. C., Elliott M. R., Richmond T. S., Culhane D. P., Wiebe D. J. Alcohol consumption alcohol outlets and the risk of being assaulted with a gun. *Alcohol Clin Exp Res* 2009; **33**: 906–15.
13. Theall K. P., Scribner R., Cohen D., Bluthenthal R., Matthias S., Lynch S. *et al.* The neighborhood alcohol environment and alcohol-related morbidity. *Alcohol Alcohol* 2009; **44**: 491–9.
14. Treno A. J., Gruenewald P. J., Johnson F. W. Alcohol availability and injury: the role of local outlet densities. *Alcohol Clin Exp Res* 2001; **25**: 1467–71.
15. Wiebe D. J., Richmond T. S., Guo W., Allison P. D., Hollander J. E., Nance M. L. *et al.* Mapping activity patterns to quantify risk of violent assault in urban environments. *Epidemiology* 2016; **27**: 32–41.
16. Cohen L. E., Felson M. Social change and crime rate trends: a routine activity approach. *Am Sociol Rev* 1979; **44**: 588–608.
17. Haberman C. P., Ratcliffe J. H. Testing for temporally differentiated relationships among potentially criminogenic places and census block street robbery counts. *Criminology* 2015; **53**: 457–83.
18. Gmel G., Holmes J., Studer J. Are alcohol outlet densities strongly associated with alcohol-related outcomes? A critical review of recent evidence. *Drug Alcohol Rev* 2015; **35**: 40–54.
19. Treno A. J., Gruenewald P. J., Remer L. G., Johnson F., LaScala E. A. Examining multi-level relationships between bars hostility and aggression: social selection and social influence. *Addiction* 2008; **103**: 66–77.
20. Treno A. J., Grube J. W., Martin S. E. Alcohol availability as a predictor of youth drinking and driving: a hierarchical analysis of survey and archival data. *Alcohol Clin Exp Res* 2003; **27**: 835–40.
21. Scribner R., Mason K., Theall K., Simonsen N., Schnieder S. K., Towvim L. G. *et al.* The contextual role of alcohol outlet density in college drinking. *J Stud Alcohol Drugs* 2008; **69**: 112–20.
22. Scribner R. A., Cohen D. A., Fisher W. Evidence of a structural effect for alcohol outlet density: a multilevel analysis. *Alcohol Clin Exp Res* 2000; **24**: 188–95.
23. Huckle T., Huakau J., Sweetsur P., Huisman O., Casswell S. Density of alcohol outlets and teenage drinking: living in an alcogenic environment is associated with higher consumption in a metropolitan setting. *Addiction* 2008; **103**: 1614–21.
24. Spoerri A., Zwahlen M., Panczak R., Egger M., Huss A. Alcohol-selling outlets and mortality in Switzerland—the Swiss National Cohort. *Addiction* 2013; **108**: 1603–11.
25. Weitzman E. R., Folkman A., Folkman K. L., Wechsler H. The relationship of alcohol outlet density to heavy and frequent drinking and drinking-related problems among college students at eight universities. *Health Place* 2003; **9**: 1–6.
26. Kwan M. P. Gender and individual access to urban opportunities: a study using space–time measures. *Prof Geogr* 1999; **51**: 210–27.
27. Basta L. A., Richmond T. S., Wiebe D. J. Neighborhoods daily activities and measuring health risks experienced in urban environments. *Soc Sci Med* 2010; **71**: 1943–50.
28. Gesler W. M., Albert D. P. How spatial analysis can be used in medical geography. In: Albert D. P., Gesler W. M., Levergood B., Chealsea M. I., editors. *Spatial Analysis GIS and Remote Sensing Applications in the Health Sciences*. Ann Arbor, MI: Ann Arbor Press; 2000, pp. 11–38.
29. Mason M., Cheung I., Walker L. substance use social networks and the geography of urban adolescents. *Subst Use Misuse* 2004; **39**: 1751–77.
30. Mason M. J., Korpela K. Activity spaces and urban adolescent substance use and emotional health. *J Adolesc Health* 2009; **32**: 925–39.
31. Freisthler B., Thomas C. A., Curry S. R., Wolf J. P. An alternative to residential neighborhoods: an exploratory study of how activity spaces and perception of neighborhood social processes relate to maladaptive parenting. *Child Youth Care Forum* 2015; **45**: 259–77.
32. Crawford T. W., Pitts S. B. J., McGuirt J. T., Keyserling T. C., Ammerman A. S. Conceptualizing and comparing neighborhood and activity space measures for food environment research. *Health Place* 2014; **30**: 215–25.
33. Gesler W. M., Meade M. S. Locational and population factors in health care-seeking behavior in Savannah, Georgia. *Health Serv Res* 1988; **23**: 443–62.
34. Sherman J. E., Spencer J., Preisser J. S., Gesler W. M., Arcury T. A. A suite of methods for representing activity space in a healthcare accessibility study. *Int J Health Geogr* 2005; **4**: 24–24.
35. Jones M., Pebley A. R. Redefining neighborhoods using common destinations: social characteristics of activity spaces and home census tracts compared. *Demography* 2014; **51**: 727–52.
36. Lipperman-Kreda S., Morrison C., Grube J. W., Gaidus A. Youth activity spaces and daily exposure to tobacco outlets. *Health Place* 2015; **34**: 30–3.
37. Byrnes H. F., Miller B. A., Wiebe D. J., Morrison C. N., Remer L. G., Wiehe S. E. *et al.* Tracking adolescents with Global Positioning System-enabled cell phones to study contextual exposures and alcohol and marijuana use: a pilot study. *J Adolesc Health* 2015; **57**: 245–7.
38. Morrison C., Mair C. F., Lee J. P., Gruenewald P. J. Are barroom and neighborhood characteristics independently related to local-area assaults? *Alcohol Clin Exp Res* 2015; **39**: 2463–70.
39. Public Health Management Corporation. *Southeastern Pennsylvania Household Health Survey*. Philadelphia, PA: PHMC; 2008.

40. Environmental Systems Research Institute (ESRI). *ArcGIS Desktop: Release 10.1*. Redlands, CA: Environmental Systems Research Institute; 2011.
41. StataCorp. *Stata Statistical Software: Release 14*. College Station, TX: StataCorp LP; 2015.
42. Bushman B. J. Effects of alcohol on human aggression: validity of proposed explanations. *Recent Dev Alcohol* 1997; **13**: 227–43.
43. Quigley B., Leonard K., Collins R. L. Characteristics of violent bars and bar patrons. *J Stud Alcohol Drugs* 2003; **64**: 765–72.
44. Parker R. N. The effects of context on alcohol and violence. *Alcohol Health Res World* 1993; **17**: 117–22.
45. Parker R. N., Rebhum L. A. *Alcohol and Homicide: A Deadly Combination of Two American Traditions*. New York, NY: State University of New York Press; 1995.
46. Felson M., Boba R. L. *Crime and Everyday Life*, 4th edn. Thousand Oaks, CA: Sage; 2010.
47. Averdijk M., Bernasco W. Testing the situational explanation of victimization among adolescents. *J Res Crime Delinq* 2015; **52**: 151–80.