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RESEARCH PAPER

A spatial analysis of community level overweight and obesity

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Abstract

Background: Rates of overweight and obesity are now considered to be epidemic. Few studies have examined the spatial distribution of overweight and obesity at the community level, an area of geography recommended for prevention and intervention. Therefore, the present study aimed to examine the spatial variation of overweight and obesity using community geographic boundaries.
Methods: A cross-sectional secondary spatial data analysis was conducted using three combined cycles of Canadian Community Health Survey data for the province of Nova Scotia with community level boundaries. Descriptive rates were calculated using standardised incidence ratio values and spatial analysis was carried out using Global and Local Moran's I and the GetisOrdGi* statistic for cluster identification.
Results: Maps illustrating local cluster analysis showed a significant degree of similarity between neighbouring communities in urban areas more so than rural communities. Hot spot analysis maps showed communities clustering together in the urban centre tended to have lower incidence of overweight and obesity ('cool spots'), whereas clustered communities in a more rural area had a higher incidence of overweight and obesity ('hot spots).
Conclusions: The present study showed that there was geographical variation in overweight and obesity between urban and rural communities, and also there was a tendency for communities to cluster based on the incidence of overweight and obesity. This highlights the importance of understanding community level obesity rates and associated behavioural determinants, such as diet and physical activity, as well as the role that urbanisation or rurality may play in intervention initiatives for these behavioural determinants. Specifically, public health nutrition efforts for community level food environments in rural areas should ensure an individualised approach is used, whereas urban areas may be amenable to more general approaches aiming to support healthy weight status among the broader population.

Introduction

The impact of obesity on the health of individuals and communities is an important public health issue. It is estimated that, by 2015, over 700 million people globally will be obese, a problem of epidemic proportions given the role that obesity plays in the development and progression of many chronic diseases, including type 2 diabetes, various types of cancer and heart disease (World Health Organization, 2000; Birmingham *et al.*, 2003; Choudhary *et al.*, 2007; Low *et al.*, 2009).

Although traditional intervention and prevention efforts to reduce overweight and obesity have focused on individual behaviour change (most specifically those behaviours relating to nutritional intake and energy expenditure), a range of complex social and environmental influences are implicated in the development of obesity and chronic disease, which go beyond the concept of individual choice. Recently, there has been a shift toward understanding the development of overweight and obesity from an ecological perspective (Egger & Swinburn, 1997). This broader perspective provides opportunities to move beyond a focus on individual behaviours and to develop a more sophisticated model of how population health determinants, such as features of the built environment, cultural and socio-economic influences, might interact with individual characteristics to produce variations in overweight and obesity in society, through the creation of an 'obesogenic environment' (Swinburn *et al.*, 1999). In the context of nutrition, this population approach therefore recognises the importance of access to and availability of healthy food both outside the home and within it.

The obesogenic environment is challenging to characterise, often leading to inconsistent evidence concerning links between weight status, behaviour and environment (Kirk *et al.*, 2010). Geographical methodologies provide opportunities to associate individuals with characteristics of their local environment and to assess spatial patterning of health outcomes such as rates of overweight and obesity (Cromley & McLafferty, 2002). However, this type of research is still in its infancy and the potential for understanding its utility within the nutrition field is as yet under-explored. Geographic information systems can help to connect features of where we live with our health outcomes and experiences, and have been employed in several innovative studies of overweight and obesity. For example, mapping and spatial analytical techniques have been used to explore regional variations and spatial clustering of obesity rates (Pouliou & Elliott, 2009). Similar techniques were employed to identify locations for targeted obesity intervention efforts; however, these techniques often utilise administrative rather than meaningful boundaries to the residence of a particular geographical area (Abayomi *et al.*, 2009). Specifically, geographical variations in overweight and obesity may still persist even after accounting for individual and community-level characteristics, suggesting the existence of other factors (e.g. land use, fast food availability or local health promotion policies) in explaining variations of overweight and obesity (Lebel *et al.*, 2009). Collectively, these results provide evidence to support the notion that place has a role in explaining differences in rates of overweight, in addition to individual and lifestyle factors, although further exploration is needed to understand its contribution.

Although geographical analyses can offer exploratory and explanatory insights beyond traditional epidemiological approaches, they can be particularly sensitive to the selected scale of analysis. For example, analyses conducted using large geographical units such as provincial/state boundaries may not provide results at a resolution suitable for the development of more local policies or decisions for obesity prevention. Selecting the most appropriate scale of analysis depends on the availability of data, as well as the scale or geographical extent to which policies and interventions may be most effective. Misalignment of scale in the context of population health research can occur when the spatial unit of analysis does not match the scale to which the conclusions are applied. For example, it would be inappropriate to make conclusions about the association between socio-economic status and obesity at the neighbourhood level when the analysis was conducted at a county or state scale (Openshaw, 1984). The shape of an area may also influence the accuracy in assessing spatial variations of health outcomes. Access to individual level data permits aggregation to areas of a size meaningful for intervention or the development of health policy. Features of the built environment that influence overweight and obesity (e.g. influencing food choices and the nutrition environment) are very local phenomena that are best described and identified by geographical analyses that go beyond standard administrative or census geographies (Hackett *et al.*, 2008).

The importance of a geographical approach to understanding obesity is well illustrated by analysing Canadian obesity data geographically. In Canada, obesity rates vary substantially from west coast to east coast, with rates of obesity being among the lowest in the west coast province of British Columbia and among the highest in the east coast province of Nova Scotia (Shields & Tjepkema, 2006). Specifically, the rates of overweight and obesity in Nova Scotia have risen to a staggering 59.7% of the population. However, there are significant differences between urban (47.8%) and rural (67.4%) populations, suggesting marked geographical variation even within a predominantly rural province with a small number of large urban centres including Halifax. A recent effort to link data on the determinants of population health, with the purpose of informing decision-making and provincial policy development, has led to the development of unique geographical boundaries intended to represent distinct and meaningful communities across the province called Nova Scotia Community Counts (NSCC, 2007). The aim of this research was to estimate rates of overweight and obesity at the community level and apply geographic techniques to investigate the spatial variation of these rates across the province. Improving our understanding of where rates of overweight and obesity are clustered, or are higher than expected can provide a focus for intervention efforts aimed at modifying environmental features, including those related to food and nutrition.

Materials and methods

This analysis was conducted using nationally collected data for the province of Nova Scotia, Canada. Geographically, Nova Scotia is a peninsula bounded by the Atlantic Ocean, Bay of Fundy and Northumberland Strait and one of 10 provinces and three territories in Canada; the second smallest covering 55 284 km^2. The population (as of 2009) was 940 397, with almost half (403 188 people) of the total population residing in the capital region, Halifax Regional Municipality (Statistics Canada., 2009). Ethical approval for secondary data analysis was obtained from Dalhousie University Health Sciences Research Ethics Board.

Study design and data sources

The present study comprised a cross-sectional population-based secondary data analysis of the spatial distribution of overweight and obesity across Nova Scotia communities, using nationally collected data from the Canadian Community Health Survey (CCHS; Statistics Canada, 2003). The CCHS is a cross-sectional survey that collects self-reported information related to health status, healthcare utilisation and health determinants for the Canadian population, and is administered every few years. We abstracted individual records for the residents of Nova Scotia, including postal codes, age, sex, and measure of overweight or obesity, across three independent samples. Areas not covered by the survey include First Nation reserves, institutions and national parks. The survey includes all individuals aged ≥ 12 years, with cycle 1.1 conducted in 2000–2001, cycle 2.1 in 2003 and cycle 3.1 in 2005. By combining three CCHS cycles, the data for this small province formed a sufficiently large sample size to allow for community level analysis. The method of pooling data without adjusting sample weights when analysis is based upon a ratio (as for the present analysis) has been discussed previously (Thomas & Wannell, 2009). Spatial analysis was conducted using Global and Local Moran's *I* and the Getis-Ord G_i* statistic for cluster identification. Additional details related to deployment, sample selection and questionnaires for each cycle of the CCHS are available from Statistics Canada (Statistics Canada, 2008).

CCHS data were accessed through the Atlantic Research Data Centre (ARDC) at Dalhousie University in Halifax, Nova Scotia. The combined dataset (n = 10 054) was then geo-coded using the postal code conversion file (PCCF+) package available from Statistics Canada (Statistics Canada PCCF+, 2009), resulting in a sample of individual CCHS respondents geographically distributed across the entire province. The body mass index (BMI) variable was precalculated and included in the CCHS data using appropriate methods of calculation for youth and adults in all cases (Cole *et al.*, 2000), excluding pregnant women and individuals with outlying values for height [i.e. anyone less than 0.914 m (3 feet) or 2.108 m (7 feet) and over, consistent with CCHS-derived data]. Values were then categorised into risk levels using the standard World Health Organization classifications (World Health Organization, 1995) (i.e. overweight as a BMI between 25 and 29.9 kg m^{-2} and obese as a BMI > 30 kg m^{-2}). Each respondent was allocated to a community-level geographical unit using a spatial query procedure in ARCGIS (ESRI, Redlands, CA, USA). Counts of being overweight and obese were then summed for each community. Community-level population data were then used to estimate internal indirect standardised incidence ratios (SIR) by age (five cohorts which are predetermined by the CCHS from 15 to 64 years) and community for each sex, as has been described previously (Curtin & Klein, 1995). After weight and age filtering, this produced a final sample size of 5681.

The community-level geographical units used for this analysis were based on natural clusters of populations, rather than census or local government boundaries. At the time of analysis, Nova Scotia comprised 275 distinct communities; 20 Indian reserves (not included in CCHS data collection as previously mentioned because there are specific ethical issues involved in conducting surveys in these communities) and four provincial parks, leaving 251 communities for our analysis. The geography files were provided by Nova Scotia Community Counts (NSCC), a programme funded by the Nova Scotia Department of Finance, established to develop a statistical infrastructure system of information about Nova Scotian communities because locally representative community boundaries are more likely than census boundaries to represent areas meaningful to the local population (NSCC, 2007).

Spatial data analysis

The first phase of spatial data analysis included mapping the distribution of SIRs for being overweight or obese in males and females by community. A SIR is a value that represents the ratio of observed incidence of disease to expected incidence of disease, whereas a value of zero indicates a community with no observed overweight and obese cases. Phase two included the use of three spatial statistics to determine spatial clustering (global Moran's *I*, local Moran's *I* and Getis-Ord *G**). Global Moran's *I* statistic is a global measure of spatial autocorrelation, a geographical phenomenon that can test whether community SIR values are randomly distributed or whether neighbouring SIR values tend to be more similar than non-neighbouring (Thomas & Wannell, 2009). Moran's *I* shows the strength of spatial autocorrelation on a scale ranging from +1 to −1. A value of +1 indicates positive spatial autocorrelation where high values are proximal to other high values. Conversely, a value of −1 represents negative spatial autocorrelation where high values tend to be near low values. A value of zero indicates no spatial autocorrelation, or that the data are randomly distributed within the studies geographical boundaries (Anselin, 1995).

The local Moran *I* statistic reveals whether or where local clustering occurs, which is not provided by the global Moran's *I* statistic (Anselin, 1998). The local Moran's *I* identifies individual clusters, or small regions of clusters that may not be evident within the global pattern (Rogerson, 2006). A cluster and outlier analysis tool in a geographic information system (GIS) was used to calculate the local Moran's *I* statistic and associated *Z*-score. This tool tests whether the homogeneity (or heterogeneity) in values between a community and its neighbouring communities are greater than would be expected by chance. A community with a high Moran's *I* statistic indicates that its SIR values are close in magnitude to the neighbouring community's SIR values. A low Moran's *I* statistic indicates an 'outlier' where the SIR of a community is dissimilar to the neighbouring values.

Local Moran's *I* is a useful test for spatial autocorrelation; however, the output does not signify whether areas of high local spatial autocorrelation are clustered together. The G_i* statistic is an effective tool for measuring high rates (also called hot spots or areas of similar high values as indicated by a positive G_i* value) and low rate (also called cool spots – clusters of low values identified by negative G_i* figures) (Getis & Ord, 1992). Cluster tolerance is defined as the distance between features to be tested (e.g. inverse distance weighting). A 50-km distance threshold was adopted, as determined through sensitivity analysis (Rogerson, 2006).

Results

Standardised incidence ratio

Community SIR values of overweight and obesity were higher for females compared to males and ranged from zero (n = 5) to 12.2 for males and 14.7 for females with the provincial mean at 1.2. Of the 251 Nova Scotian communities, 145 (58%) and 138 (55%) communities exhibited above-expected SIRs and 106 (42%) and 113 (45%) exhibited below-expected SIRs for males and females, respectively (χ^2 = 0.40, P = 0.53), showing no significant difference between male and females. SIR values were also mapped according to sex at the community level, and then classified by SD. The male and female map showed a high degree of spatial heterogeneity (Fig. 1).

Spatial autocorrelation and cluster identification

Global Moran's *I* values indicated that, overall, the SIRs were spatially randomly distributed for males (Moran's I = −0.017; *Z*-score = −1.626) and females (Moran's I = −0.017; *Z*-score = −1.625).

Despite showing no spatial autocorrelation using the global test, the results of the local Moran's *I* test reveal clusters of communities with similar SIR values and outlying communities with dissimilar values. Figure 2 shows the degree of local spatial autocorrelation for both males and females, with lighter areas showing lower levels of autocorrelation and the darker areas showing higher levels of autocorrelation. The community clusters found to be highly autocorrelated were similar across sex, with the degree of autocorrelation being higher for males than for females.

Figure 3 displays the results of the Getis-Ord G_i* statistical test. The main urban centre of Nova Scotia (Halifax metropolitan area) found on the eastern shore, which holds almost half the population of the province, emerged as a cluster of low SIR values. Although this pattern holds similar for both sexes, the female values formed a larger, contiguous cluster, whereas male values appeared as three distinct areas of low rates. The northwestern shore, a rural area of the province, showed high SIRs for both sexes. Again, the female values formed a larger, contiguous grouping than the male values. These clustered hot and cool spots were statistically significant at the 95% confidence level.

Discussion

The present study aimed to estimate rates of overweight and obesity at the community level and apply geographical techniques to investigate the spatial variation of these rates across the province. This was accomplished by exploring the spatial distribution and clustering of rates of overweight and obesity among naturally formed small area communities in Nova Scotia, Canada. The overall results confirm the global upward trend of overweight and obesity, showing that 58% (males) and 55%

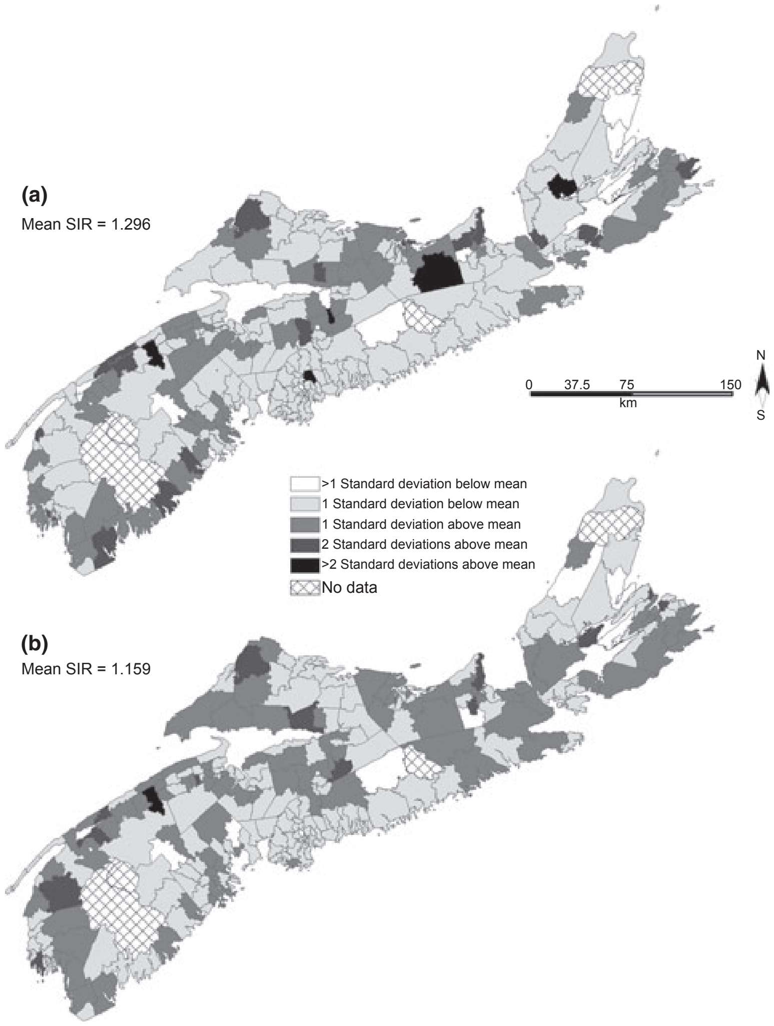

Figure 1 Standard incidence ratios (SIRs) by community and sex. (a) Males. (b) Females.

(females) of Nova Scotia communities have higher than expected rates of overweight and obesity. In addition to confirming the prevalence of overweight and obesity, our spatial analysis showed a great deal of spatial heterogeneity across the province, surprising given the relatively small geographical area. Although there is considerable range in rates of overweight and obesity in Nova Scotian communities, no clear pattern is visible when these are mapped spatially.

In addition to describing the spatial distribution of overweight and obesity, clusters of similar rates of overweight and obesity by community were found. These results showed higher levels of correlation in rates between communities in the provincial capital region compared to rural regions. This could indicate that, in neighbouring communities with similar rates (i.e. high spatial autocorrelation), the behavioural determinants of overweight and obesity also cluster. Research that has examined community spatial autocorrelation of behavioural determinants, such as diet and physical activity, is rare and represents a focus for future research. Also, it is reasonable to assume that these community clusters may share similar social or built environment features that have contributed to the common community rates of overweight and obesity, including those relating to food intake (Diez-Roux *et al.*, 1999; Reidpath *et al.*, 2002). If true, these communities may benefit from similarly designed prevention efforts to modify the food and physical activity environments within them. Conversely, those communities with dissimilar rates (i.e. low spatial autocorrelation) likely possess additional complex and varied aetiology of community overweight and obesity. Therefore, the findings of the present study suggest that environmental determinants of diet and physical activity for rural regions may follow a heterogeneous pattern similar to the weight status found in the present analysis, which would need to be better understood before any effective, community-level intervention could be developed. For

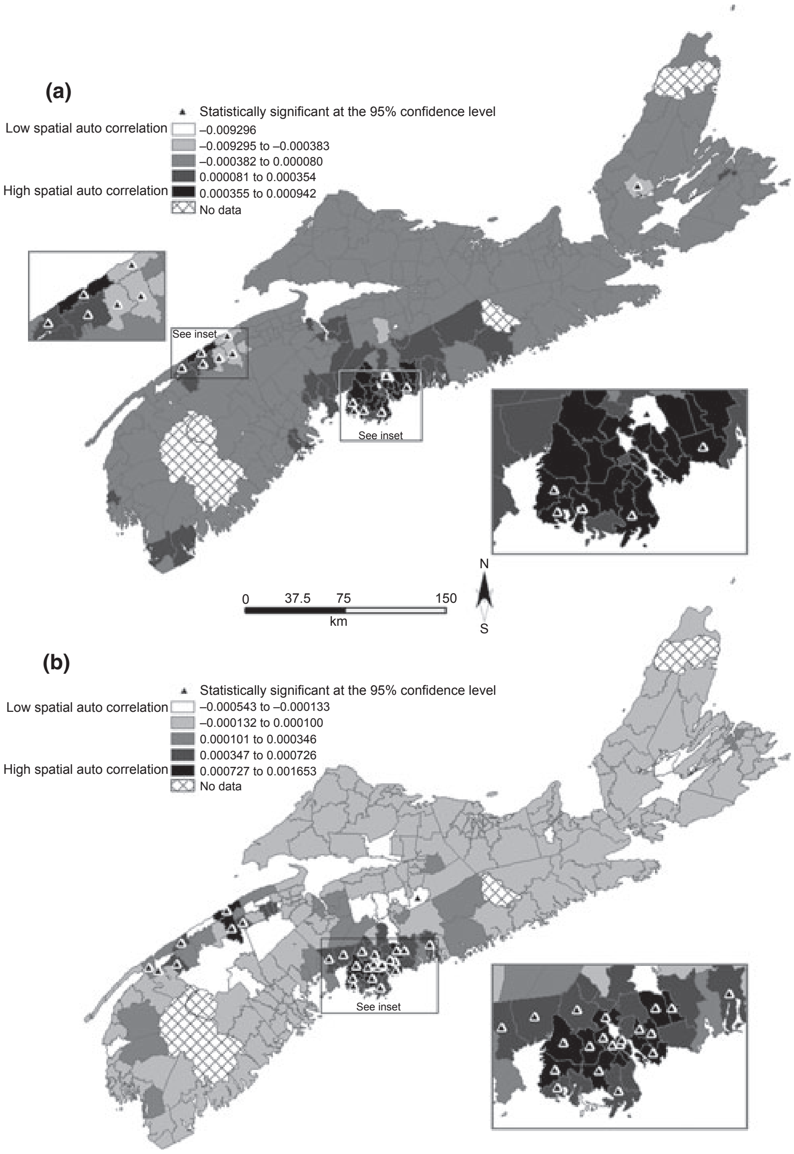

Figure 2 Local Moran's *I* for Nova Scotia by community and sex. (a) Males. (b) Females.

example, one community may have higher rates of socio-economic deprivation that limit access to healthy nutritious food (Black & Macinko, 2008; Larsen & Gilliland, 2008; Drewnowski, 2009; Black *et al.*, 2010; Ruel *et al.*, 2010), whereas another community may have more supportive built environment features, including a mixed neighbourhood design that does not require reliance on automobiles and long commuting distances for work and play (Lopez-Zetina *et al.*, 2005). Similarly, neighbouring community residents may share similar socio-economic backgrounds, a well-established correlate to obesity, whereas others may not.

Given the potential for determinants of weight status to vary by community, population health intervention efforts should be preceded by a type of community health needs assessment related to environmental barriers and facilitators for weight status. However, there is a paucity of research in this area, and a particular lack of robust measures of the nutritional environment at the population level (Lytle, 2009). A potential framework for assessment of the environmental determinants of walking and cycling was developed that could provide guidance for similar efforts in nutrition, although this has yet to be tested (Pikora *et al.*, 2003). Improving the assessment and application of population nutrition exposures is therefore critical to understanding the causes and consequences of obesity, as well as other chronic diseases, and to the implementation and evaluation of population-level interventions aimed at reducing diet-related disease (Kirk *et al.*, 2010).

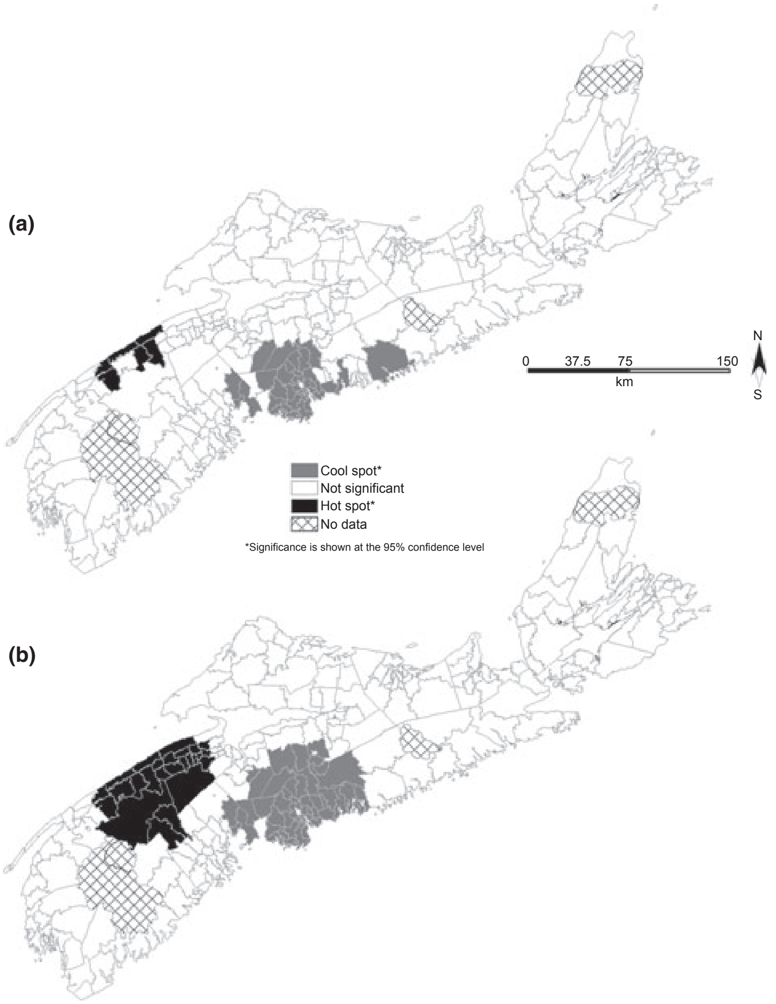

Figure 3 G_i* statistic (hot spot analysis) for Nova Scotia by community and sex. (a) Males. (b) Females.

The mixed homogeneous and heterogeneous spatial patterning found in the present study has also been reported in previous geographical analysis related to obesity, including a national Canadian study that found similar clustering of overweight and obesity using administratively defined, provincial health regions (Pouliou & Elliott, 2009). It was also speculated that individual level factors including behavioural and socio-economic characteristics might explain the variation in weight status. The explanations for our diverse clusters are likely to be similar, with some communities holding a larger amount of opportunities for poor dietary habits and others having greater opportunities for physical activity, both identified as correlates of weight status (Sallis & Glanz, 2009). Specifically, the link between the influence of small privately owned grocery stores, large corporately owned supermarkets and fast food outlets on community diet quality has been discussed, including the potential impact of reduced shelf space for healthy foods comprising fresh produce (i.e. fruits and vegetables) in community grocery stores or supermarkets, on the consumption of those foods. In addition, the lack of access to grocery stores in rural areas has been identified as a potential contributor, especially in communities that are less affluent (Cummins & MacIntyre, 2006).

The present study also suggests that this pattern may differ depending on the urbanisation or rurality of a community, with rural regions having more variation in weight status and possibly the underlying behavioural determinants. The existence of an urban/rural difference in weight status has been reported in the literature previously (Bruner *et al.*, 2008). In particular, research has found that living in a rural area is a risk factor for overweight and obesity in children in the USA (Lutfiyya *et al.*, 2007). Other findings have reported reduced obesity when rural communities were perceived to have environments that supported healthy eating and activity (Casey *et al.*, 2008). In addition, there are results showing small differences between neighbourhoods with respect to diet, and there is a need for additional research to better understand neighbourhood level determinants of diet (Curtin & Klein, 1995). The results of the present study support these findings with a clear urban–rural difference in community clustering and hot spot analysis. This also suggests that it may be challenging to use large-scale, 'one size fits all' approaches to prevention or intervention, especially in areas that include large rural areas such as Nova Scotia and most other provinces in Canada. However, determining the specific mechanisms responsible for this complex interaction warrants further investigation into what physical, economic, political and sociocultural aspects of those communities might contribute to higher or lower rates of overweight and obesity.

The results of the present study are important for understanding the role that place might play in the health status and the prevention of disease in a community and to the evolution of GIS spatial analysis for health research. However, there are some specific limitations related to the present study, including the use of self-reported height and weight, a less than ideal measure of adiposity. Because individuals tend to overestimate their height and underestimate their weight, leading to an underestimation of overweight and obesity, we consider it is reasonable to view the data reported here as conservative estimates of true size (Katzmarzyk, 2002). The study may also be affected by the modifiable areal unit problem, which recognises that areal units used in geographical studies are typically arbitrary and modifiable, and that the results are subject to decisions of aggregation (Openshaw, 1984). The Nova Scotia Community Counts geographical units (described in the Materials and methods) have been developed to create more meaningful boundaries when investigating issues affecting residents. Combining three cycles of the survey data creates the potential for the same individuals to be included in multiple survey cycles, even though each cycle is assumed to be independent from the next. The survey data were checked for duplicates, first by checking for replicates of postal codes, and then using demographic characteristics such as age, education level and income. Suspected duplicates were removed and all cases were treated as independent measurements. The geocoded locations of rural postal codes are likely to be less accurate than those in urban areas. However, any spatial differences between the true location and the geocoded location are a result of a random process and unlikely to systematically bias rate calculations. In addition, the inclusion of possible determinants of community level overweight and obesity, including genetic variation and determinant of weight-related behaviours such as food purchase and access to recreation opportunities, was beyond the scope of the present study.

Conclusions

The findings of the present study clearly illustrate distinct regions of geographical homogeneity and heterogeneity for rates of overweight and obesity. Although our analysis used a small geographical boundary and a meaningful unit of analysis (i.e. communities) compared to previous work, the explanation for why a particular geographical area has a rich mix of homogeneous and heterogeneous patterning remains elusive. Future research should include a comprehensive, spatial analysis including environmental determinants of both diet and physical activity measures aiming to disentangle the complex role that place plays in the health of communities. GIS will be a critical tool to help answer these questions; however better measures of the nutrition environment are much needed (Lytle, 2009).

The findings of the present study show clusters of significantly lower rates ('cool spots') found in the most urbanised areas, whereas the higher rates ('hot spots') of obesity were found in the rural areas of the province, with an increased variation in rates also found in rural areas. The most probable explanation for this variation is the differing environmental determinants found across communities. Specifically, prevention and intervention efforts should consider that rural areas have a varied aetiology for community weight status compared to urban areas and therefore may need a different approach to intervention.

The present study demonstrates the value of geographical research with respect to the understanding of nutritional determinants of obesity and other chronic diseases. Specifically, public health nutrition efforts for community level food environments in rural areas should ensure an individualised approach is used, whereas urban areas may be amenable to a more generalisable approach to supporting healthy weight status among the broader population; therefore, public health professionals should examine specific community level characteristics prior to intervention to establish important behavioural and environmental determinants of overweight and obesity. The development of a community needs assessment that captures robust measures of the population-level food environment (e.g. grocery stores, supermarkets and fast food outlets) would be an important next step.

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Conflicts of interest, sources of funding and authorship

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TLP lead the conception and design, conducted the data analysis and drafted the original manuscript, and approved the final copy for publication. DGCR participated in the conception, design and data analysis, reviewed the drafted manuscripts, approved the final copy for publication, and provided overall direction. TJBD participated in the conception, design and provided input on data analysis, reviewed the drafted manuscripts, approved the final copy for publication, and provided overall direction. SFLK participated in the conception and design, reviewed the drafted manuscripts, approved the final copy for publication, and provided overall direction.

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