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ORIGINAL ARTICLE

Food access and children's BMI in Toronto, Ontario: assessing how the food environment relates to overweight and obesity

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Abstract

Objectives The objective was to examine how access to fast food restaurants, less healthy/healthier food outlets and supermarkets relate to measured levels of overweight and obesity among grade 5 and 6 students.

Methods Measured height and weight data were obtained to measure BMI. The location and type of food outlet were derived from Toronto Public Health. The density of fast food, less healthy/healthy food outlets and supermarkets within a 1-km walk of the child's home was calculated along with the distance to the closest. Logistic regression models examined the relationship between food access and overweight/obesity.

Results Lower income residents were more likely to be overweight or obese, as were boys. Living in an area with a higher density of healthy food outlets and in close proximity to a supermarket decreased the odds of being overweight or obese.

Conclusions Addressing several limitations in the literature, the findings confirm an association between the food retail environment and body weight. Density of healthy food outlets and distance to the nearest supermarket are important factors to be considered in addressing the childhood obesity pandemic.

Keywords Food environment · GIS · BMI · Children's health · Obesity

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Introduction

The prevalence of obesity among Canadian children has increased dramatically in recent years. Data based on three national health surveys estimated the prevalence of obesity for 12–19-year-olds at 1.8 % in 1981, 2.4 % in 1988 and 12.8 % in 2007–2009 (Janssen et al. 2011). Furthermore, body composition indicators (body mass index, waist circumference, skinfold measures) have also experienced substantial increases over the same time period (Tremblay et al. 2010). According to National data on Canadian children and youth aged 5–19 (Roberts et al. 2012), 31.5 % are classified as overweight (19.8 %) or obese (11.7 %). The prevalence of obesity is higher among boys than girls (15.1 vs. 8.0 %), a difference that is magnified among 5–11-year-olds, where boys are more than three times as likely to be overweight or obese than girls (19.5 vs. 6.3 %). Among 5–11-year-olds, 32.8 % are classified as being overweight or obese. The main determinants of obesity include genetic disposition, increased energy intake, and decreased energy expenditure (Hill and Peters 1998; Andersen 2000).

The environment or neighbourhood features have been identified as being a potential risk factor for obesity, as they may relate to both eating behaviour (energy intake) and physical activity levels (energy expenditure) (Hill and Peters 1998). Research in Canada and the United States reports that people are eating more meals away from home (French et al. 2001; Statistics Canada 2003; Burdette and Whitaker 2004) (at fast food restaurants and other types of restaurants), which relates to obesity and weight gain (Binkley et al. 2000; Pereira et al. 2005; Bisset et al. 2007; Rosenheck 2008). Studies in the United States have reported that easy access to fast food restaurants or convenience stores relates to obesity among adults (Chou et al. 2004; Maddock 2004; Morland et al. 2006; Li et al. 2008; Wang et al. 2008), but these findings are not conclusive as some studies have reported no association (Simmons et al. 2005; Lopez 2007; Crawford et al. 2008; Viola et al. 2013). Access to healthier foods or supermarkets and body weight have also produced mixed results to date, but many studies have found that good supermarket access lowers the risk of obesity (Morland et al. 2006; Bodor et al. 2010; Gibson 2011).

For children, a growing body of research in the United States has uncovered a relationship between obesity and the consumption of fast food, but mixed results have been reported as to whether food access relates to body weight (Fleischhacker et al. 2011). One study conducted in Indiana, USA reported that increased access to fast food was associated with a higher body mass index (BMI) for children aged 3–18 (Liu et al. 2007), while another study in Minnesota (Minneapolis/St. Paul), USA reported that residential proximity to restaurants, convenience stores or other food retail facilities within one half or one mile (800 or 1,600 m) were associated with adolescents' (aged 11–18) sugar-sweetened beverage intake, and having a convenience store within 1 mile of the home was significantly associated with higher BMI and percentage of body fat (Laska et al. 2010). However, these findings are not conclusive, as other studies in Ohio and nationally in the US found no relationship between proximity or density of fast food restaurants and children's body weight (Burdette and Whitaker 2004; Sturm and Datar 2005). Furthermore, a recent study found a positive association between supermarket access and higher obesity rates (Fiechtner et al. 2013), while a longitudinal study found that increased supermarket availability related to a lower BMI for elementary-aged children (Powell and Bao 2009). To date, much of the research on food access and obesity has produced mixed results and further work is necessary. A recent review reported little evidence of an effect of the retail food environment surrounding schools on food purchases and consumption, but some evidence of an effect on body weight (Williams et al. 2014).

There is even less Canadian research to date examining the link between the food environment and children's health. One recent study in London, Ontario reported an association between both proximity and density of fast food restaurants around the home along with fast food density around the school with increased purchasing of fast food by adolescents (aged 11–13), while supermarket access did not relate to food intake (He et al. 2012). Also in London, Ontario, a higher number of convenience stores within 500 m of the home was associated with higher self-reported BMIs in children aged 10–14 (Gilliland et al. 2012). A study in the province of Ontario reported that a greater number of fast food restaurants around the school corresponded with an increased likelihood of being overweight for children in grades 5–8, as did a higher density of supermarkets (Leatherdale et al. 2011). Once again these findings are not conclusive, as one national study in Canada found no relationship between the density of fast food outlets or supermarkets around schools and BMI in children (aged 11–16) (Seliske et al. 2008).

The inconsistent findings may relate to the methods used to, (a) measure BMI, (b) examine the environment, and (c) classify food outlets. All of the Canadian studies to date have used self-reported height and weight to obtain a child's BMI (Leatherdale et al. 2011; Gilliland et al. 2012). Furthermore, how the environment is measured also varies between studies: some researchers use straight line buffers to define the neighbourhood (Seliske et al. 2008; Leatherdale et al. 2011), while others use multiple approaches (Gilliland et al. 2012). Finally, how data on fast food, supermarket or convenience store locations are obtained also differ in recent research (Seliske et al. 2008; Gilliland et al. 2012). Some studies use company websites and telephone directories to classify outlets (Seliske et al. 2008), while others only examine popular fast food chains (Crawford et al. 2008), and some use previously collected data (Leatherdale et al. 2011). All of these methodological factors may explain the inconsistent results concerning relationships between the food environment and children's body weight.

The purpose of this study was to examine how access to fast food restaurants, less healthy convenience stores, supermarkets and healthier food outlets relate to overweight and obesity in grade 5 and 6 students residing in Toronto, Canada. This study extends and improves upon pre-existing Canadian literature by introducing a number of methodological improvements, which include the use of directly measured height and weight (to calculate BMI), network buffer analysis and accurate up-to-date records of food outlets obtained from Toronto Public Health.

Methods

Study area and data

Data were collected as part of Project BEAT which was a large-scale, multidisciplinary study examining how the built environment influences school travel patterns and levels of physical activity in Toronto (2010–2011; www.beat.utoronto.ca). Toronto is Canada's largest and most culturally diverse city with a population of approximately 2.6 million people. The University of Toronto research ethics board and the Toronto District School Board ethics review board granted permission prior to data collection. Data collection took place at 17 selectively sampled schools in neighbourhoods of contrasting built environments and income levels. While there are many ways to classify built environment, this study applied two broad categories that reflect the historical and political context of Toronto's development: the central city and inner-suburbs. The central city consists of many older neighbourhoods surrounding the downtown core, while the inner-suburbs include more recently constructed neighbourhoods amalgamated in 1998. Nine of the sampled schools were in the central city, while eight were in the inner-suburbs. Furthermore this sample was stratified by income, with nine schools located in census tracts in the lowest quartile for median household income and eight schools in the highest quartile. This sampling method allowed for diversity in both the built and social environment.

Grade 5 and 6 students ($n = 1035$) and parents completed consent forms prior to data collection. Researchers measured height and weight to calculate BMI for each of the students. Height was recorded to the nearest 0.1 cm using a rigid stadiometer, and weight was recorded to the nearest 0.1 kg using an electronic weighing scale. The weighing scale was a Lifesource Profit Precision Scale. The stadiometer was a Seca Measuring Device Scale Model 2141817009. Measurements took place in a private setting, with children wearing light clothing, and no shoes. Children were classified as underweight, normal weight, overweight or obese using age- and sex-specific published international BMI cut-points (Cole et al. 2000).

Children and parents also completed a survey, which obtained the gender and age of the child and provided the home address. Gender was not only used to accurately determine the child's weight status (underweight, normal weight, overweight or obese), but also entered into the models to explore a potential gender interaction. Since no individual level income variable was available (due to a low response rate to these questions in the survey), the median household income (2011) for each dissemination area (DA) was the measure of income used in this study. Children were assigned a neighbourhood income value based on the home location. The mean size of a DA in Toronto is 0.187 km^2, while the average median household income in Toronto is $74,312.

Fast food and less healthy food locations: GIS analysis

Fast food locations were derived from Toronto Public Health's Toronto Healthy Environments Inspection System (THEIS) (2012). Fast food locations were defined as establishments classified in the inspection database as a restaurant, cafeteria, food court vendor, food take out, hot dog cart, or ice cream/yogurt vendor. Establishments were also required to have takeout options available, limited or no wait staff, and customers having to pay prior to receiving food. Locations with restricted access to the public were removed (e.g. food outlets in arenas where patrons must pay admission to access the food outlet). Business names with keywords suggesting a focus on healthier items were also removed (e.g. juice, salad). The City of Toronto's Social Development, Finance and Administration division provided a network dataset for the city to measure walking distances.

Since much of the research to date has provided mixed results as to how the food environment actually relates (or does not relate) to body weight, access to less healthy and healthier food outlets along with supermarkets were also explored. A 'Less Healthy Food Retail' and 'Healthier Food Retail' category were created. Healthier Food Retail were classified in the THEIS as a bake shop, bakery, butcher shop, fish shop, food store (convenience/variety), or supermarket; and, sells a significant quantity and diversity of vegetables and/or fruit or specializes in one category of Canada's Food Guide (e.g. vegetables and fruit, grain products, milk and alternatives, meat and alternatives). If outlets did not meet the definition for healthy food retail, they were classified as less healthy food establishments. To account for locations outside of the City of Toronto in bordering municipalities, additional field work was completed to ensure all fast food restaurants and less healthy food outlets within 2 km of the respondents' home were included in the analysis. To explore how supermarkets only may relate to body weight, the supermarket category was examined separately. A supermarket is defined by Toronto Public Health as: "a premises similar to a food store but offers large volume of food for sale and is multifunctional, and may include speciality departments/units such as delis, butcher shops, bakeries or seafood counters" (Toronto Public Health 2004).

The home location of the child, all fast food restaurants, healthy/less healthy food outlets and supermarkets were geocoded using ArcGIS (Version 10.2) as points to the exact address. The first method of analysis was the closest facility and measured the distance from the home to the nearest fast food restaurant, healthy/less healthy food outlet and supermarket. Within a geographic information system (GIS), the distance from each child's home to the closest fast food restaurant (healthy/less healthy food outlet and supermarket) was calculated along the walking network. The walking network includes streets, multi-use pathways, and pedestrian walkways, and compiles distance based on the shortest path to the nearest food outlet.

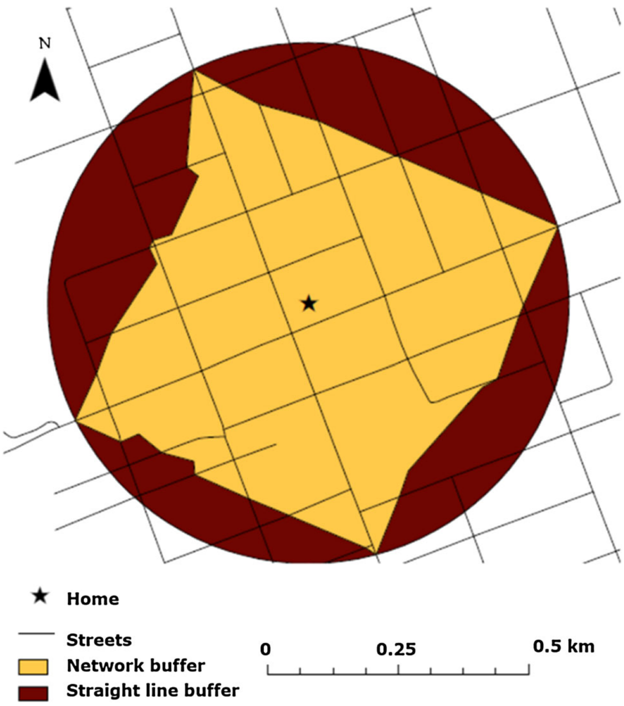

Fig. 1 Comparison of a network buffer and straight line buffer around a home in Toronto, Canada, 2010–2011

The second method of analysis examines the density or concentration of fast food outlets, healthy/less healthy food outlets and supermarkets around the child's home. For this, a 1-km network service area (buffer) was compiled around each of the respondents' homes. The network service area is once again calculated based on the walking network. All of the area within the network service area can be reached within a 1-km walk. A distance of 1 km was selected as it has been used in previous work on food access and is a common measure of accessibility (Apparicio et al. 2007; Larsen and Gilliland 2008; Williams et al. 2014), but it also represents close proximity around the home (approximately a 12–15 min walk). Some previous studies have used a straight line 'buffer' or radius to identify all sites located within a defined distance from the origin (Crawford et al. 2008; Leatherdale et al. 2011), but the circular buffer technique does not take into consideration how variations in the configuration of the walking network relate to the actual distance travelled. Figure 1 displays the difference between a network and straight line buffer. Recent work highlights the difference between buffer types (Gilliland et al. 2012), but the use of the network buffer should more accurately capture access to food retail. For the home neighbourhood (i.e. 1-km network service area), the number of fast food outlets, healthy/less healthy food stores and supermarkets were calculated. These values were weighted based on the size of the buffer (area in km^2) to create a fast food density, healthy/less healthy food density and supermarkets variable for each child.

Statistical analysis

Children were classified as being underweight, normal weight, overweight or obese. These classifications allowed for the creation of a binary outcome variable for children who were (and were not) overweight/obese. Due to data errors or absences during data collection, the sample was reduced to a total of 944 children. Using SPSS (version 21), four separate binomial logistic regression models examined how proximity to, and density of, fast food restaurants, less healthy food outlets, healthy food outlets and supermarkets relate to the likelihood of being overweight or obese. Gender, age and median household income were also included in the model to examine their influence. Following initial analysis, all of the variables were tested for multicollinearity issues and no issues existed. Four models were created rather than including all of the variables in one model, as the different categories of food retail were correlated with one another. Variables were considered significant with a p value of <0.05.

Results

The median age of the sampled children was 11 years. The sample included 54 % girls ($n = 508$) and 46 % boys ($n = 436$). The median neighbourhood household income for the sample was $69,418. Just over 26 % of children were classified as being overweight or obese, while 69 % of students had a healthy body weight (Table 1). A total of 3,888 fast food restaurants and 2,520 less healthy food outlets, 1,235 healthy food outlets and 481 supermarkets were included in the analysis for this study. Most homes had an average (median) of just under six fast food restaurants per square kilometre around their home, while the median distance to the nearest fast food restaurant was 0.48 km. There were also nearly six less healthy food outlets per square kilometre around the home (median) and the median distance to a less healthy food outlet was 0.37 km. There was an average of between two and three healthy food outlets per square kilometre around the home, with a median distance to the nearest healthy food outlet of just over half a kilometre (0.57 km). Most homes have over one supermarket around the home with the median distance to the closest being 0.66 km. These findings suggest that most households had easier access to both fast food and less healthy food outlets, than healthy food stores and supermarkets, but overall the median access to food retail outlets was quite high. For children, living in a neighbourhood with a higher density of fast food restaurants or

Table 1 Descriptive statistics of sample in Toronto, Canada, 2010–2011

Variable	Mean	Median	SD	*N*	Percent
Body mass index (BMI)	18.85	18.02	3.55	943	–
Density of fast food outlets in 1 km (per km^2)	7.82	5.67	10.11	943	–
Distance to nearest fast food outlet (km)	0.63	0.48	0.49	943	–
Density of less healthy food outlets 1 km (per km^2)	8.98	5.99	9.49	943	–
Distance to nearest less healthy food outlet (km)	0.59	0.37	0.56	943	–
Density of supermarkets (per km^2)	1.58	1.28	1.59	943	–
Distance to nearest supermarket (km)	0.89	0.66	0.63	943	–
Density of healthier food outlets (per km^2)	3.38	2.35	3.59	943	–
Distance to nearest healthy food outlet (km)	0.815	0.57	0.69	943	–
Median household income $CDN	70,912.75	69,418.50	38,099.51	943	–
Child's age	11.02	11.00	9.63	943	–
Number of girls	–	–	–	508	53.80
Number of boys	–	–	–	436	46.20
Number of underweight children	–	–	–	45	4.80
Number of children with healthy bodyweight	–	–	–	651	69.00
Number of overweight children	–	–	–	145	15.40
Number of obese children	–	–	–	103	10.90
Number of overweight or obese children	–	–	–	248	26.30

less healthy food outlets was not associated with the likelihood of being overweight or obese (Tables 2, 3). The distance to the nearest fast food restaurant or less healthy food outlet was also not a significant independent variable, nor was the age of the child, but there was little variation in age within this sample. Both gender and median household income were significant variables in all of the models: boys are more likely to be overweight or obese, while living in a higher income neighbourhood reduces the likelihood of being overweight or obese. Findings for gender and neighbourhood income produced nearly identical results for all of the models.

The food environment did play a role in the healthier food outlet and supermarket models. Distance to the closest supermarket was significantly related to the odds of being overweight or obese, while the density was not significant (Table 4). As distance to the nearest supermarket increases, so too does the corresponding odds ratio. An extra kilometre increases the odds of being overweight or obese by nearly 1.5 times. For the healthier food outlet model, living in a neighbourhood with a higher density of healthy food retailers, lowers the odds of being overweight and obese, while proximity does not appear to be important (Table 5). Overall, it appears that living in an area with a higher density of healthy food outlets and in close proximity to a supermarket decreases the odds of being overweight or obese, independent of income or gender, while unhealthy food outlets do not appear to relate to body weight.

Discussion

Addressing several methodological limitations in the existing literature, this study examined how fast food restaurants, less healthy and healthy food outlets along with supermarkets related to measured BMI for children in Toronto. Findings concerning gender and socioeconomic status are consistent with the existing literature. Households of lower income commonly have higher rates of childhood obesity (Wang and Beydoun 2007). Boys also commonly have higher rates of overweight and obesity (Tremblay et al. 2010; Roberts et al. 2012). Notably, our findings demonstrated that the density of healthier food outlets around the home and proximity to supermarkets was significantly associated with overweight/obesity independent of gender or household income. The fact that fast food restaurants and less healthy food outlets were not significant likely relates to the ubiquitous presence of these food outlets in the study area. In Toronto there were 2,520 less healthy food outlets and 3,888 fast food restaurants.

The fact that density of healthier food outlets and proximity to supermarkets remained significant predictors should be considered in light of the methodological strengths of our study in terms of objective measures of height and weight, the measurement of food access and density, and the use of a network buffer. The methods used to measure height and weight and calculate BMI along with the exposure to food outlets and classification of food stores all have the potential to significantly influence the

Table 2 Logistic regression estimation results for fast food with overweight or obesity as the dependent variable in Toronto, Canada, 2010–2011

	Coefficient	SE	Wald	*p* value	Odds ratio	95 % CI	
						Lower	Upper
Density of fast food outlets (per km^2)	−0.022	0.013	2.913	0.088	0.978	0.953	1.003
Distance to nearest fast food outlet (km)	0.232	0.189	1.505	0.220	1.261	0.871	1.825
Gender[a]	**0.517**	**0.151**	**11.753**	**0.001**	**1.677**	**1.248**	**2.254**
Median household income[b]	**−0.006**	**0.002**	**8.127**	**0.004**	**0.994**	**0.989**	**0.998**
Child's age[c]	−0.011	0.007	1.995	0.158	0.990	0.975	1.004
Constant	0.554	1.011	0.300	0.584	1.740		

Significant variables in bold

[a] Girls as referent

[b] Home dissemination area level in increments of $1,000 CAD

[c] Age in months

Table 3 Logistic regression estimation results for less healthy food outlets with overweight or obesity as the dependent variable in Toronto, Canada, 2010–2011

	Coefficient	SE	Wald	*p* value	Odds ratio	95 % CI	
						Lower	Upper
Density of less healthy food outlets (per km^2)	−0.021	0.013	2.947	0.086	0.979	0.955	1.003
Distance to nearest less healthy food outlet (km)	<0.001	<0.001	0.980	0.322	1.000	1.000	1.001
Gender[a]	**0.522**	**0.151**	**11.963**	**0.001**	**1.686**	**1.254**	**2.266**
Median household income[b]	**−0.007**	**0.002**	**8.153**	**0.004**	**0.993**	**0.989**	**0.998**
Child's age[c]	−0.010	0.007	1.922	0.166	0.990	0.975	1.004
Constant	0.602	1.014	0.353	0.552	1.826		

Significant variables in bold

[a] Girls as referent

[b] Home dissemination area level in increments of $1,000 CAD

[c] Age in months

Table 4 Logistic regression estimation results for supermarkets with overweight or obesity as the dependent variable in Toronto, Canada 2010–2011

	Coefficient	SE	Wald	*p* value	Odds ratio	95 % CI	
						Lower	Upper
Density of supermarkets (per km^2)	0.051	0.072	0.503	0.478	1.052	0.914	1.211
Distance to nearest supermarket (km)	**0.390**	**0.169**	**5.296**	**0.021**	**1.477**	**1.060**	**2.059**
Gender[a]	**0.511**	**0.150**	**11.614**	**0.001**	**1.668**	**1.243**	**2.238**
Median household income[b]	**−0.005**	**0.002**	**4.510**	**0.034**	**0.995**	**0.990**	**1.000**
Child's age[c]	−0.163	0.110	2.200	0.138	0.849	0.685	1.054
Constant	0.341	1.189	0.082	0.774	1.407		

Significant variables in bold

[a] Girls as referent

[b] Home dissemination area level in increments of $1,000 CAD

[c] Age in months

results. Existing research may over- or underestimate actual rates of overweight and obesity depending on the type of measurement. Many studies rely on self-reported data to calculate BMI. However, self-report measures are prone to bias, particularly among children (Sherry et al. 2007). For example, Leatherdale et al. (2011) reported that

Table 5 Logistic regression estimation results for healthier food outlets with overweight or obesity as the dependent variable in Toronto, Canada, 2010–2011

	Coefficient	SE	Wald	p value	Odds ratio	95 % CI	
						Lower	Upper
Density of healthier food outlets (per km^2)	**−0.101**	**0.033**	**9.329**	**0.002**	**0.904**	**0.847**	**0.964**
Distance to nearest healthier food outlet (km)	−0.020	0.144	0.019	0.892	0.981	0.739	1.301
Gender[a]	**0.513**	**0.151**	**11.547**	**0.001**	**1.671**	**1.243**	**2.246**
Median household income[b]	**−0.006**	**0.002**	**6.692**	**0.010**	**0.994**	**0.990**	**0.999**
Child's age[c]	−0.011	0.007	2.292	0.130	0.989	0.974	1.003
Constant	0.917	1.007	0.829	0.363	2.501		

Significant variables in bold

[a] Girls as referent

[b] Home dissemination area level in increments of $1,000 CAD

[c] Age in months

a higher density of fast food restaurants around the school related to the likelihood of being overweight in Ontario. A higher density of convenience stores within 500 m (straight line) and fast food restaurants (500 m network) related to self-reported BMI in London, Ontario (Gilliland et al. 2012). Our findings of a positive association with healthy food outlets but no relationship to less healthy outlets through the application of objective height and weight measures help to address measurement concerns with the existing research.

There are multiple methods to measure food access and density. This relationship is highlighted by recent work, as different methods of examining the built environment produced different results (Gilliland et al. 2012). This study assessed both the proximity and density of fast food restaurants, supermarkets and healthy/less healthy food outlets to examine multiple dimensions of access. The use of a network buffer is an improvement over previous work (He et al. 2012) as it uses the walking network to determine actual walking access, rather than using a straight line distance. Recent work in Canada has highlighted the importance of how different methods may produce conflicting results (Gilliland et al. 2012). Studies to date use various distances (500, 800, 1,000 m, 2 km) (Crawford et al. 2008; Gilliland et al. 2012), but there is little information within the current literature to guide these decisions. This study used a 1-km distance as it resembles approximately a 12–15 min walk or a 1–2 min drive, which is long enough to look at neighbourhood level features, but short enough to represent convenience. The 1-km distance has also been applied in similar work on food access (Apparicio et al. 2007; Larsen and Gilliland 2008; Williams et al. 2014). The method of classifying fast food outlets, healthy, less healthy or supermarkets can also cause discrepancies with results. This study used the Toronto Healthy Environments Inspection System (THEIS) which includes all food outlets within the City of Toronto and should be more accurate than relying on websites and phone directories. The classification of all food retailers from the THEIS database is a contribution within this work.

While there were many methodological contributions, this work does have limitations. Individual household income data were not available due to poor response rates on these questions, thus aggregated census data had to be applied. Also, although this work suggests that living in an area with healthier food options may actually relate to a lower risk of being overweight or obese, this work does not examine dietary behaviour. Findings to date have been inconclusive in determining whether living in an area with easy access to healthy or less healthy food actually influences eating behaviour (Williams et al. 2014).

In summary, these methodological improvements strengthen the case that density of healthy food outlets and proximity to supermarkets are significant and independent predictors related to children's overweight and obesity levels. Access to healthy food outlets may be another way the environment is influencing children's health, while no relationship was found regarding fast food restaurants or less healthy food outlets. More work should examine children's purchasing behaviour and where they are eating to get a better understanding of the relationship between food access and body weight. Although the findings suggest that healthier food access may be related to body weight, the cross-sectional nature of the study precludes any inference about causality. However, this study demonstrates that the density of healthy food outlets and supermarket proximity is potentially one important factor to be considered by Canadian researchers, practitioners, and policy makers in addressing the childhood obesity pandemic.

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