A spatial analysis of the association between restaurant density and body mass index in Canadian adults

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A R T I C L E   I N F O

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A B S T R A C T

Objective. To investigate the association between fast-food restaurant density and adult body mass index (BMI) in Canada.

Methods. Individual-level BMI and confounding variables were obtained from the 2007–2008 Canadian Community Health Survey master file. Locations of the fast-food and full-service chain restaurants and other non-chain restaurants were obtained from the 2008 Infogroup Canada business database. Food outlet density (fast-food, full-service and other) per 10,000 population was calculated for each Forward Sortation Area (FSA). Global (Moran’s I) and local indicators of spatial autocorrelation of BMI were assessed. Ordinary least squares (OLS) and spatial auto-regressive error (SARE) methods were used to assess the association between local food environment and adult BMI in Canada.

Results. Global and local spatial autocorrelation of BMI were found in our univariate analysis. We found that OLS and SARE estimates were very similar in our multivariate models. An additional fast-food restaurant per 10,000 people at the FSA-level was associated with a 0.022 kg/m² increase in BMI. On the other hand, other restaurant density is negatively related to BMI.

Conclusions. Fast-food restaurant density is positively associated with BMI in Canada. Results suggest that restricting availability of fast-food in local neighborhoods may play a role in obesity prevention.

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Introduction

Much of the obesity research has been aimed at the modification of individual-level factors such as physical activity and/or diet (Prentice and Jebb, 1995) and has examined how these choices are affected by demographic and socio-economic variables such as, education (Banks, et al., 2011; Brown and Siahpush, 2007; Roskam and Kunst, 2008), income (Amarasinghe, et al., 2009), employment and ethnicity (Liu, et al., 2010; Tremblay, et al., 2005). In addition, behavioural factors can be important in influencing personal preferences with regard to healthy eating choices.

Although individual-level socio-economic and behavioural factors are important, policy interventions supported by this strand of research have had very limited success (Booth, et al., 2005; Giles-Corti and Donovan, 2003; Yen and Kaplan, 1998; Young and Nestle, 2003; Elinder and Jansson, 2009). Moreover, during the last 30 years the population has remained genetically stable (Ebbeling, et al., 2002). Researchers are now considering the contextual effects of the neighbourhood built environment, that promotes over-eating and consumption of unhealthy foods and/or discourages physical activity, as potential risk factors for obesity prevalence (Booth, et al., 2005; Ewing, et al., 2006; Peng, et al., 2010; Gilliland, et al., 2012). In fact, these contextual factors can adversely interact with the eating behaviours of individuals, leading to increased risk of obesity.

These environmental risk factors, to a large extent, are spatial by nature, as they involve complex pathways and interactions between individuals and their neighbourhood surroundings. To date, spatial analysis of obesity in Canada is very limited. Two papers investigated spatial patterns of obesity and overweight prevalence using 2003 Canadian Community Health Survey (CCHS) (Lebel, et al., 2009; Vanasse, et al., 2006). The study by Vanasse et al. (2006) was motivated by the spatial relationship linking low levels of physical activity and fruit and vegetable consumption, whereas Lebel et al. (2009)
were interested in isolating the contextual or spatial effects stemming from individual- and area-level characteristics. Both studies observed significant geographic variations in obesity/overweight prevalence. Pouliou and Elliott (2009) and Hajizadeh et al. (2012) utilized more sophisticated spatial methods to assess spatial autocorrelation in the distribution of obesity in Canada. Using 2005 CCHS Pouliou and Elliott (2009) observed significant spatial clustering of overweight and obesity rates at the health region level across Canada even after adjusting for age and sex. Hajizadeh et al. (2012) investigated the extent to which spatial autocorrelation of obesity was present after considering the effects of demographical, socio-economic and behavioural factors. They concluded that at the health region level, spatial heterogeneity was important; however, spatial heterogeneity was unimportant when lower units of geography such as Canadian Forward Sortation Areas (i.e. 3-digit postal codes) were considered. The authors suggest this could be due to the fact that local factors could account for spatial heterogeneity that may be unobserved at the health region level.

One important influence of BMI that has not been adequately studied in the Canadian context is the area-level food environment. Area-level fast-food density is arguably an important factor in determining regional variations in obesity rates in the international literature (Heisschlacker, et al., 2011; Fraser, et al., 2010); however, the literature on this relationship, especially accounting for spatial heterogeneity, is virtually non-existent in Canada.

Although it has been suggested that smaller geographic areas can offer new insights into the spatial determinants of health (Reidpath, et al., 2002; Marmot, 2000; Drewnowski, et al., 2007), most previous spatial analyses of obesity in Canada relied on larger geographic areas (i.e. about 125 health regions) (Pouliou and Elliott, 2009; Vanasse, et al., 2006), thereby masking geographic variations at the local level. Alternatively, previous studies examining geographic variations in obesity at smaller scales (i.e. home addresses or postal codes) in Canada have tended to focus on single cities rather than the entire country (Gilliland, et al., 2012). Our study is considerably improved on this strand of literature by use of FSAs as the geographic unit of analysis.

In this paper, we analyzed spatial heterogeneity of BMI values and then examined the spatial relationship between area-level restaurants and BMI. Our analysis also incorporated the influence of full-service and non-chain restaurants in an attempt to capture the influence of the spectrum of food-service environment on obesity. We employed advanced spatial econometric methods using detailed data on restaurants in Canada, for the first time, to examine the relationship between fast-food restaurant density and adult BMI using FSA-level data.

Methods

Data sources and study design

We conducted a population-based, cross-sectional study to examine the relationship between fast-food environment and adult BMI using FSA as the areal unit of observation. In Canada, an FSA is the first 3-digits of a postal code, which varies in geographic area with respect to population density. The data for this study came from the 2007/08 CCHS which is a nationally representative survey designed to collect information on health determinants of the Canadian general population. Survey methodology can be found elsewhere (Statistics Canada, 2009). Self-reported data on BMI and 3-digit postal codes were obtained from the confidential master file accessed through Statistics Canada’s Research Data Centre at the University of Western Ontario. The use of the master file was important as it contained un-suppressed data, including postal codes that were not available in the public use CCHS files used in the previous literature. Adults aged 18–65 years who resided in the ten Canadian provinces were included. Individuals with missing or extreme BMI values (BMI < 10 or BMI > 70), and those who were pregnant or breastfeeding were excluded. To maintain reasonable estimates of BMI and in adherence to confidentiality, FSAs with fewer than 15 respondents were excluded from the analyses. These inclusion/exclusion criteria generated 1,269 valid FSAs (out of 1,558 available FSAs) for our analyses.

Outcome Variables

BMI (kg/m²) was the outcome of interest and was adjusted by means of a validated error correction factor (Gorber, et al., 2008) as follows: females, BMI corrected = −0.12 + 1.05 [BMI self-report]; males, BMI corrected = −1.08 + 1.08 [BMI self-report]. In aggregating data to the FSA-level sampling weights provided by Statistics Canada were applied.

Restaurant variables

The names and geographic locations for all restaurants in Canada with the standard industry classification code (SIC) 5812-08 for 2008 were purchased from Infogroup Canada. This data holding firm collected the information through public directories and subsequently telephone-verified entries to ensure accuracy. We cleaned this database in three steps. First, observations with missing postal codes were automatically matched using ArcGIS software ESRI (2011) using street level addresses found in the Infogroup Canada business database. Second, the unmatched addresses were geocoded using the user written “geocode” command of STATA (Ozimek and Miles, 2011). Finally, if postal codes were left unmatched after the automation processes, these missing cases were obtained, if possible, through Google Earth and manual Internet searches. We were unable to retrieve postal codes for 358 restaurants in Canada and hence these were excluded from our analysis.

We defined fast-food chain restaurants as those food establishments, including general coffee outlets, that provide services to customers on the basis that food is ordered and paid before eating or taking out. Full-service restaurants are defined as those establishments that provide food services to customers on the basis that customers are being served food and pay after eating (i.e., availability of waiter/waitress services). Similar approaches have been used in a number of studies in the US (Currie, et al., 2010; Davis and Carpenter, 2009; Dunn, 2008, 2010; Dunn, et al., 2012; Howard, et al., 2011; Li, et al., 2009). The above classification schemes were based on the business names published in 2008 Directory of Restaurant and Fast Food Chains in Canada (Monday Report on Retailers, 2010) consistent with the names provided in the Infogroup Canada business database. We then constructed the number of fast-food, full-service and non-chain restaurants per 10,000 persons at the FSA-level as the number of outlets for each restaurant category divided by the corresponding FSA population from the 2006 Canadian census. Note that non-chain category refers to independent restaurants.

Table 1

FSA-level descriptive statistics (n = 1,269).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Demographic Age in years</td>
<td>41.62</td>
<td>3.28</td>
</tr>
<tr>
<td>Females</td>
<td>0.49</td>
<td>0.11</td>
</tr>
<tr>
<td>Married</td>
<td>0.64</td>
<td>0.13</td>
</tr>
<tr>
<td>Socio-economic status Education (less than high school)</td>
<td>0.12</td>
<td>0.09</td>
</tr>
<tr>
<td>Canadian born (non-immigrant)</td>
<td>0.82</td>
<td>0.20</td>
</tr>
<tr>
<td>Has a job (part time or full time, not student)</td>
<td>0.76</td>
<td>0.10</td>
</tr>
<tr>
<td>Low income a</td>
<td>0.15</td>
<td>0.11</td>
</tr>
<tr>
<td>Has child ≤ 5 years old</td>
<td>0.14</td>
<td>0.08</td>
</tr>
<tr>
<td>Has child 6–11 years old</td>
<td>0.16</td>
<td>0.09</td>
</tr>
<tr>
<td>Food secure (no income related difficulty with food access)</td>
<td>0.93</td>
<td>0.07</td>
</tr>
<tr>
<td>Lifestyle Low fruit and vegetable consumption (&lt; 5 times per day)</td>
<td>0.58</td>
<td>0.13</td>
</tr>
<tr>
<td>Daily smoker (at least 1 cigarette per day)</td>
<td>0.21</td>
<td>0.11</td>
</tr>
<tr>
<td>Regular drinkers (≥ one once a month)</td>
<td>0.69</td>
<td>0.13</td>
</tr>
<tr>
<td>Inactive (Low daily energy expenditure in transportation and leisure time)</td>
<td>0.47</td>
<td>0.13</td>
</tr>
<tr>
<td>Low level (0–9 h) of sedentary activity per week (Excluding Reading)</td>
<td>0.20</td>
<td>0.10</td>
</tr>
<tr>
<td>Restaurant Fast-food restaurant density (per 10,000 FSA population)</td>
<td>7.69</td>
<td>6.87</td>
</tr>
<tr>
<td>Full-service restaurant density (per 10,000 FSA population)</td>
<td>1.19</td>
<td>1.83</td>
</tr>
<tr>
<td>Other restaurant density (per 10,000 FSA population)</td>
<td>16.6</td>
<td>18.77</td>
</tr>
</tbody>
</table>

a Lowest two income adequacy deciles. Derived category in the CCHS takes into account household size in calculations.
and are very specific to the local area (for example, non-chain ethnic restaurants). It is impossible to classify these restaurants into fast-food or full-service with any verifiable source of Directory.

**Confounder variables**

The following factors were identified in the literature as potential confounding variables and available in the CCHS: Demographics (age, sex, marital status), Socio-economic status (education, immigrant status, employment, having children, food security) and lifestyle factors (fruit and vegetable consumption, smoking, alcohol use, physical activity – transportation/leisure and sedentary activity). These variables were dichotomized for aggregate analysis as presented in Table 1. Means (±SD) for these variables represent the mean values of the proportion of each factor across FSAs.

**Statistical analyses**

Mean BMI values across available FSAs were mapped using Arc GIS software and then Moran’s I, a widely used test for global spatial autocorrelation (Moran, 1950; Lesage and Pace, 2009), was performed. A statistically significant positive Moran’s I value suggests that similar BMI values were in close proximity to each other. To examine the spatial distribution further, local indicators of spatial autocorrelation (LISA) were used (Anselin, 1995). LISA allows for the decomposition of Moran’s I into the contribution of each observation. LISA significance maps present a spatial typology which consists of five categories, but most pertinently: “High–High” and “Low–Low” which indicate the clustering of higher (positive spatial autocorrelation) and lower (negative spatial autocorrelation) than average BMI values.

To analyze the association between fast-food restaurant density and BMI, we used a linear regression model using OLS method. To account for the presence of spatial clustering of obesity, we utilized the spatial auto-regressive error (SARE) model. The technical details of the SHARE model are presented in the Appendix A.

**Results**

**Descriptive statistics**

Mean fast-food and full-service restaurant density were 7.69 and 1.19 per 10,000 FSA population, respectively. The mean density for other restaurants was 16.6 per 10,000 people. The mean (SD) age of the sample

Fig. 1. Mean Canadian BMI at the FSA-level.
Provinces: British Columbia (BC), Alberta (AB), Saskatchewan (SK), Manitoba (MB), Ontario (ON), Quebec (QC), New Brunswick (NB), Nova Scotia, Prince Edward Island (PE), Newfoundland (NL)

**Fig. 2.** Mean BMI in Canada at the FSA-level for males and females.

Provinces: British Columbia (BC), Alberta (AB), Saskatchewan (SK), Manitoba (MB), Ontario (ON), Quebec (QC), New Brunswick (NB), Nova Scotia, Prince Edward Island (PE), Newfoundland (NL)

**Fig. 3.** LISA Mean BMI.
was 42.2 (13.2) and mean (SD) BMI was 27.1 (1.52). Descriptive statistics for demographics (age, sex, marital status), socio-economic status (education, immigrant status, employment, having children, food security), lifestyle variables (fruit/vegetable consumption, smoking, alcohol use, physical activity – transportation/leisure and sedentary activity) and restaurant data were presented in Table 1.

Spatial distribution of BMI

The spatial distribution of mean BMI at the FSA level is shown in Fig. 1. The map exhibits a noticeably heterogeneous distribution of BMI values across geographic space which ranged from 22.58 to 32.36 (kg/m²). Higher mean BMIs were seen in the central provinces (i.e. Manitoba, Saskatchewan and Alberta) as well as in the Atlantic Provinces. Mean BMI values were noticeably lower in British Columbia and some parts of Quebec. In Ontario and Quebec, the spatial pattern appears to be random. Sex specific maps are presented in Fig. 2. For males in the central provinces, the BMI distribution is similar to the full sample. Both sexes demonstrated high values in the eastern provinces.

Moran’s I at the FSA-level indicated presence of global clustering of BMI values (full sample I = 0.116 (p < 0.001), females I = 0.1 (p < 0.001), males I = 0.06 (p < 0.001)). This finding suggests that BMI values do not follow a random distribution across FSAs in Canada. Figs. 2–3 graphically display LISA plots. Significant clusters of high BMI values were primarily found in Saskatchewan, Manitoba, Southwestern Ontario and in the Atlantic Provinces. Statistically significant clustering of low BMI values was found on the west coast of British Columbia. The pattern was similar in females, except for Southern Ontario where minimal clustering was present. For males, there was significant clustering in Southern Saskatchewan, which is in direct contrast to females where clustering was found in the Northern Areas of the province. Clustering appeared to be more pronounced in the Atlantic Provinces for females versus (Fig. 4).

Spatial analysis of fast-food restaurant density and BMI

The OLS and SARE model regression results are presented in Table 2. The bivariate analysis, without controlling for confounders, showed a positive and statistically significant association between fast-food restaurant density and BMI. Rho (ρ), which measured the extent to which the error in the BMI terms was correlated, was of considerable size (ρ = 0.432 p < 0.01). The difference in the restaurant density coefficients between the OLS and the SARE model was substantial. For instance, the fast-food density coefficient in the SARE model was 0.031 (p < 0.01) while the OLS estimate was 0.041 (p < 0.01). Once confounders were included in the model, the adjusted value of rho dropped considerably, with the coefficients on restaurant density variables for the SARE model approaching to that of the OLS model. The multivariate results suggested that an additional fast-food restaurant per 10,000 people in the FSA is associated with a 0.022 kg/m² increase in BMI.

The coefficient for full service restaurants was not significant in the adjusted model, and an additional other non-chain restaurant per 10,000 people in the FSA was associated with 0.013 km² decrease in BMI. The estimated coefficients for the confounders are presented in the Appendix B. The direction and magnitude of the association between BMI and the confounders were qualitatively similar between the two models with the exception of some province covariates.

Discussion

Clustering of BMI was found in several regions, delineated by smaller geographic units and with more recent data, than what was previously reported in the literature. However, our finding is smaller in magnitude compared to what was found when obesity/overweight rates were analyzed at the health region level. A Moran’s I (p < 0.05) of 0.23 (overweight), 0.53 (obese) was previously found (Pouliou and
Table 2
Association between restaurant density and BMI.

<table>
<thead>
<tr>
<th>Restaurant Variables</th>
<th>Bivariate</th>
<th>Multivariate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OLS</td>
<td>SARE</td>
</tr>
<tr>
<td>Fast−food density</td>
<td>0.041***</td>
<td>0.030***</td>
</tr>
<tr>
<td>(0.024, 0.059)</td>
<td>(0.012−0.048)</td>
<td>(0.006, 0.04)</td>
</tr>
<tr>
<td>Full−service density</td>
<td>−0.11***</td>
<td>−0.08***</td>
</tr>
<tr>
<td>(−0.033, −0.015)</td>
<td>(−0.145−0.021)</td>
<td>(−0.079, 0.03)</td>
</tr>
<tr>
<td>Other restaurant density</td>
<td>−0.024***</td>
<td>−0.019***</td>
</tr>
<tr>
<td>(−0.033, −0.015)</td>
<td>(−0.024−0.013)</td>
<td>(−0.018−0.007)</td>
</tr>
<tr>
<td>Constant</td>
<td>27.32***</td>
<td>27.21***</td>
</tr>
<tr>
<td>(27.18, 27.47)</td>
<td>(27.05, 27.37)</td>
<td>(17.81, 25.55)</td>
</tr>
<tr>
<td>Rho</td>
<td>0.439***</td>
<td>0.439***</td>
</tr>
<tr>
<td>(0.392, 0.486)</td>
<td>(0.392, 0.486)</td>
<td>(0.392, 0.486)</td>
</tr>
</tbody>
</table>

Robust 95% CI in parentheses *** p < 0.01, ** p < 0.05, * p < 0.1

Note: All confounders are controlled for in both regressions, the details of which are presented in the Appendix.

Elliott, 2009). The differences may be due to different geographical aggregation considered or different data sets used.

We found that area-level fast-food restaurant density was positively associated with area level mean BMI. The direction of this result is consistent with the findings of a number of studies in the US (Davis and Carpenter, 2009; Dunn, 2010; Mehta and Chang, 2008), though the magnitude of the association differed. Mehta and Chang (2008) reported a higher effect when comparing areas in lowest 25th percentile of fast-food density to the highest 75th percentile to differences in BMI (β: 0.09 (0.02−0.16)), while other studies failed to find an effect (Rundle, et al., 2009; Wang, et al., 2007). Another important finding of our study was that independent non-chain restaurants were found to be inversely associated with area level mean BMI.

The effect of spatial autocorrelation in our study was shown to be important when bivariate relationships were analyzed without controlling for confounders. However, once all potential confounders were included in our SARE model, the effects of spatial autocorrelation reduced substantially.

The results of our multivariate SARE model were comparable to OLS estimates. This finding was somewhat different from those of Lebel et al. (2009) who concluded that in Quebec even after controlling for individual- and area-level characteristics, there remained significant geographic variations in overweight. The apparent differences in the results of Lebel et al. and our study may be explained by the conclusions of (Chaix, et al., 2005): the multi-level approach involves fragmenting space into arbitrary areas whereas spatial methods capture space as a continuous dimension and hence more relevant.

This paper is not without limitations. The cross-sectional design of the study did not enable us to obtain the causal effect of restaurant density on obesity. Also, the ecological nature of the study design was focused on areas (FSAs) not individuals, therefore one should be conscious of a potential ecological fallacy. Another limitation was that BMI was self-reported. Although measured BMI would have been ideal, this would not be economically feasible for a nationally representative sample of Canadians. The authors declare that there are no conflicts of interests.

Acknowledgments

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.ypmed.2013.07.002.

References


Conclusions

The spatial clustering analysis revealed a Moran’s I of 0.116 (p < 0.001), suggesting that the distribution of BMI across Canada is not random. Accounting for spatial clustering of BMI and other known confounders, we found that each additional fast-food restaurant per 10,000 people was associated with a 0.022 kg/m² increase in area level mean BMI. On the other hand, an additional independent non-chain restaurant per 10,000 people in the FSA was associated with 0.013 kg/m² decrease in mean BMI. These results suggest that municipal-level interventions in restricting availability of fast-food may play an important role in the prevention of obesity.

Conflict of interest statement

The authors declare that there are no conflicts of interests.


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