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Original quantitative research

Exploring and visualizing the small-area-level socioeconomic factors, alcohol availability and built environment influences of alcohol expenditure for the City of Toronto: a spatial analysis approach

Andrew Leung, MSc (1); Jane Law, PhD (1,2); Martin Cooke, PhD (1,3,4); Scott Leatherdale, PhD (1)

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Abstract

Introduction: Many Canadians continue to drink alcohol in excess of the recommended low-risk guidelines. In this study, we visualized the geographic variation of licensed premises alcohol expenditures in Toronto and examined the effects of area-level socioeconomic characteristics, alcohol availability and built environment influences on alcohol expenditures at the Dissemination Area (DA) level.

Methods: Dissemination Area average total household expenditures on alcohol from licensed premises, from the 2010 Survey of Household Spending, was the main outcome variable. Moran's I and Local Moran's I were used to quantify geographic variation and determine hot spots and cold spots of expenditure. We used DA-level socioeconomic characteristics from the 2006 Census of Canada, and the density of licensed premises and other built environment characteristics from the 2008 DMTI Spatial and 2010 CanMap datasets to predict alcohol expenditures in multivariate spatial regression models.

Results: The results indicated that the most significant area-level predictors of alcohol expenditure were the percentage of individuals in management or finance occupations and the percentage with postsecondary education (one-unit increases associated with 78.6% and 35.0% increases in expenditures respectively). Presence of subway lines in the immediate and neighbouring areas was also significant (one-unit increases resulted in 5% and 28% increases respectively). Alcohol outlet density was also positively associated with alcohol expenditures.

Conclusion: The associations identified between licensed premises alcohol expenditures and small-area-level characteristics highlight the potential importance of small-area-level factors in understanding alcohol use. Understanding the small-area-level characteristics of expenditures and geographic variation of alcohol expenditures may provide avenues for alcohol use reduction initiatives and policies.

Highlights

- Alcohol use exceeding low-risk drinking guidelines remains a public health problem. Small-area-level associations with alcohol expenditures have not been examined, leaving potentially significant factors affecting alcohol use unidentified.
- Understanding the geographical variation of alcohol expenditures in the city of Toronto can help provide target areas for interventions. Spatial regression models can control for geographical variation when looking for associations with small-area-level characteristics.
- This study quantified the level of geographical variation in the licensed premises alcohol expenditures and helped visualize the areas of high expenditures using maps.
- Significant positive associations were found for small-area-level socioeconomic and built environment factors.

Keywords: *small-area studies, dissemination areas, spatial analysis, spatial regressions, alcohol expenditure, alcohol use, low-risk drinking guidelines, geographic variation, GIS*

Introduction

Harmful alcohol use is recognized as one of the main modifiable behavioural risks for noncommunicable disease. Despite the negative consequences, many Canadians continue to drink in excess of the recommended low-risk guidelines, and thus may be at risk for experiencing alcohol-related harms. In Canada, alcohol use was estimated to be responsible for 8953 deaths and 172 255 potential years of life lost in 2005.[1] In 2011, the indirect and direct costs of alcohol use were estimated to be $5.3 billion for the province of Ontario.[2-4] These economic and social costs of alcohol use are projected to rise with increasing levels of consumption.[2]

Author references:
1. School of Public Health and Health Systems, University of Waterloo, Waterloo, Ontario, Canada
2. School of Planning, University of Waterloo, Waterloo, Ontario, Canada
3. School of Pharmacy, University of Waterloo, Waterloo, Ontario, Canada
4. Department of Sociology and Legal Studies, University of Waterloo, Waterloo, Ontario, Canada

Correspondence: Andrew Leung, School of Public Health and Health Systems, University of Waterloo, Waterloo, ON N2L 3G1; Tel: 647-825-2667; Email: as2leung@uwaterloo.ca

Various individual-level factors have also been related to alcohol consumption, including ethnicity, occupation, income, housing and education.[5-8] There is evidence that the physical and demographic aspects of neighbourhoods can also potentially influence alcohol use.[9,10] These neighbourhood-level factors include area-level socioeconomic factors, characteristics of the built environment and local alcohol availability.[11-16]

A number of area-level socioeconomic measures have been found to be associated with alcohol use, although the directions of the effects found are not always consistent. Cerdá and colleagues[17] found that models including a measure of deprivation provided better estimates of alcohol use compared to models that omitted measures of deprivation. Studies by Galea et al.[18] and Pollack et al.[19] found that areas with the lowest levels of neighbourhood deprivation had the highest prevalence of alcohol use. Area-level income and education inequality have also been found to be positively associated with alcohol use.[18,20]

In general, the built environment can be defined as the aspects of a physical area that are not characteristics of the people who live there but rather capture the physical resources available in the particular location.[21] Elements of the built environment that might affect alcohol consumption include the presence of public transportation[21,22] and alcohol availability, reflected by the presence of alcohol retailers, restaurants and bars.[23] Prior work has also suggested that the physical condition of buildings in a neighbourhood is a significant factor. Bernstein et al.[9] identified that rates of heavy drinking were 150% higher among individuals in neighbourhoods characterized by high levels of dilapidation, an effect that was significant in multilevel models that also included individual income and education.

A significant portion of research relating neighbourhood factors to alcohol use has used survey measures that capture alcohol consumption. Although we have self-reported alcohol consumption data collected from self-report surveys, those data potentially suffer from the typical problems of self-reported measures. Alcohol *expenditure* data, while conceptually close to consumption, have been examined less frequently and provide an alternative way of capturing alcohol use.[5,24] Expenditure data can also be obtained from self-report surveys, such as the data used in the present analysis. These data are therefore subject to the same limitations, but similar research might be done using alcohol sales data that are reported by liquor authorities as well as retailers.

The goal of our study was to examine the association between geographic and environmental influences on licensed premises alcohol expenditures for the City of Toronto. We used expenditure data on alcohol purchased in licensed premises as the main outcome variable and examined the effects of area-level socioeconomic factors, alcohol availability and built environment influences. We employed small-area-level analysis and multivariate spatial regression models to examine the associations between these area-level factors and reported alcohol expenditures, and we used geographic information systems (GIS) techniques to visualize "hot" and "cold" spots of alcohol expenditure for the City of Toronto.

Methods

Unit of analysis

The unit of analysis for the study was the Dissemination Area (DA), which is the smallest Statistics Canada geographic unit that covers all of Canada, with each DA containing 400 to 700 persons.[25] Socioeconomic and built environment variables are more homogenous within DAs than within larger geographic areas, and using a small spatial scale allows for identification of spatial patterns that might have been masked at larger geographic scales. Figure 1 shows the 3685 Dissemination Areas that make up the City of Toronto from the 2006 Census of Canada.[26]

Data sources

We used data from four different sources. Licensed premises alcohol expenditures were taken from the 2010 Survey of Household Spending.[27] The 2008 DMTI Spatial Enhanced Points of Interest dataset[28] provided licensed premises outlet locations, and 2010 CanMap Route Logistics data[29] provided built environment data (subway lines, highways and land-use). The 2006 Census of Canada data[26] provided DA-level socioeconomic characteristics. These characteristics were collected by the census "2B long form," which was distributed to 20% of the population in 2006. In this study, we used the 2006 census because of changes to the 2011 census and to the National Household Survey (NHS), which replaced the long form in 2011. In particular, because the NHS was made voluntary, Statistics Canada did not release the socioeconomic characteristics of some DAs due to nonresponse.[30] In order to conduct the analysis at the Dissemination Area level, this study used the 2006 data.

Measures

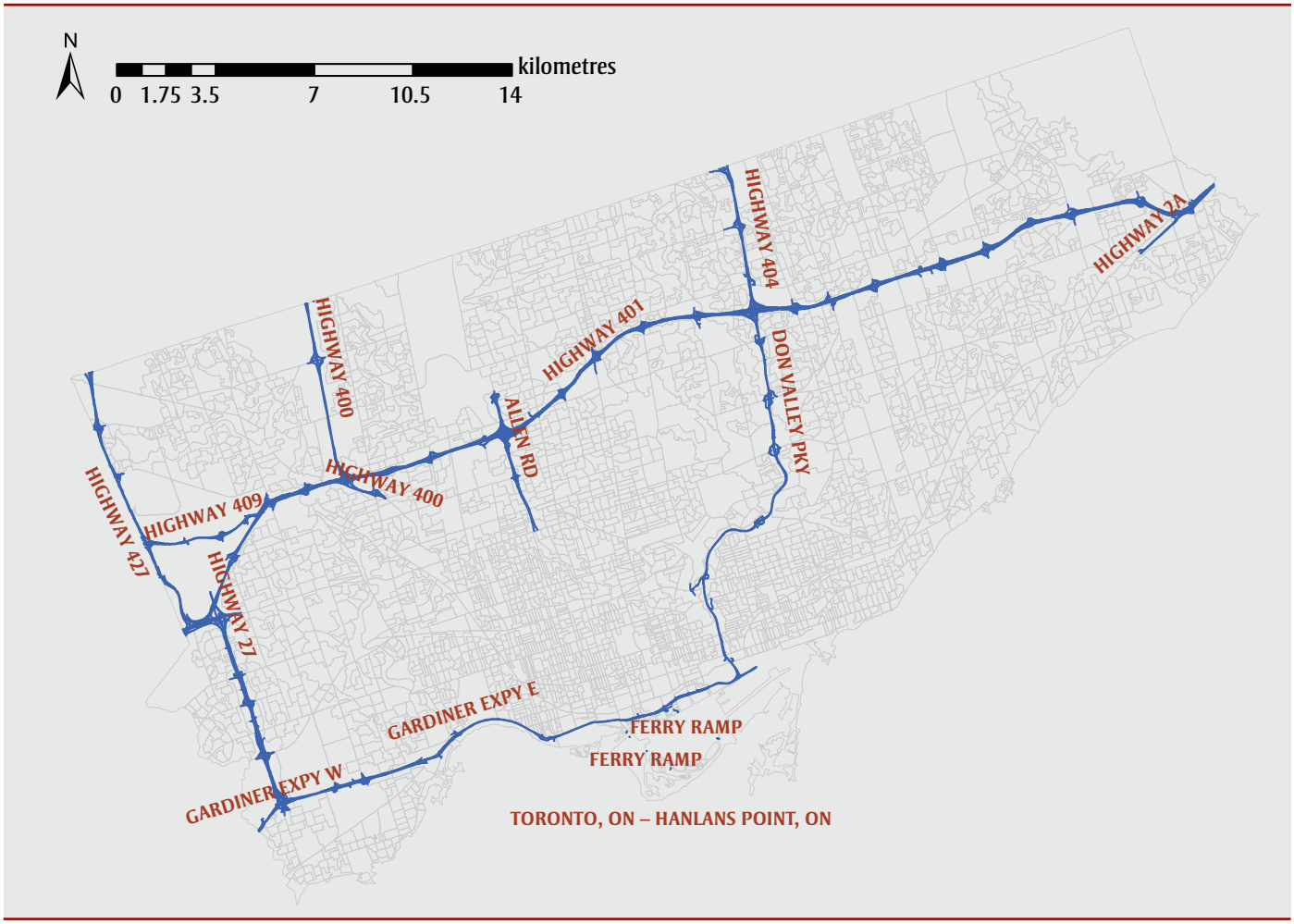
The main outcome variable was the DA average total household alcohol expenditure per year from licensed premises in 2010. These data were collected using diary and short-period recall questions.[27] We applied a log transformation to correct for skewness.

Consistent with previous alcohol use and expenditure studies,[5-8,31] we examined a number of relevant socioeconomic variables as predictors of licensed premises expenditure, including neighbourhood ethnic composition, visible minority concentration, occupation, income, neighbourhood deprivation, housing and education. These were taken from the 2006 census data.

We measured area ethnic composition using the percentage of the DA population reporting Black, Chinese, South Asian and Filipino ethnicities. The concentration of nonvisible minorities was measured using the percentage of the DA population identifying as "not a member of a visible minority." We defined occupation as the percentage of employed DA population reporting working in management, business, finance and administration. This variable was created by combining several groups of occupations according to the 2001 National Occupational Classification for Statistics (NOCS) definition.[32]

We used two measures of area income: median household after-tax income and the average income from government transfer payments. Education was defined as the proportion of the DA population that reported having completed one of the following qualifications: registered apprenticeship, trades certificate or diploma, college, CEGEP, other non-university certificate or diploma and university certificate, degree or diploma.

FIGURE 1
Dissemination Area map of Toronto, Canada, with major highways



Data source: Statistics Canada. 2006 Census of Population [Internet]. Ottawa (ON): Statistics Canada; 2006. Available from: http://www12.statcan.gc.ca/census-recensement/2006/index-eng.cfm

Three measures captured the nature of housing in each DA. These were the proportion of dwelling types that were apartment buildings with fewer than five floors, the proportion of single detached houses and the proportion of row (attached) houses. We included the presence of subway lines in a neighbourhood as the number of subway intercepts (access points) within the DA. Spatially "lagged" subway intercepts indicated the presence of subway lines in an adjacent DA.

Alcohol outlet data were retrieved from the 2008 DMTI Enhanced Points of Interest dataset.[28]

We measured local alcohol availability by the densities of two types of restaurant in each DA. "Primary drinking restaurants" were those whose main business was serving alcohol, while "restaurants" were those with a dual focus on serving both food and alcohol. The densities of these two types of business were calculated by dividing the number of restaurants by the area of the DA in square kilometres. Spatially "lagged" versions of these variables captured the effect of outlet density in neighbouring DAs.[33]

Analyses: global spatial autocorrelation, local cluster analysis procedure and multivariate spatial regression

We first calculated Global Moran's I statistic to quantify the average level of spatial autocorrelation and to test the null hypothesis that the alcohol expenditure levels in DAs were fully independent of expenditure in adjacent DAs.[34] We then calculated Local Moran's I measures to identify clusters of hot spots and cold spots, where hot spots were clusters of adjacent DAs with similarly high levels of licensed premises expenditures and cold spots were clusters with low levels of licensed premises expenditures. Clustering techniques were carried out using GeoDa v1.6.7.[35] High resolution maps were created in ArcGIS 10.3 (Environmental Systems Research Institute, Inc., Redlands, CA, USA).

Consistent with the approach used by Pridemore and Grubesic,[36] Grubesic et al.[24] and Zhu, Gorman and Horel,[37] we used multivariate spatial regressions to estimate the effects of the area-level factors on area-level alcohol expenditure. In the presence of positive spatial autocorrelation, ordinary least squares (OLS) regression can result in biased and inefficient parameter estimates.[37] Spatial regression models have been developed to address this problematic effect and have been widely employed in spatial econometrics.[38]

Spatial regression models include at least one additional variable, known as a *spatial autoregressive term*, to control for geographical variation. We estimated four main spatial regression models: a spatial lag regression model (also known as *spatial autoregressive model* or SAR), a spatial error regression model (SEM), a spatial Durbin model (SDM) and a spatial Durbin error model (SDEM).[14,34,38-42] In the spatial lag model, values of the dependent variable (y) for a unit (i) are assumed to be directly influenced by the values of y in neighbouring units.[14,43] In order to account for this effect, a spatially lagged dependent variable (pWy) is included as an explanatory variable (Figure 2). Alternatively, the SEM incorporates geographical variation by adding a spatial autoregressive error term as a dependent variable (Figure 2). The SDM and SDEM are extensions of the spatial lag and spatial error models respectively, as these models are the same as their counterparts, except for an additional spatial autoregressive term for independent variables (Figure 2).

Our procedure began with descriptive statistics and correlation analysis to describe the distribution of the dataset and to identify issues of multicollinearity. Preliminary bivariate OLS regressions suggested positive spatial autocorrelation, therefore we calculated bivariate regressions using an SEM. We then included statistically significant explanatory variables in a multivariate SEM. The number of insignificant explanatory variables was reduced with backwards stepwise regression ($\alpha = 0.10$). We tested four different spatial regression models, with the best-fitting model determined by the highest log-likelihood value. All regression models were estimated using the software package R version 3.2.3.[44]

Results

Descriptive statistics

In 2010, the average annual household alcohol expenditure in licensed premises was $337.51 (range: $47.54 to $2963.02). Table 1 provides descriptive statistics for licensed premises expenditure and the area-level explanatory variables.

Spatial autocorrelation

For licensed premises alcohol expenditure, the Global Moran's I value was 0.634 and highly significant *($p = .001$)* (Figure 3), indicating a high degree of positive spatial autocorrelation. A total of three hot spots and three cold spots were identified for alcohol expenditures, using Local Moran's I (Figure 4).

Spatial regression results

For the licensed premises expenditure, the SDEM model had the largest log-likelihood, indicating the best fit. The model coefficients and significance of coefficients are provided in Table 2.

Socioeconomic and demographic variables

The percentage of people reporting Filipino ethnicity was the only significant ethnicity variable in the final model. A one-unit increase in the percentage of Filipino ethnicity was associated with a decrease in alcohol expenditures of 0.28%. The percentage that was nonvisible minority was positive and significant, with a one-unit increase associated with an increase in alcohol expenditures of 0.44%.

The percentage of employed residents working in management and administration was significantly associated with alcohol expenditures, with a one-unit increase leading to a predicted increase in expenditures of 78.57%. Median after-tax income was also found to have a positive association, as a one-dollar increase was found to increase predicted expenditures by 0.0006%. Conversely, the percentage of income from transfer payments was negatively associated with alcohol expenditures, as a one percentage point increase was associated with a decrease in expenditures by 1.74%. Postsecondary education had a significantly positive effect on expenditures, with a one-unit increase in the proportion of a DA with postsecondary qualifications associated with an increase in predicted expenditures of 35.00%.

FIGURE 2
Spatial regression models for calculating average total alcohol expenditures levels for licensed premises in Toronto, Canada, Dissemination Areas, 2010

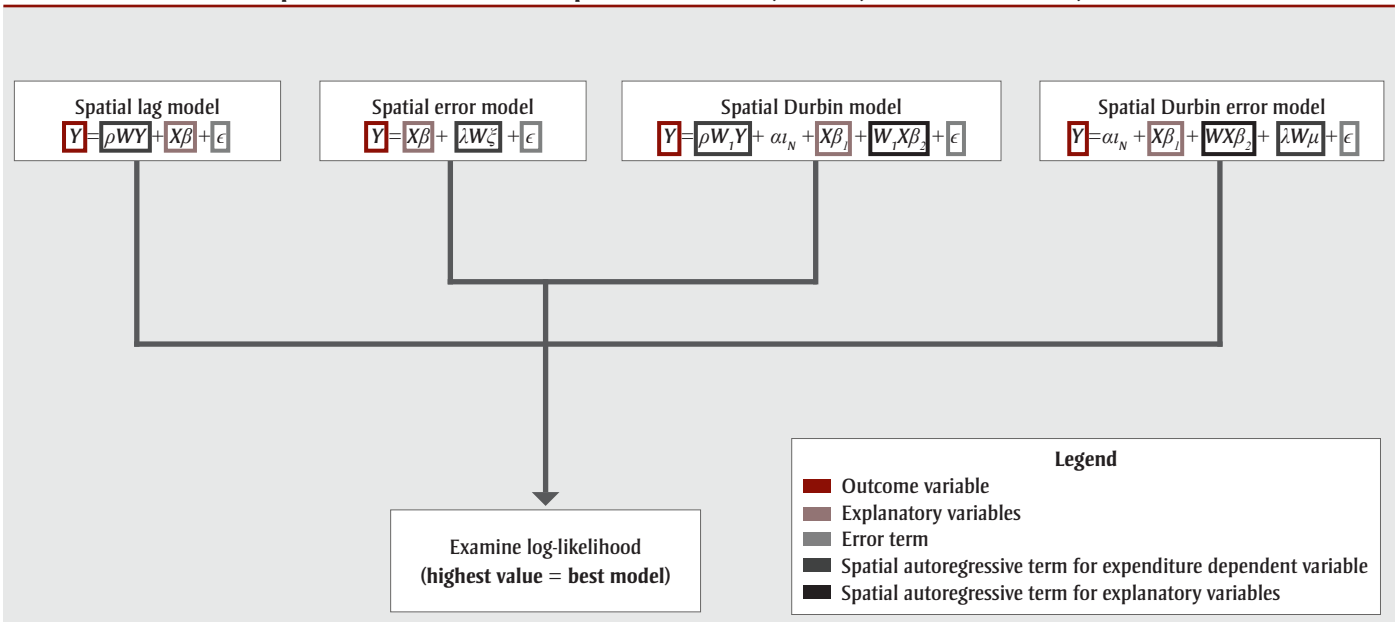


TABLE 1
Table of descriptive statistics for all outcome and explanatory variables, Dissemination Areas in Toronto, Canada, 2010

Variable	N	Minimum	Maximum	Mean	Standard Deviation
Expenditures in LP	3512	47.54	2963.02	337.51	291.01
Log transformed LP	3512	3.86	7.99	5.56	0.70
% nonvisible minority	3512	0.00	100.00	59.72	26.62
% ethnicity Filipino	3512	0.00	60.86	3.11	5.38
% employed in management	3512	0.07	0.93	0.53	0.15
Median household income—after tax	3512	11776.00	335039.00	56303.79	25201.81
% income from transfer payments	3512	0.00	56.30	11.17	7.37
% apartments < 5 floors	3512	0.00	100.00	19.04	23.95
% apartments—duplex	3512	0.00	61.39	6.60	7.92
% row houses	3512	0.00	100.00	5.62	14.00
% single detached	3512	0.00	100.00	39.87	34.50
% postsecondary education	3512	0.00	0.94	0.48	0.16
Subway intercept	3512	0.00	1.00	0.06	0.23
Lagged subway intercept	3512	0.00	1.00	0.07	0.16
Primary drinking restaurant density by DA	3512	0.00	116.78	1.10	6.46
Lagged primary drinking restaurant density by DA	3512	0.00	38.79	1.13	3.43
Eating restaurant density by DA	3512	0.00	826.78	21.54	59.30
Lagged eating restaurant density by DA	3512	0.00	493.35	21.53	41.11

Abbreviations: DA, Dissemination Area; LP, licensed premises.

Notes: A lagged variable considers the effect of a variable of interest (i.e., alcohol expenditures) in neighbouring areas to a specific DA. For example, for a DA called DA1, if DA2 and DA3 are considered neighbours, their average total alcohol expenditure values can be averaged and included as a spatially-lagged independent variable. What constitutes a neighbour is dependent on the contiguity definition (i.e., rook criterion: sharing a common edge or queen criterion: sharing a common edge or a common vertex), and the resulting neighbourhood structure is stored as a spatial weight matrix.

Lagged restaurant density: The effect of restaurant densities in areas immediately adjacent to a DA.

Lagged subway intercept: The effect of the presence of subways in areas immediately adjacent to a DA.

The percentage of apartments with fewer than five floors, the percentage of single-detached houses and the percentage of row houses were all positively associated with alcohol expenditure. The associated expenditure increases from a one-unit increase were 0.13%, 0.23% and 0.48% respectively.

Built environment variables

Both the presence of subways and geographically lagged subway presence (the presence of subways in neighbouring areas) were positively associated with alcohol expenditures. A one-unit increase in subway intercepts was found to increase expenditures by 5.01%. Having subways in adjacent areas (lagged subways) resulted in an increase to expenditures by 28.28%. The density of primary drinking restaurants and lagged primary drinking restaurants were also both positively associated with alcohol expenditures, as one-unit increases resulted in 0.06% and 0.73% increases in expenditure respectively. Finally, both restaurant density and lagged restaurant density were positively associated with alcohol expenditure. A one-unit increase in restaurant density led to an increase in expenditures by 0.03%. As for lagged restaurant density, a one-unit increase was associated with an increase in expenditures by 0.10%.

Discussion

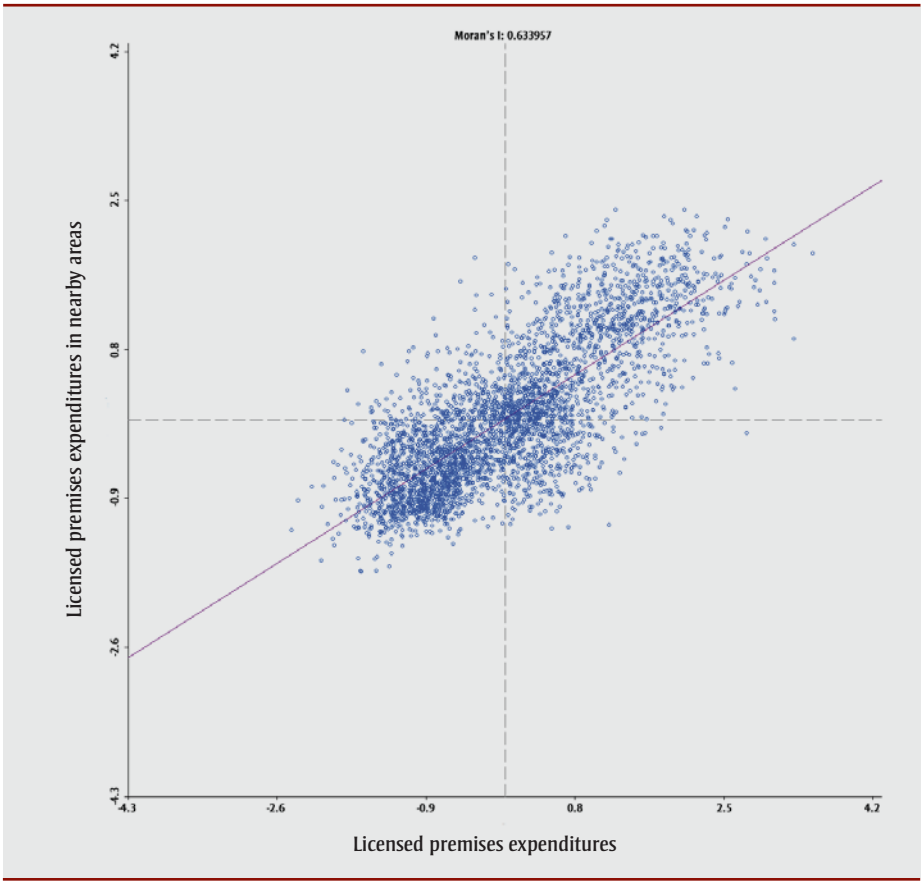
Our study found that significant associations existed between area-level socioeconomic variables and licensed alcohol expenditures. Most notably, the proportions of residents in management occupations and with postsecondary degrees were highly positively associated with alcohol expenditures. For public health promotion, this suggests that campaigns such as The Centre for Addiction and Mental Health's (CAMH) "Rethink Your Drinking" might be tailored to target these sociodemographic groups or the establishments that they frequent. It is possible that many drinking establishments in Toronto target clientele from management and administrative occupations, as they may have more disposable income.

This study also found a positive association between the presence of subways and area-level alcohol expenditure. Previous studies have acknowledged the possibility that increased access by public transportation to areas with high alcohol outlet densities could lead to greater alcohol consumption.[19] The findings in this study lend their support to this notion, as having a subway line in the same DA led to an average increase of 5.00% in alcohol expenditures. Furthermore, having subway lines in neighbouring areas was also related to higher alcohol expenditures. For policy makers, this could serve as an additional consideration in recommending alcohol outlet densities.

The density of primary drinking restaurants and other restaurants increased expenditures slightly. The direction of association for this finding agrees with previous work by Gruenewald, Ponicki and Holder[16] who found that, independent of alcoholic beverage pricing and while controlling for sales and availability, physical availability in the form of alcohol outlets increased the sales of alcoholic beverages.

Several systematic reviews of international alcohol outlet density literature have found considerable evidence of a significant positive association between alcohol outlet density and consumption. Livingston et al.[45] examined literature from North America, the UK and Nordic countries, including cross-sectional studies, natural experiments and time-series experiments. The majority of these studies found significant positive associations between alcohol outlet density and alcohol consumption. In another review, Campbell et al.[46] also reported that studies generally found outlet density to be associated with increased alcohol consumption, and showed that alcohol bans and changes to

FIGURE 3
Global Moran's I statistic scatterplot for licensed premises alcohol expenditures, Toronto, Canada, 2010



Note: The Global Moran's I statistic plots the licensed premises expenditure values (x-axis) against expenditure values in nearby areas (y-axis). The resulting correlation value is the Moran's I value. Monte Carlo testing using 999 permutations was used to produce a p-value that determined whether the points plotted form a significant cluster. The Moran's I values were significant at the .001 significance level.

licensing arrangements for alcohol can be effective strategies. Popova et al.[47] conducted a systematic review with a focus on both the density of outlets and the hours of sale and their relation to consumption and property damage. Similarly, a majority of the studies reported a positive association between alcohol outlet density and higher overall alcohol consumption.

Several studies have examined the effect of alcohol outlet density and retail arrangements on alcohol consumption in Canada. Xie et al., examining Canadian data from 1968 to 1986, found a significant association between reductions in the density of off-premises sales outlets and reduction in alcohol consumption.[46] Trolldal conducted a time-series analysis of the relationship between alcohol sales and availability in four Canadian provinces; however, he did not find a significant positive association.[45] Trolldal also examined the impact of allowing wine sales in grocery stores in Quebec and alcohol retail privatization in Alberta. He found the change in Quebec led to a 10% increase in sales of wine and a smaller increase in total alcohol sales.[46] In Alberta, privatization was found to have resulted in a permanent increase in the sale of spirits only.

It may be that some of the variability in the results of the outlet density–consumption relationship is due to that relationship being a nonlinear one. Livingston et al.[48] distinguish between two different effects of increasing alcohol outlet density on alcohol-related harms: a *proximity* effect and an *amenity* effect. The proximity effect hypothesizes that the effect of outlet density on consumption is reduced at higher density levels, and that outlet density eventually reaches a saturation point. As a result, the corresponding levels of alcohol-related harms from consumption will also plateau. Conversely, the amenity effect postulates that as alcohol outlet density increases, alcohol-related harms increase at an accelerating rate, as more drinkers are brought into closer proximity with each other.

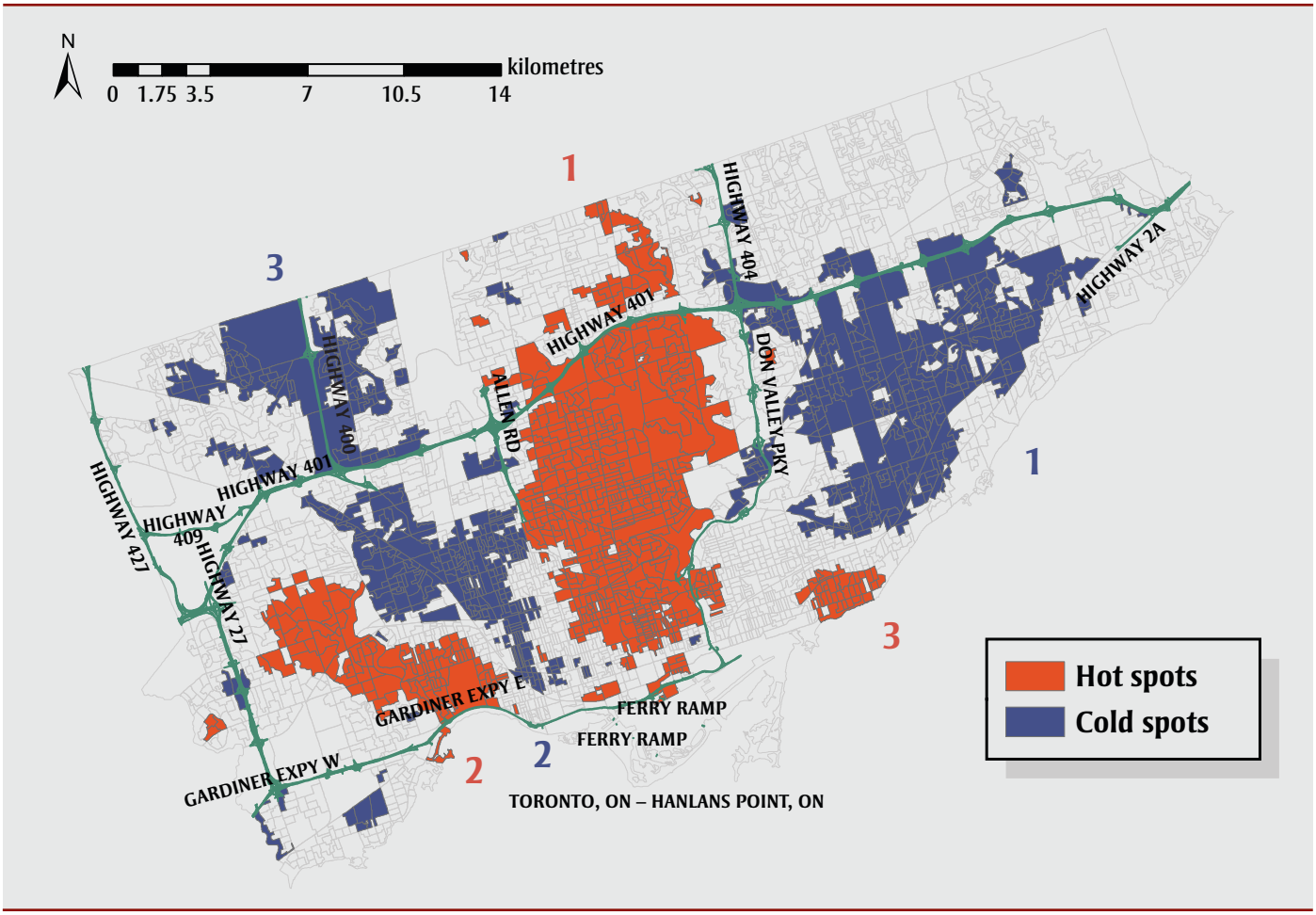
Future research is needed to improve our understanding of these possible relationships. However, the present study does provide evidence of the clustering of both alcohol sales and consumption, which we think can help inform decisions regarding the number and distribution of alcohol sales licenses. In the future, critical values for outlet density could be determined, in order to mitigate alcohol-related harms.[46,48,49]

Strengths and limitations

This study, using a novel approach, was able to replicate the impact of alcohol availability and income on expenditure observed using more traditional methods. To our knowledge, this was the first study to quantify and visualize the spatial structure of alcohol expenditure and examine associations between expenditures and area-level characteristics in the City of Toronto. It demonstrates the application of spatial methods and use of alcohol expenditure data in the Canadian context.

One of the limitations of this study is the use of DA characteristics in 2006 to predict 2010 licensed premises expenditures. These were the only data available at the time of the study; however, it is hoped that future studies will be able to use area data that are closer in time to the expenditure data. For small-area studies, another primary problem is the issue of the "modifiable area unit problem" (MAUP), in which analyses at different spatial scales result in differing associations between explanatory variables and the outcome variable.[13] For this study, the Dissemination Area was chosen as the unit of analysis to balance data availability, limiting MAUP and finding local patterns that have applicability to policy efforts. Another possible limitation is the risk of the ecological fallacy, in which associations observed at a group level are used to make causal inferences at an individual level[50,51] leading to erroneous conclusions.[52,53] It is, therefore, important to remember that the findings here are only applicable for understanding alcohol expenditure in Toronto at the DA level. Furthermore, it should also be kept in mind that our results are based on cross-sectional data

FIGURE 4
Hot spot and cold spot map for licensed premises alcohol expenditures by Dissemination Area in Toronto, Canada, 2010



Data source: Licensed premises alcohol expenditures are from Statistics Canada. Survey of Household Spending (SHS): detailed information for 2013 [Internet]. Ottawa (ON): Statistics Canada; 2013 [modified 2017 Dec 12; cited 2015 Aug 7]. Available from: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3508

Notes: This map shows the hot spots (areas with high levels of alcohol expenditure clustered together) in red and the cold spots (areas with low levels of alcohol expenditure clustered together) in blue. The major highways have also been overlaid to provide a sense of location for the clusters. The correspondingly coloured numbers indicate the locations of the 3 hot spots and 3 cold spots.

and causal inferences should not be made. Future studies could make use of spatial multilevel models to allow findings to be generalizable to the individual level. Time-series analyses could also be done to address the cross-sectional nature of our study.

Finally, the use of sociodemographic characteristics of residents of a DA to predict alcohol expenditures in the same DA assumes that purchases are made in the area of residence. It is likely that household expenditures often include purchases made in other areas, and this is particularly true because of the small size of this geographic classification and the fact that people travel for work. To fully account for this would require data on the location of expenditures and household characteristics, which are presently unavailable. However, some purchasing activity in other DAs can be statistically accounted for by the spatial Durbin error model, as the spatially lagged alcohol outlet density variables capture the effects of alcohol outlet density in adjacent DAs on the average expenditures in a local DA. The positive associations found indicate that purchases at outlets outside of a local DA have a significant impact on the average expenditures within that DA. The significant spatial error term (Lambda) in the models might also be the result of purchases in adjacent DAs increasing expenditure levels within the DA of residence. In the absence of more in-depth data, one way to overcome this disconnect between place of residence and place of retail behaviour is to employ "gravity models," such as the kernel density estimation method, to better account for retail behaviour in external DAs affecting the expenditures in a local DA.[54]

Conclusion

The results of this study suggest that both area-level socioeconomic factors and built environment variables may be related to levels of alcohol expenditure. The results corroborated the findings of previous individual-level studies of socioeconomic correlates of alcohol use, and also found associations between small-area-level alcohol expenditure and socioeconomic characteristics for the first time. We also identified significant built environment associations with alcohol expenditures, which underscore the importance of examining contextual factors as significant influences of health behaviours. Moreover, this study adds considerably to the current

TABLE 2
Spatial Durbin error model regression results for licensed premises expenditures in Toronto, Canada, Dissemination Areas, 2010: coefficients and significance

Socioeconomic variables	
Percentage nonvisible minority	0.004***
Percentage of Filipino ethnicity	−0.003*
Percentage employed in management occupations	0.580***
Median household income, after tax	0.00001***
Percentage of income from transfer payments	−0.018***
Percentage of apartments < 5 floors	0.001***
Percentage of single detached houses	0.002***
Percentage of row houses	0.005***
Percentage postsecondary education	0.300***
Built environment variables	
Subway intercepts	0.049
Lagged subway intercepts	0.249***
Primary drinking restaurant density by DA (km^2)	0.001
Lagged primary drinking restaurant density by DA (km^2)	0.007*
Restaurant density by DA (km^2)	0.0003*
Lagged restaurant density by DA (km^2)	0.001**
Constant	4.506***
Spatial autoregressive error term	
Lambda	0.639***

Data source: Statistics Canada. Survey of Household Spending (SHS): detailed information for 2013 [Internet]. Ottawa (ON): Statistics Canada; 2013 [modified 2017 Dec 12; cited 2015 Aug 7]. Available from: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3508.

Abbreviation: DA, Dissemination Area.

Notes: A lagged variable considers the effect of a variable of interest (i.e., alcohol expenditures) in neighbouring areas to a specific DA. For example, for a DA called DA1, if DA2 and DA3 are considered neighbours, their average total alcohol expenditure values can be averaged and included as a spatially-lagged independent variable. What constitutes a neighbour is dependent on the contiguity definition (i.e., rook criterion: sharing a common edge or queen criterion: sharing a common edge or a common vertex), and the resulting neighbourhood structure is stored as a spatial weight matrix.

Lagged restaurant density: The effect of restaurant densities in areas immediately adjacent to a DA.

Lagged subway intercept: The effect of the presence of subways in areas immediately adjacent to a DA.

* $p < .05$.

** $p < .01$.

*** $p < .001$.

understanding of alcohol expenditures by recognizing geographic influences. The findings in this study demonstrate the utility of a spatial analysis approach for understanding alcohol use, and furthermore, highlight how the spatial methods used may help municipalities more effectively formulate alcohol-use reduction strategies to assist in reducing alcohol-related harms. Future research will benefit from this spatial understanding of licensed premised alcohol expenditures and can explore other avenues, such as examining additional built environment variables and applying models that explicitly address area-level effects.

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Conflicts of interest

The authors state that they have no competing interests in this work.

Authors' contributions and statement

AL, JL, MC, and SL all proposed and planned the analysis. AL conducted the analysis and wrote the first draft. AL, JL, MC, and SL commented and edited subsequent drafts.

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