THE BUILT ENVIRONMENT AND OBESITY-RELATED BEHAVIOURS IN CANADIAN YOUTH

By

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A thesis submitted to the Graduate Program in Community Health & Epidemiology in conformity with the requirements for the degree of Doctor of Philosophy

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Kingston, Ontario, Canada

January, 2012

ABSTRACT

The objectives of this thesis were to examine the relationship between the built environment and obesity-related behaviours in Canadian youth, and to address measurement issues relevant for studying these relationships. The thesis is comprised of four manuscripts.

The first manuscript determined the accuracy of the food retailer locations surrounding 34 schools in Ontario as provided by two geographic information system (GIS) databases. The GIS locations of 25% of the food retailers were located within 15 m of their actual location, 50% were within 25 m, and 75% were within 50 m. These values did not differ by GIS database source.

The second manuscript examined the association between the presence of food retailers surrounding schools and students' lunchtime eating behaviours. It also determined whether a circular or road network buffer provided a better geographic boundary of the food retail environment surrounding schools. It was carried out in 6,971 9th and 10th grades students from 158 schools. The presence of food retailers near schools was strongly associated with students regularly eating their lunch at a snack-bar, fast-food restaurant or café. The road network buffers provided the better measure of the food retail environment.

The third manuscript determined the optimal buffer size of the food retail environment surrounding schools. Six road network buffers were created around 158 schools. These ranged in size from 500 m to 5000 m. Results indicated that the 1000 m buffer was the optimal size.

The fourth manuscript explored associations between urban sprawl and active transportation, moderate to vigorous physical activity (MVPA) and overweight/obesity in 7,017 youth aged 12 to 19 who resided in one of Canada's 33 Census Metropolitan Areas. Increasing levels of sprawl were modestly associated with increased active transportation (only among 12 to 15 year olds) and MVPA. No associations were found for overweight/obesity.

Taken together, the results from this thesis provide a better understanding of the role of the built environment on obesity-related behaviours in Canadian youth. Important measurement issues in this topic area were also addressed.

STATEMENT OF CO-AUTHORSHIP

The manuscripts presented in this thesis are the work of Laura Seliske, in collaboration with her co-authors. Laura Seliske was responsible for the study design, implementation, analyses and the initial drafts of the manuscripts. Her supervisors, Dr. Ian Janssen and Dr. William Pickett, were co-authors on all four manuscripts in this thesis, providing advice on research methods and editorial feedback. In addition, Rebecca Bates, an undergraduate research assistant, helped with the data collection for the first manuscript. For the second and third manuscripts, Andrei Rosu provided technical advice for the GIS related work.

Chapter 3 – Manuscript 1: *Field validation of food retailer listings: a comparison of online and commercial geographic information systems databases.* This manuscript is presented as it was submitted to BMC Public Health. Funding for this manuscript was provided through the research allowance provided by the Frederick Banting and Charles Best Canada Graduate Scholarships from the Canadian Institutes of Health Research (CIHR). Additional funding was provided through operating grants from CIHR and the Heart and Stroke Foundation of Canada.

Chapter 4 – Manuscript 2: *Food retailers surrounding schools and lunchtime eating behaviours of students.* This manuscript is presented as it will be submitted to the Journal of Nutrition and Metabolism for a special issue on “Health Effects of Local Food Environments”. Funding for this manuscript was provided by research contracts with the Public Health Agency of Canada and Health Canada as well as operating grants from CIHR and the Heart and Stroke Foundation of Canada.

Chapter 5 – Manuscript 3: *Identification of the optimal geographic boundary size to use when measuring the food retail environment surrounding schools.* This manuscript will be jointly submitted with Manuscript 2 to the special issue within the Journal of Nutrition and Metabolism, and has been formatted in the same matter. Funding for this manuscript was provided by research contracts with the Public Health Agency of Canada and Health Canada as well as operating grants from CIHR and the Heart and Stroke Foundation of Canada.

Chapter 6 – Manuscript 4: *Urban Sprawl and its relationship with active transportation, physical activity and obesity in Canadian youth.* This manuscript has been provisionally accepted for publication by Health Reports, which is affiliated with Statistics Canada. The manuscript within the thesis is the revised version which incorporated feedback provided by the reviewers of the article. Funding for this manuscript was provided by operating grants from CIHR and the Heart and Stroke Foundation of Canada.

ACKNOWLEDGEMENTS

First and foremost, I would like to start by acknowledging my supervisors, Drs. Ian Janssen and William Pickett. Without their guidance, it would not have been possible to carry out this thesis. They both have made valuable contributions that helped me gain skills and expertise as a researcher during my graduate studies and I am most grateful for their support. Thank you also to the faculty in the Community Health & Epidemiology department, who provided challenging and insightful discussions on various topics.

I would also like to thank my fellow PhD students for their support, especially the inaugural PhD class. It was a pleasure sharing the unique experiences associated with being the first group of students in the Doctoral program in Community Health & Epidemiology. I wish you all the very best in your future endeavors. I would also like to thank the students in Dr. Janssen's epidemiology lab and Dr. Will Pickett's KGH group for their very helpful feedback on various projects during my MSc and PhD.

Finally, I would like to thank my family and friends for their support and encouragement through my graduate school endeavours. Also, thank you to Kevin for your never ending love and support throughout this process.

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LIST OF ABBREVIATIONS

AIC	Akaike's Information Criteria
BMI	Body Mass Index
CI	Confidence Interval
CCHS	Canadian Community Health Survey
CMA	Census Metropolitan Area
FAS	Family Affluence Scale
GIS	Geographic Information System
GPS	Global Positioning System
HBSC	Health Behaviour in School Aged Children
ICC	Intraclass Correlation Coefficient
IQR	Interquartile Range
MVPA	Moderate to Vigorous Physical Activity
OR	Odds Ratio
PAR	Population Attributable Risk
RR	Relative Risk
SD	Standard Deviation

CHAPTER 1: GENERAL INTRODUCTION

1.1 Public Health Relevance of Obesity in Children and Youth

Over the past three decades, the prevalence of obesity among Canadian youth has increased threefold [1]. Results from the 2004 Canadian Community Health Survey (CCHS) found that 18% of youth aged 2 to 17 years were overweight and 8% were obese [1]. This is cause for concern due to the many health problems associated with obesity in young people, ranging from cardiovascular and metabolic health risks [2-5] to psychosocial issues such as depression [6] and social marginalization [7]. In addition, obesity tends to track from the adolescent to adult years, with longitudinal studies indicating that 75 to 90% of obese youth will remain obese as young adults [8]. Because of the numerous health problems associated with obesity and its persistence into adulthood, it is important to gain a comprehensive understanding of its determinants in order to inform prevention and treatment efforts.

1.2 Role of the Built Environment

Interventions that have targeted young peoples' physical activity and dietary behaviours without addressing their surrounding environments have been largely unsuccessful in preventing obesity [9]. Researchers now recognize the importance of the built environment on obesity-related behaviours such as diet and physical activity, with the earliest studies in young people appearing in 2004 [10]. The 'built environment' refers to our surrounding physical environment and provides the context in which health-related behaviours occur. Srinivasan et al. [11] provide a broad definition of the built environment adapted from Health Canada, stating: *"The built environment includes our homes, schools, workplaces, parks/recreation areas, business areas* *and roads. The built environment encompasses all buildings, spaces and products that are created or modified by people. It impacts indoor and outdoor physical environments as well as social environments and subsequently our health and quality of life"*.

The preventive medicine strategy proposed by Rose [12] supports the notion of modifying the built environment in order to improve the health of the broader population. It emphasizes the fact that although some potentially important risk factors may be small, they can affect a large segment of the population. This strategy aligns with the concept of population attributable risk (PAR), which is equal to: $P_{exp}(RR - 1) / (1 + P_{exp}(RR - 1)$, where P_{exp} denotes the prevalence of the exposure and RR is the relative risk [13]. Thus, as the prevalence of an exposure (P_{exp}) increases, the risk of an outcome at the population level – the population attributable risk – is important, even if the magnitude of the risk is modest. Rose also notes that it is difficult for people to engage in behaviours that do not correspond to the behaviours of others around them, stating that "the efforts by individuals are only likely to be effective when they are working with the societal trends" [12]. This also supports the strategy of modifying the built environment to facilitate healthy behaviours.

There are three main components of the built environment that are hypothesized to be associated with obesity. They include the food environment (e.g. access to various food retailers) and the physical activity environment (e.g. access to amenities such as parks and recreational facilities). In addition, it also includes a component referred to as urban form, which refers to the design and organization of cities, including features such as layout of streets and the availability of sidewalks and bike paths. This thesis will focus on the food environment and urban form as they related to eating behaviours, physical activity, and obesity in Canadian youth.

1.3 Summary of Built Environment Research in the Obesity Field

1.3.1 Research in Young People

Obesity and its causal behaviours are associated with features of the built environment, including: the food environment [14-16] and urban sprawl [17,18]. The food environment refers to the availability of various types of food retailers within a given area, including fast food restaurants, convenience stores, coffee/donut shops and other types of food retailers. Urban sprawl is related to the layout of cities, and for the purposes of this thesis, refers primarily to features of metropolitan areas that influence how people travel from one place to another.

Changes to the built environment provide one potential strategy to prevent a further rise in obesity levels by influencing its causal behaviours. Young people may be affected by the built environment differently than adults, particularly with respect to mobility, since many cannot use a vehicle as their primary mode of transportation and may be more reliant on forms of active transportation such as walking or cycling. Furthermore, young people are undergoing a rapid period of development and the choices presented to them through their environments may influence their behaviour differently. With a more thorough understanding these influences, public health professionals and policy makers will be in a better position to intervene at a young age when health habits are being formed. Research into the effects of the built environment on obesity levels in young people may inform urban planning and policies surrounding the design of neighbourhoods and schools by encouraging the creation of built environments that facilitate healthy choices.

1.3.2 Methodological Limitations of Existing Studies

A key measurement issue for large-scale studies of the food environment is their reliance on the accuracy of information that is provided in commercial lists or publicly available databases. In order to be feasible, large-scale studies must rely on secondary sources to obtain information on the location of food retailers, as opposed to obtaining this information via direct observation. Few studies have examined issues of accuracy with respect to this information, particularly the accuracy of Canadian sources. Only one such study has been conducted to date in Canada [19], but it took place within a single city and combined the physical activity and food environment features into one measure of the built environment. This is problematic due the challenges associated with measuring access to parks, which can span large geographic areas and have multiple access points, versus restaurants, which are smaller and have more clearly identifiable access points.

Another methodological issue in this field concerns the methods used to measure access to components of the built environment. Studies that have examined access to food retailers have differed considerably in terms of their measurement approach. Some studies have measured the number of destinations within pre-existing boundaries such as ZIP codes [20,21]. The limitation of pre-existing boundaries is that they were designed for administrative purposes and may not be consistent in size**.** Other studies have determined the number of food retailers within a certain distance, using either circular buffers [14,22] or road network buffers [15,16,23]. Studies using radius or road network distances may avoid the problems associated with pre-existing administrative boundaries**,** but to date, no methodological studies have determined the distance to the destinations that is most relevant to health, and little is known about whether using a road network buffer or a circular buffer is more optimal for the measurement of access to the food environment.

1.4 Thesis Purpose and Objectives

1.4.1 Thesis Purpose

The overall purpose of this thesis is to examine the influence of the built environment on the causal behaviours of obesity in Canadian youth. The built environment is an important area of research because it takes into account the broader contextual influences on health behaviours. Since research in this field is relatively new, there are key measurement issues regarding how to measure the built environment which need to be resolved. The purpose of this thesis is to examine how the built environment affects eating behaviours and physical activity in large samples of Canadian youth. In addition, this thesis will also help identify the optimal methods to use to measure the built environment.

1.4.2 Thesis Objectives

Objective 1: To address some of the methodological issues surrounding the use of Geographical Information Systems (GIS) to measure features of the built environment, with an emphasis on the food environment. This included comparing different measurement approaches and quantifying the level of error in publicly available GIS databases used to measure features of the built environment.

Objective 2: To examine the relationship between the built environment and the behavioural determinants of obesity in young people, including eating behaviour and physical activity. This was accomplished using nationally representative samples of Canadian youth and incorporated the built environment measurements refined in Objective 1.

1.4.3 Thesis Organization

This thesis is organized as a manuscript-based thesis. Prior to the manuscripts, there is a literature review that will outline the relationships between the built environment and the causal behaviours associated with obesity in young people. Also, methodological limitations of the measurement of the built environment will be reviewed, with a focus on the food environment. Next, the four manuscripts will be included. They are organized as follows: the ***first manuscript*** addresses an important measurement issue related to the use of GIS databases to obtain information on the location of food retailers. It quantifies the measurement error of the positional information provided by a commercial database and an online directory for food retailers located near schools in urban and non-urban areas. The focus of the ***second manuscript*** will be on determining whether circular or road network based buffers provide the more optimal measure of the school food retail environment and its relationship with students' lunchtime eating behaviours. For the ***third manuscript***, various sized buffers will be used to determine the relevant distance from schools to capture food retailers in order to examine their relationship with students' lunchtime eating behaviours. Finally, the ***fourth manuscript*** shifts focus to urban sprawl and its relationship with physical activity in a large sample of Canadian youth. Following the four manuscripts, a discussion chapter will summarize the results and implications of the findings of the four manuscripts.

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CHAPTER 2: LITERATURE REVIEW

2.1 Overview

The influence of the built environment on the determinants of obesity in young people is a relatively new area of research. The purpose of this chapter is to explore the literature on the influence of the built environment on outcomes related to obesity, including physical activity and eating behaviours. The first section of this chapter will define key concepts that are used throughout this chapter and the thesis in general. Next, a conceptual model will be presented to provide an overview of the relationships to be examined. This will be followed by a review of the literature examining the first theme of this thesis, which investigates the role of the food retail environment on eating behaviour and obesity in young people, as well as the associated measurement issues. Following this, the second theme of this thesis will be outlined, which is related to the components of the built environment that are associated with physical activity and obesity. The chapter concludes with a brief summary of the key issues regarding the relationship between the built environment and the behavioural determinants of obesity in young people.

2.2 Definitions

The *built environment* is defined as the physical environment surrounding homes, schools and workplaces. The key components of the built environment for this thesis include the food retail environment, the physical activity environment and urban form. The built environment is thought to influence our health by encouraging or discouraging healthy lifestyle choices [1,2].

The *food retail environment* refers to the quantity and types of food retailers available within a particular geographic area. It includes the following retailers: fast food restaurants, convenience stores, coffee/donut shops, grocery stores, supermarkets, and ethnic/specialty stores. The food retail environment can influence dietary choices and *unhealthy eating behaviours*, which involve the consumption of foods that are high in calories, sugar, salt and fat.

The *physical activity environment* consists of parks and other green space and recreational facilities (e.g. gyms, arenas, pools, soccer fields, etc.) that are located within a given area.

Urban form refers to the layout of the metropolitan areas and consists of many different components. These include *street connectivity*, which is a measure of the number of street intersections within a given area, and is an indicator of the ease of travel between destinations via road networks [3]. Another component of urban form is *land use mix*, which refers to the proportions of land that are zoned for particular purposes, including residential, industrial, commercial and recreational [3]. *Residential density* is another component of urban from, and refers to the number of residential units within a geographic area [4]. Finally, *urban sprawl* refers to a pattern of urban development where cities extend over large geographic areas in a "leap frog" pattern of development [5]. It can make it difficult to travel between destinations using active transportation. *Active transportation* refers to the use of non-motorized transportation (walking, cycling, inline skating) [6].

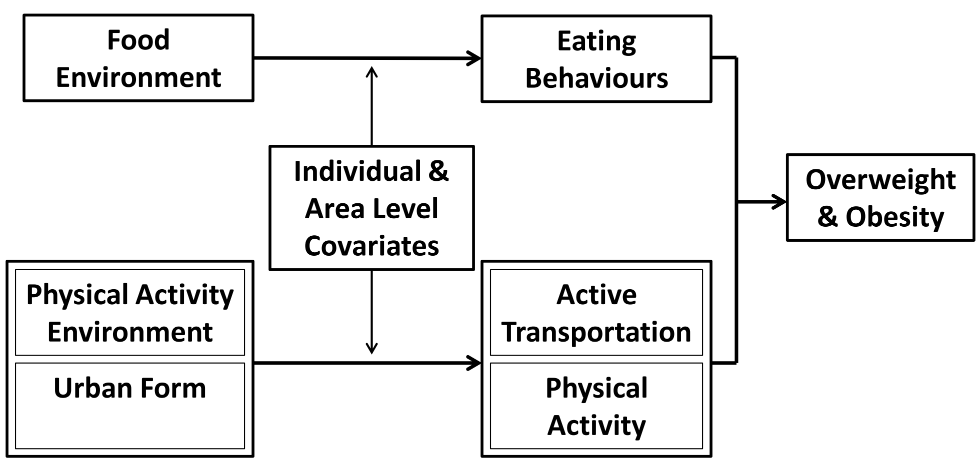
The term *child* refers to an individual between the ages of 6 and 11 years and *adolescent* refers to an individual aged 12 to 19 years. The terms *youth* and *young people* are used interchangeably in this thesis and refer to children and adolescents, collectively.

Geographic information systems (GIS) refers to the computer-based systems designed to collect, manipulate and analyze spatial data such as measures of the built environment [7,8].

2.3 The Built Environment and Obesity-Related Behaviours in Youth: Overview & Conceptual Model

Obesity is a complex health issue that is caused by a multitude of factors. Fundamentally, body fat content is determined by energy balance, which is maintained when energy intake, obtained through food consumption, is balanced by energy expenditure, which is a function of resting metabolism and the amount of physical activity a person engages in [9-11]. Thus, eating behaviours and physical activity are key determinants of obesity. Figure 1 provides a brief conceptual model of the components of the built environment that are the focus of this thesis and how they relate to overweight and obesity.

Figure 1. Conceptual model depicting the relationship between features of the built environment and obesity-related outcomes



The key components of the built environment are the food retail environment, the physical activity environment and urban form, which affect eating behaviours and overweight and obesity. The focus of this thesis is primarily on the more immediate outcomes of eating behaviours, physical activity and active transportation.

The food retail environment can influence eating behaviour as it determines the availability of healthy and unhealthy food items within a given geographic location. Since young people spend a large portion of their day in school, the food retail environment surrounding schools may be an important determinant of their eating behaviour. Most research on the school food retail environment has focused directly on sources within the schools (e.g., cafeteria, vending machines) [12-14]. However, many students are permitted to leave school grounds during the school day and have access to nearby food retailers. Previous research has demonstrated that there can be a preponderance of fast food restaurants near schools [15,16], and these types of food retailers tend to sell food that is high in calories, sugar and fat [17]. Less is known about the presence of other types of food retailers near schools, such as coffee/donut shops and convenience stores. However, given the secular increases in the consumption of snack foods [18] and sugar sweetened beverages by young people [19], having these food retailers in close proximity to schools may also play an important role in influencing students' eating behaviours.

Features of the built environment can influence physical activity levels in a variety of ways. Urban form is a component of the built environment that can either facilitate or inhibit active transportation [20]. Components of urban form that have been associated with active transportation in young people include street connectivity, land use mix, and residential density [20]. Having well-connected street networks near the residences of young people has been associated with a greater frequency and duration of walking [21], and similar positive associations have been found for land use mix and residential density [21]. Urban form primarily influences physical activity by determining the likelihood of individuals engaging in active transportation, but there are other features of the built environment that influence physical activity as well. Urban sprawl is related to urban form, and is an overall measure of how densely populated and well-connected metropolitan areas are [5]. Individuals living in metropolitan areas with high levels of urban sprawl may spend more time in motorized transport, which can impact their physical activity levels [22]. In addition to urban form and urban sprawl, there are other features of the built environment that influence physical activity as well. For example, having access to nearby parks has been related to increased physical activity in young people [23], and similar relationships have been found for other recreational facilities such as fitness facilities, ice rinks, pools, etc.[24]

There are many features of the built environment that influence eating behaviours and physical activity among young people, which can then affect the prevalence of overweight and obesity. Each of these features is outlined in more detail in the following sections of this literature review. The relationship between the food retail environment and the associated measurement issues will be outlined in detail in Sections 2.4 and 2.5. Section 2.6 briefly outlines the role of physical activity environment, which is an important determinant of physical activity and obesity, but is not a major focus of this thesis. Finally, Section 2.7 reviews the literature that examines how urban form is related to physical activity and obesity, with a focus on urban sprawl and active transportation.

2.4 The Relationship Between the Food retail environment, Eating Behaviours, and Obesity in Youth

2.4.1. Relationships Between the Food Retail Environment Surrounding Homes, Eating Behaviours, and Obesity

Over the past 30 years, the consumption of foods prepared away from home has increased dramatically. Among 2 to 18 year olds, the proportion of energy obtained from fast food and other restaurants has tripled [25]. Temporal trends have also shown increased consumption of sugar sweetened beverages [19] increased and calories obtained from snack foods [18]. The increased consumption of these foods is cause for concern, since they tend to be of poor nutritional quality [26,27] and have been associated with adverse health outcomes in young people, including obesity [28-30] as well as early indicators of cardiovascular disease [31-33] and type 2 diabetes [33].

There is consistent evidence to support a relationship between the presence of food retailers surrounding homes and obesity outcomes in youth. In a study of 9 and 10 year olds in Leeds, UK, Jennings et al. [34] found that youth with fast food restaurants and convenience stores within 800 m of their homes had higher BMI z-scores (0.49 vs. 0.34) and higher body fat percentages (31.2% vs. 30.2%) compared to those with no nearby fast food restaurants and convenience stores. Although these associations are small, it is important to note that this study only considered the presence or absence of the food retailers and not the specific quantity. Therefore, stronger associations may have been obscured by not considering the number of food retailers present. Fraser et al. [35] examined the presence of fast food restaurants in 3 to 14 year olds living in Leeds, UK. They used the super output area as their geographical unit of analysis, which is a pre-existing administrative area containing approximately 1,500 to 7,200 people [36].

Each additional fast food restaurant per super output area was associated with an increased likelihood of obesity (OR=1.01, 95% CI: 1.002-1.02). While this odds ratio may seem small, the confidence interval is quite narrow, which indicates that this effect estimate is precise and not unduly affected by measurement error. In addition, the odds ratio has been calculated for the addition of a single food retailer within a potentially large area. Therefore, the relationship would likely have been stronger if the researchers considered a smaller geographic area. Robust relationships were found for Californian girls by Leung et al.[37], but only for convenience stores. Girls (mean age=7.4, SD=0.4) who had at least one convenience store within 400 m of their homes had a higher relative odds of obesity (OR=3.38, 95% CI: 1.07 - 10.68) compared to girls with no convenience stores near their homes. The lack of relationships with fast food restaurants may have been due to a small sample size (N=353).

Some studies have also examined the relationship between the home food retail environment and eating behaviours in young people. Jennings et al. [34] found that among 9 to 10 year olds in Leeds, UK, those with fast food restaurants and convenience stores within 800 m of their homes had an 11.8% higher intake of fruit drinks and a 15.3% higher intake of soda compared to those with neither food retailer present. Skidmore et al. [38] measured the distance to various food retailers and examined associations with dietary intake in 9 to 10 year olds living in Norfolk, UK. For each 1 km increase in the distance to the nearest convenience store, there was a decrease in the consumption of potato chips (-0.16 servings/week, 95% CI: -0.06 to -0.25), french fries (-0.09 servings/week, 95% CI: -0.03 to -0.16), chocolate (-0.09 servings/week, 95% CI: -0.01 to -0.20) and white bread (-0.19 servings/week, 95% CI: -0.07 to -0.30). Similar relationships were found for fast food restaurants. When considering the number of food retailers within 800 m of participants' homes, findings were not as robust. Each additional convenience store per km^2 was associated with a 0.25 (95% CI: 0.05 to 0.45) increase in fruit juice servings per week. No associations were found for fast food restaurants. It is important to note that the dietary intake measures did not consider where food was obtained (e.g. at school, at home or elsewhere), and this may have weakened the relationships between the home food retail environment and dietary behaviours.

The above studies indicate that there is evidence to support a relationship between the presence of fast food restaurants and convenience stores and indicators of obesity. Few studies have incorporated eating behaviours as an outcome of interest, but there appears to be a modest relationship between availability of food retailers near homes and eating behaviours. However, since many young people spend a notable proportion of their day elsewhere, the examination of other food retail environments, such as the school food retail environment, is warranted.

2.4.2 Relationships Between the Food Retail Environment Surrounding Schools and Obesity

Evidence suggests a relationship between the presence of various food retailers near schools and obesity-related outcomes in young people. For example, in a large national study of 8^{th} and 10^{th} grade students in the U.S., Powell et al. [39] found that each additional convenience store per 10,000 people within school ZIP codes was associated with a 0.03 unit increase in body mass index (BMI) and a 0.2% increase in the prevalence of obesity. Although these relationships appear to be relatively weak, the addition of a single convenience store per 10,000 people may cover a large geographic area. Davis and Carpenter [40] examined the association between the presence of chain fast food retailers near schools and overweight and obesity in 7^{th} to 12^{th} grade students in California. Compared to students with no nearby fast food restaurants, those who had one or more chain fast food restaurants within 800 m of their school had a greater relative odds of overweight (OR=1.06, 95% CI: 1.02-1.10) and obesity (OR=1.07, 95% CI: 1.02-1.12). Not all studies were able to find a relationship. In a study of 5^{th} to 8^{th} grade students in Ontario, Leatherdale et al. [41] found no relationships between obesity and the presence of a variety of food retailers, including gas stations, fast food restaurants and bakeries/doughnut shops. Although there were a large number of students included in the study (n=2,449), there were only 30 schools, which may have been inadequate to detect associations.

One of the limitations of the above studies is that they considered measures of overweight and obesity as their primary outcomes. Obesity is a complex health problem, and it may also be influenced by factors within the home environment as well other environments, in addition to individual-level characteristics such as age, sex and socioeconomic status [42-45]. Therefore, it is difficult to solely attribute the higher prevalence of obesity with the presence of food retailers near schools when factors within the home environment have not been considered. In addition, features within the built environment that promote physical activity, such as the availability of parks and recreational facilities and having well-connected streets may also influence obesity levels. These features of the built environment will be expanded upon in Sections 2.6 and 2.7. However, this highlights the difficulty in attributing differences in the prevalence of obesity solely to the food retail environment, while other features of the built environment may also have an important role. To avoid this issue, studies of the food retail environment should also consider the more direct relationships between the food retail environment and eating behaviours. Finally, previous studies have often quantified the effects of the food retail environment for large geographic areas [38,39], and this may result in the magnitude of the effects appearing trivial when in reality, their influence may be important on a smaller scale.

2.4.3 Relationships Between the Food Retail Environment Surrounding Schools and Eating Behaviours

Recently, researchers have begun to include dietary outcomes in their analysis of the food retail environment in young people. In addition to obesity, Davis and Carpenter [40] also examined the association between the presence of chain fast food retailers near schools and eating behaviours. Dietary intake was obtained by a 24 hour dietary recall and the outcomes of interest included the consumption of vegetables, fruits, juice, soda and french fries. They found that the presence of fast food restaurants within 800 m of schools was marginally associated with soda consumption (OR=1.05, 95% CI: 1.00-1.11), but no notable associations were found with other food items. Laska et al. [46] also examined the relationship between the food retail environment surrounding schools and sugar sweetened beverage intake in 10 to 17 year olds living in Minneapolis-St. Paul, Minnesota. They were unable to find a relationship between sugar sweetened beverage intake and the availability of fast-food restaurants, convenience stores and other food retailers near schools. Finally, a study of the school food retail environment by van der Horst et al. [47] found that small food stores (convenience stores, small grocery stores, and ethnic food stores) were associated with *decreased* soft drink consumption, and no associations were found for snack food intake.

Based on these studies of the school food retail environment, it appears that there is no relationship with the eating behaviours in students. However, there is a key methodological limitation in the outcome measures used in the existing studies. All of the studies used general dietary intake questions, such as 24 hour dietary recalls [40] or questions about the typical consumption of certain food items within the past week or month [46,47]. These questions cannot decipher whether the foods of interest were eaten at home, at school, or elsewhere. This highlights the need for context-specific eating behaviour questions that assess where and when food is eaten. By not accounting for this, the previous studies of the school food retail environment may be susceptible to error introduced by misclassification, which may partly explain the absence of relationships with the food retail environment.

2.5 Methodological Limitations of GIS-Based Measures of the Food Retail Environment

2.5.1 Secondary Sources of Food Retailer Locations

Large scale studies that examine the food retail environment need to rely on secondary sources of information for food retailer locations due to feasibility issues associated with the direct measurement (e.g., physical audit) of the food retail environment. Audits of the food retail environment are carried out by confirming whether food retailers are present or absent within a given geographical location [48,49]. More detailed validation studies involve recording the location of food retailers using a hand-held Global Positioning Systems (GPS) device [50]. Using the GPS device, the location of each food retailer is obtained by recording its longitude and latitude coordinates. The coordinates can then be uploaded into mapping software, and the GPS-derived coordinates can be compared to the street address given by the food retailer databases. Studies of the food retail environment typically rely on three types of geographic information systems (GIS) databases: online databases (e.g. Yellow Pages) [51,52], commercial food retailer databases [48,50], or listings of food retailers provided by the health departments of local governments [49,53].

To date, six studies have examined the accuracy of the information on food retailer locations provided by GIS databases [49-54]. With the exception of the field validation study by Liese et al. [50], existing studies took place in a single city [48,49,51-53] and recorded the food retailers as present or absent. The proportion of GIS-listed food retailers that were located in the field ranged from 60% [52] to 88% [53]. Although this gives an indication of how many of the listed food retailers exist within a given area, there is no indication of the positional accuracy of the x,y coordinate location for the food retailers. In other words, information on the distance between where the food retailers are truly located and where the GIS database suggests they are located is also important. Furthermore, only one study using multiple food retailer databases (e.g. online, commercial or government sources) compared the accuracy between different types of GIS databases [52]. Other limitations of current food retailer validation studies include a small sample size (n<200) [52] and the lack of differentiation between various food retailer types [51-53].

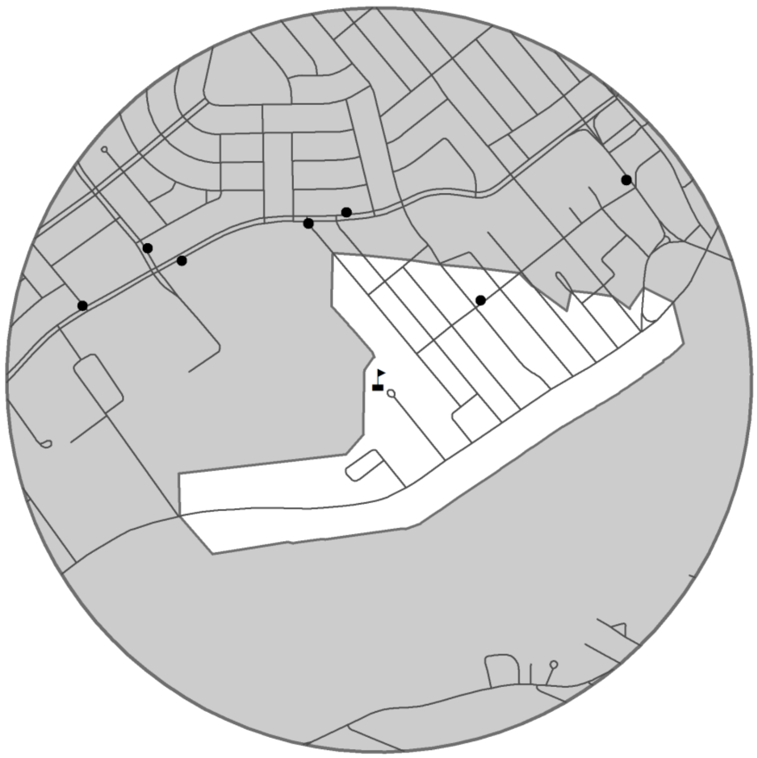
2.5.2 Methods Used to Capture Food Retailers Surrounding Schools

Research on the food retail environment is relatively new, with the earliest studies in youth published in 2004 [55]. Recent reviews have outlined the need to apply consistent measures of the food retail environment across studies in order to increase comparability [56,57]. This includes the consideration of the size and shape of the area of geographic boundary used to capture the food retail environment. Early studies of the food retail environment tended to use pre-existing boundaries such as ZIP codes to define the boundaries for the food retail environment [39,58]. The limitation of pre-existing boundaries is that they were designed for administrative purposes and may not be consistent in size. The use of GIS software has addressed this limitation by allowing researchers to define their own food retail environment boundaries, but this has resulted in the emergence of a variety of measurement issues.

There are two common methods employed by GIS software to define the shape of the geographic area used to capture food retailers. The simpler method is to use circular buffers, which measure the Euclidean straight line distance (also referred to "as the crow flies") from a point of interest to create a circular buffer. The advantage of this method is that it is easy to carry out and requires less time and expertise in using GIS software. However, it does not account for barriers such as bridges, waterways, major highways, or disconnected road networks. In order to address this limitation, road network buffers have been used as an alternative method to capture food retailers. Road network buffers are created by following roads extending outwards from a location of interest for a certain distance. Lines are then drawn to connect the endpoints of the road networks, creating an irregular shaped buffer surrounding the point of interest. Road network buffers capture what is actually accessible to a person when using the roads to travel to and from food retailers.

Figure 2 on the next page contrasts a 1 km circular and a 1 km road network buffer around a school. It is apparent that the two buffers can be quite dissimilar in size and capture different numbers of food retailers despite using the same distance to create the buffer. Theoretically, road network buffers would provide a better measure of the food retail environment than circular buffers. However, there have been no direct comparisons between the food retailers measured using these different buffer types and there is a need to define the optimal method of capturing food retailers in order to standardize these measurement methods across studies.

Figure 2 A comparison of a 1 km circular buffer and a 1 km road network buffer to measure access to food retailers. The road network buffer is represented by the white area and the circular buffer encompasses both the white and gray areas. The food retailers are represented by the black circles



In addition to the shape of buffers used to capture the food retail environment, there are notable variations in the size of buffers employed in studies of the food retail environment. Most have used two approaches to this issue: either using multiple buffer sizes [40,46] or by choosing one buffer size based on estimates of reasonable walking time [41,47]. Food retail environments have been measured with buffers ranging from 400 m [37] to 5000 m [59] in size. Researchers have identified the need to standardize buffer sizes [56,57]. The wide variation in buffer size makes it difficult to make comparisons across studies, and studies using buffers that are too large or too small may not capture associations that exist. Furthermore, it is possible that the relevant buffer size of the food retail environment may differ depending on the setting. For youth it may be different for their home versus their school. This remains a relatively unexplored measurement issue for the food retail environment and research is needed to examine the relevant size of the food retail environment, both at home and at school.

There is some variation in how access to food retailers is measured. Some studies measured the number of food retailers within a given area (also referred to as the density of food retailers) [34,37,41], while others have also considered the distance to the nearest food retailer [35,38,46,60]. In general, the density measure has shown more consistent relationships with eating habits and obesity outcomes [35,40,46,60]. An exception was the study by Skidmore et al. [38], which found more associations when assessing the distance to the nearest food retailer. However, some distance-based relationships were inconsistent. For example, Skidmore et al. [38] found that having grocery stores further away from young peoples' homes, indicating *decreased* access, was associated with healthy eating behaviours, while an *increased* density of grocery stores was also associated with healthy eating behaviours. A similar pattern was found for grocery stores and vegetable consumption by Timperio et al. [60]. Given the stronger and more consistent findings with the density measures, it is more commonly used in studies of the food retail environment.

2.6 The Physical Activity Environment and Physical Activity-Related Outcomes in Youth

The built environment has many components that provide opportunities for physical activity among youth. One component is facilities that allow for physical activity, including parks and recreational facilities. For example, 12 to 17 year olds living in urban areas who had access to a park were more likely to participate in moderate- to-vigorous physical activity (MVPA), (RR=1.10, 95% CI 1.01-1.17) compared to those who did not have access to a park

[23]. Although the magnitude of this relationship is relatively small, it is important to consider that access to parks was obtained through self-report, and the strength of the relationship may be diminished by inaccurate recollection of the presence of parks.

The relationship between the presence of recreational facilities and physical activity showed a dose-response pattern, whereby increases in the number of facilities were accompanied by increases in physical activity levels. Powell et al. [24] examined a wide variety of recreational facilities (e.g. fitness facilities, ice rinks, swimming pools, etc.) near residences and self-reported physical activity in a large sample of U.S. adolescents in the 8^{th}, 10^{th} and 12^{th} grades. Each additional facility per 10,000 people was associated with a 0.23% increase in MVPA. Although the magnitude of this relationship appears to be quite small, the findings apply to a large number of people. On a smaller scale, it is likely that the addition of a single recreational facility would result in a stronger relationship.

A dose-response pattern was particularly evident in older students, whereby an increase in the number of facilities from 1 to 8 resulted in a 6.4% and a 9.0% increase in vigorous physical activity in males and females, respectively. Gordon-Larsen et al. [61] found a similar dose-response relationship for MVPA in youth in grades 7 to 12 in the U.S. Youth with 1 physical activity facility near their homes had a greater relative odds of engaging in ≥5 bouts of MVPA per week (OR=1.03, 95% CI: 1.01-1.06) and the relative odds increased for 7 nearby facilities (OR=1.26, 95% CI: 1.06-1.50) compared to those with no nearby facilities. This relationship was confirmed in students in the 7^{th} and 8^{th} grades living in London Ontario [62]. Students with at least 2 recreational facilities within 1.6 km of schools were more likely to be in the upper quartile for physical activity (OR=1.65, 95% CI: 1.09-2.50) compared to those with access to fewer than 2 recreational facilities.

Despite the fact that young people may have access to recreational facilities near their homes, perceived safety is an important factor that influences whether they utilize them. Utter et al. [63] examined the relationship between the presence of parks and recreational facilities and vigorous physical activity among 13 to 17 year olds in New Zealand. They found that those who perceived their neighbourhoods as safe were also more likely to engage in vigorous physical activity (OR=1.46, 95% CI: 1.30-1.60) compared to youth who did not. Although Nichol et al. [64] did not find a relationship between access to parks and recreational facilities and physical activity in 11 to 15 year old Canadian youth, they found that perceptions of being safe lead to a and increased likelihood of being physically active. Males and females who had the highest perception of safety were 1.31 (95% CI: 1.17-1.45) and 1.45 (95% CI: 1.26-1.65) times more likely to participate in physical activity compared to those with the lowest perceived safety.

There are many limitations to the studies that have examined physical activity amenities and MVPA in youth. Similar to the food retail environment, there are a variety of distances used when measuring physical activity amenities. Distances ranged from the length of one side of a residential block [65] to a 3 km buffer [66]. Some studies used a sensitivity analysis approach with 2 or 3 options [67,68], and one study by Boone-Heinonen [69] took a more systematic approach using 4 distances (1 km, 3 km, 5 km and 8 km) to measure associations between access to recreational facilities and MVPA in a large sample of U.S. students in grades 7 to 12. The analysis was simultaneously stratified by sex and 3 urban-rural categories, which made it difficult to provide an overall recommendation for researchers. However, for recreational facilities, there appeared to be relatively consistent associations between access to recreational facilities within 1 and 3 km of respondents' homes and MVPA. Additional limitations of current studies include small sample sizes (n<100) [70] and limited geographic scope [62,71]. For example, of three studies examining access to parks and recreational facilities and their relationship with physical activity outcomes in Canadian youth, only one examined the relationship on a national scale [72], while the other two took place within a single city [62,71].

2.7 The Relationship Between Components of Urban Form and Physical Activity

2.7.1 Components of Urban Form and Physical Activity in Youth

There are many components of urban form that influence the physical activity of adults, including street connectivity, residential density and land use mix. These urban form components have been associated with the frequency of walking among young people. For example, Frank et al. [21] found that 12 to 15 year olds were more likely to walk at least 800 m per day if they lived in areas with the highest tertile of street connectivity (OR=2.4, 95% CI:1.1-5.1) and population density (OR=4.9, 95% CI: 2.1-11.4) compared to those living in the areas in the lowest tertiles. They also found that higher land use mix was associated with walking, whereby youth living in areas with the highest tertile of land use mix more were likely to walk at least 800 m per day (OR=2.7, 95% CI: 1.4-5.3) compared to those living with no mixture of land uses. Associations of a similar magnitude were also found in the 16 to 19 year olds, although land use mix was no longer found to be statistically significant. These relationships were confirmed in a study by Kerr et al. [73], who incorporated various features of urban form into a walkability measure. This measure included residential density, retail floor area (an indicator of pedestrian-friendly commercial areas), intersection density and land use mix. Youth aged 4 to 18 years living in high walkability areas were more likely to walk to school (OR=2.1, 95% CI: 1.1-4.0), but only for those living in high-income neighbourhoods.

Some studies have found that features of urban form that positively influence physical activity in adults have the opposite relationship in youth. Mecredy et al. [74] examined the relationship between street connectivity (a positive correlate of physical activity in adults) and physical activity outside school hours in a large sample of Canadian youth. Compared to those living in areas with the highest quartile of street connectivity, those in second (RR= 1.22, 95% CI: 1.10-1.35), third (RR=1.25, 95% CI: 1.13-1.37), and fourth (RR=1.21, 95% CI: 1.09-1.34) quartiles were more likely to be physically active. A possible reason for the opposite relationship with street connectivity compared to adults is that adults accumulate most of their physical activity through walking while young people accumulate most of their activity through play and sport. Thus, quiet residential streets that are not well connected may provide a playground for young people to be active. For example, Veitch et al. [75] found that 8 and 9 year old children who lived on cul-de-sacs were considerably more likely to play in the street on weekdays (OR=3.99, 95% CI: 1.65-9.66) and weekends (OR=3.49, 95% CI: 1.49-8.16) compared to those who did not live on cul-de-sacs. Furthermore, parental perceptions of traffic safety have been associated with active transportation. Among 10 to 12 year olds living in Melbourne, Australia, parental perceptions of a lack of pedestrian crossings or traffic lights was associated with a decreased likelihood of cycling or walking to school (OR=0.6, 95% CI: 0.3-0.9) [76]. Therefore, it appears that there may be features of urban form which may influence physical activity differently in young people, with safety a salient concern among their parents.

Overall, relationships between components of urban form, physical activity and active transportation in young people appear to be more complex and less well-understood than in adults. Variations in traffic safety across studies may account for part of this relationship, but further research is needed to clarify these mechanisms.

2.7.2 Urban Sprawl, Physical Activity, and Obesity in Young People

In adults, higher levels of urban sprawl contribute to greater levels of obesity through the increased reliance on cars and time spent commuting [22]. That is, adults living in cities with greater levels of urban sprawl are less likely to engage in active transportation [77] and may have less free time to engage in other forms of physical activity because of the amount of time they spend driving [78]. A key difference between the urban sprawl studies in adults versus young people may relate to the role of car use. Relationships in older adolescents may be similar to those in adults, with both groups potentially having access to a vehicle. A study by Trowbridge et al. [79] supported this notion, whereby youth aged 16 to 19 years who lived in sprawling counties were more than twice as likely to drive >32 km per day compared to youth who lived in compact counties. However, the role of driving age is not well understood in younger adolescents who may not yet have a driver's licence. Therefore, there is a need to explore the relationship between urban sprawl and active modes of transportation, while considering driving age.

There are two studies in young people which provide evidence supporting similar relationships to those found in adults. Ewing et al. [80] examined the relationship between urban sprawl and obesity in 12 to 16 year olds living in the U.S. They found a positive relationship, whereby those who lived in a county 1 standard deviation below the mean in the urban compactness score (greater urban sprawl) had a higher relative odds of overweight and obesity (OR= 1.16, 95% CI: 1.02-1.31) compared to those who lived in a county with an urban compactness score 1 standard deviation above the mean (less urban sprawl). Analysis of longitudinal data also showed a positive relationship between increased urban sprawl and overweight and obesity, although the relationship did not reach statistical significance ($p \leq 0.05$), likely due to a small sample size. Similarly, in a group of 8th and 10th grade students, Slater et al. [81] found that a 1 standard deviation increase in their urban compactness scale, indicating less urban sprawl, was associated with an 11.8% decrease in the prevalence of obesity, but no association was found with MVPA.

Further examination of the relationship between urban sprawl and physical activity in young people is needed, with the inclusion of active transportation as a key outcome variable. Active transportation may have an important role, since young people who do not have a driver's license may be more reliant on non-motorized modes of transportation such as walking or cycling. Furthermore, existing studies on urban sprawl, physical activity and obesity in young people have taken place in the U.S., and there is a need to examine these relationships within more geographically diverse populations, including Canada.

2.8 Summary

In light of the increasing prevalence of obesity among young people and the lack of notable success of interventions focusing on solely individual behaviours, there has been an increased focus on the broader contextual determinants of obesity and its related behaviours. Because of the increase in consumption of food prepared away from home among young people, there is an interest in the relationship between the food retail environment and obesity-related outcomes. However, there are many methodological issues that must be addressed regarding the measurement of the food retail environment and its association with dietary outcomes. In addition to the food retail environment, the physical activity environment and urban form also influence obesity-related behaviours in young people. There remain large gaps in knowledge regarding the built environment and its influence on the determinants of obesity in Canadian youth, some of which will be addressed by the manuscripts included in this thesis.

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CHAPTER 3

Field validation of Food Retailer Listings: A Comparison of Online and Commercial Geographic Information Systems Databases

ABSTRACT

Background: Many studies examining the retail food environment rely on geographic information system (GIS) databases for location information. The purpose of this study was to validate information provided by two GIS databases, comparing positional accuracy of different food retailer types.

Methods: The location of food retailers within a 1 km circular buffer surrounding 34 schools in Ontario, Canada were measured from online and commercial GIS databases. Actual locations were obtained using a global positioning system (GPS) device. Distances between GIS- and GPS-derived locations were determined.

Results: The InfoCanada and Yellow Pages GIS databases provided the locations for 973 and 676 food retailers, respectively. Overall, 749 (77.1%) and 595 (88.1%) of these were located in the field. The online database had a higher proportion of food retailers found in the field. The GIS locations of 25% of the food retailers were located within 15 m of their actual location, 50% were within 25 m, and 75% were within 50 m. These values did not differ by database source.

Conclusions: This validation study provided a detailed assessment of GIS food database quality, providing in-depth information on measurement error. The location information was more accurate for the online database. However, when matching criteria was more conservative, there were no differences between databases.

BACKGROUND

Recent research on the determinants of obesity has focused on how the built environment in which people live influences their physical activity and diet [1]. Several studies have documented relationships between the availability of food retailers in the local environment, such as fast food restaurants and convenience stores, with eating behaviors and obesity [2-5]. Most studies rely on geographical information system (GIS) databases to measure the food retail environment. Quantifying error in GIS databases is important because it accounts for some of the measurement bias present in etiological studies of the food environment.

To date, six validation studies have examined the accuracy of the information on food retailer locations provided by GIS databases [6-11]. With the exception of the study by Liese et al. [10], existing studies occurred in a single city and classified food retailers as present or absent, rather than quantify the distance between the true and reported locations. Furthermore, studies had small sample sizes (n<200) [8] and did not differentiate between food retailer types [7-9]. Our study objective was to assess the validity of the positional information provided by two GIS databases for different types of food retailers located in urban and non-urban areas.

METHODS

Sampling Approach

We measured the retail food environment surrounding 34 schools. The schools were located in 22 cities and towns located across southern Ontario, Canada. Eight schools were in non-urban areas (<10,000 people) and 26 were in urban areas (>10,000 people) [12]. A 1 km circular buffer was created around each school using ArcGIS (ESRI, Redlands CA, version 9.3) and no buffers overlapped. The location of all food retailers within the buffers was measured.

Food Retailers

The GIS locations of food retailers were obtained from a fee-for-service commercial database (InfoCanada) and a freely accessible online Yellow Pages database (www.yellowpages.ca). The North American Industry Classification System was used to obtain multiple categories of food retailers from the InfoCanada database including: full-service restaurants, limited-service restaurants, snack and non-alcoholic beverage bars, and convenience stores. We merged the snack and non-alcoholic beverage bars into the limited-service restaurant category. For the Yellow Pages database, full-service restaurants and convenience stores were obtained with the keywords “restaurant” and “convenience store”, respectively. Limited-service restaurants were obtained with the keywords “ice-cream & frozen desserts”, “sandwiches”, and “donut – retail”. The limited-service restaurants also included chain fast-food restaurants, which are listed in Additional File 1.

The true location of food retailers, at the curb side street entrances, was determined in the field using a Garmin Dakota 10 handheld Global Positioning System (GPS) device (Garmin International Inc., Olathe, Kansas). In downtown areas where there were no distinct street entrances, the storefront entrance was measured. If a food retailer was not initially found, it was telephoned to verify its existence and to help identify its location for GPS measures.

For a detailed description of the GIS-based measures of this study, see Appendix F.

Statistical Analysis

The differences in GIS- and GPS-derived locations were determined by measuring the Euclidian (straight line) distance in ArcGIS. Because values for these distances were skewed, medians were reported and the Wilcoxon rank-sum test was used to determine if the distances differed between the GIS databases. We also determined the proportion of the GIS-measured food retailers that were located within the 1 km buffer, and within 100 m, 50 m, and 25 m of the true GPS-measured location. Chi-square and Fisher's exact tests were used to determine whether the proportions of GIS-measured food retailers located within these distances differed between the databases.

RESULTS

The InfoCanada and Yellow Pages GIS databases provided the locations for 973 and 676 food retailers, respectively, in the 1 km buffer surrounding the 34 schools. Overall, 749 (77.1%) and 595 (88.1%) of these were located in the field, respectively. For urban schools, the proportion of food retailers found within the 1 km buffer was higher for the Yellow Pages database for all categories, with the exception of convenience stores (Table 1).

The proportion of listed food retailers located within a specific distance of their true location decreased as the size of the distance got smaller (Table 1). For example, for urban schools, the proportion of limited-service restaurants in the Yellow Pages database that were within 100 m of their true location was 77.5 %; 52.1% were within 50 m and only 25.4% were within 25 m.

Table 2 provides the median positional error, which is the Euclidean distance between the GIS- and GPS-derived locations. The median positional errors were not statistically different in the InfoCanada (24.6 m, interquartile range: 13.2-51.0 m) and Yellow Pages (25.6 m, interquartile range: 13.1-51.7 m) databases.

DISCUSSION

The key findings of this study were that the Yellow Pages directory provided a greater proportion of the listed food retailers in the 1 km buffer, but that the positional error did not differ between GIS databases. When considering the presence or absence of food retailers within a 1 km buffer, the validity of the information provided by GIS was good. However, with more precise distance thresholds (eg, within 50 m), the validity of both GIS databases was poor.

This study provides important contributions to the study of the food environment. It is important to assess the quality of GIS food retailer databases since they are used to make inferences about the food environment and eating behaviors. This was achieved by evaluating the quality of positional information provided by two different GIS databases in multiple locations using a variety of criteria.

The results for the 1 km buffer were relatively consistent with those of Hosler and Darssi [6], Lake et al. [9], and Liese et al. [10]. However, unlike the findings by Paquet et al [8], we found that a higher proportion of food retailers listed in the online database were found in the field compared to the commercial database. This may be explained by how frequently the databases are updated. The location information for InfoCanada is valid for 6 months while the Yellow Pages provides monthly subscriptions. Some of the measurement error for both databases may be explained by the fact that GIS software estimates street address locations by uniformly distributing street address numbers along road segments. These estimated locations may not precisely match the actual street address locations.

There are some limitations to our study that warrant consideration. Because we did not attempt to measure the presence of food retailers located within the 1 km buffer that did not appear in the GIS databases (due to feasibility issues), we were unable to calculate sensitivity. In addition, there were small numbers of food retailers in non-urban locations, which may account for the lack of statistically significant findings in those areas.

CONCLUSION

Half of the food retailers were positioned within ~25 m of their true location by the two GIS databases, and 75% were positioned within ~50 m. The Yellow Pages directory provided a higher proportion of matches within the 1 km buffers compared to the InfoCanada database.

ACKNOWLEDGEMENTS

This study was funded by an operating grant from the Canadian Institutes of Health Research (CIHR) (MOP 97962), and a second operating grant co-funded by CIHR and the Heart and Stroke Foundation of Canada (PCR 101415). LS was supported by the CIHR Frederick Banting and Charles Best Canada Graduate Scholarship. IJ was supported by researcher awards from CIHR and the Ontario Ministry of Research and Innovation.

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Table 1. The proportion of food retailers in the GIS databases found in the field validation

Distance	Urban				Non-Urban			
	Info Canada		Yellow Pages		Info Canada		Yellow Pages	
	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)	N	% (95% CI)
Within 1 km Buffer								
All Food Retailers	628	76.0 (72.7-79.3)	525	87.9 (85.1-90.7)†	121	82.9 (76.2-89.6)	70	89.7 (82.6-96.8)
Full Service	283	72.2 (67.0-77.4)	320	88.4 (84.9-91.9)†	55	75.3 (63.9-86.7)	48	90.6 (82.3-98.9)*
Limited Service	272	80.0 (75.2-84.8)	125	88.0 (82.3-93.7)*	54	91.5 (84.1-98.9)	15	88.2 (71.9-104.5)
Convenience	73	77.7 (68.2-87.2)	80	86.0 (78.4-93.6)	12	85.7 (65.9-105.5)	7	87.5 (63.0-112.0)
Within 100 m								
All Food Retailers	562	68.0 (64.1-71.9)	474	79.4 (75.8-83.0)†	110	75.3 (63.9-86.7)	65	83.3 (74.2-92.4)
Full Service	261	66.6 (60.9-72.3)	294	81.2 (76.7-85.7)†	50	68.5 (55.6-81.4)	45	84.9 (74.4-95.4)*
Limited Service	234	68.8 (62.9-74.7)	110	77.5 (69.7-85.3)	48	81.4 (70.4-92.4)	13	76.5 (53.5-99.5)
Convenience	67	71.3 (60.5-82.1)	70	75.3 (65.2-85.4)	12	85.7 (65.9-105.5)	7	87.5 (63.0-112.0)
Within 50 m								
All Food Retailers	450	54.5 (49.9-59.1)	382	64.0 (59.2-83.8)†	102	69.9 (61.0-78.8)	57	73.1 (61.6-84.6)
Full Service	229	58.4 (52.0-64.8)	250	69.1 (63.4-74.8)†	47	64.4 (50.7-78.1)	41	77.4 (64.6-90.2)
Limited Service	166	48.8 (41.2-56.4)	74	52.1 (40.7-63.5)	43	72.9 (59.6-86.2)	10	58.8 (28.3-89.3)
Convenience	55	58.5 (45.5-71.5)	58	62.4 (49.9-74.9)	12	85.7 (65.9-105.5)	6	75.0 (40.4-109.6)
Within 25 m								
All Food Retailers	297	36.0 (30.5-41.5)	245	41.0 (34.8-47.2)	81	55.5 (44.7-66.3)	50	64.1 (50.8-77.4)
Full Service	164	41.8 (34.3-49.3)	168	46.4 (38.9-53.9)	38	52.1 (36.2-68.0)	37	69.8 (55.0-84.6)
Limited Service	97	28.5 (19.5-37.5)	36	25.4 (11.2-39.6)	33	55.9 (39.0-72.8)	9	52.9 (20.3-85.5)
Convenience	36	38.3 (22.4-54.2)	41	44.1 (28.9-59.3)	10	71.4 (44.7-98.1)	4	50.0 (1.0-99.0)

† = proportion of food retailers differs between sources at a p value <0.01
* = proportion of food retailers differs between sources at a p value <0.05

Table 2. Positional error (meters) of food retailer locations provided the GIS databases

	InfoCanada		Yellow Pages		P value
	N	Median (IQR)	N	Median (IQR)	
Urban Schools					
All Food Retailers	628	26.9 (13.5 - 54.4)	525	27.7 (13.8-51.7)	0.98
Full Service	283	20.9 (12.3 - 41.9)	320	22.5 (12.2 - 44.2)	0.34
Limited Service	272	37.6 (16.8 - 67.4)	125	44.0 (21.1 - 69.4)	0.31
Convenience	7	24.6 (13.5 - 49.9)	80	24.6 (13.7 - 60.6)	0.61
Non-Urban Schools					
All Food Retailers	121	16.8 (10.3 - 30.3)	70	14.4 (8.1 - 27.6)	0.20
Full Service	55	16.7 (9.7 - 30.3)	48	14.4 (7.6 - 23.4)	0.70
Limited Service	54	17.1 (10.4 - 35.1)	15	17.0 (9.5 - 54.3)	0.89
Convenience	12	16.8 (13.9 - 23.6)	7	13.9 (7.4 - 32.8)	0.37

IQR = Interquartile Range

Additional File 1. Limited-service chain food retailers from online yellow pages directory

241 Pizza
A&W
Arbys
Baskin Robbins
Burger King
Coffee Time Donuts
Country Style Donuts
Dairy Queen
Dominos Pizza
Double Double Pizza & Chicken
Harvey's
KFC
McDonalds
Mr. Sub
Pita Pit
Pizza Pizza
Quiznos
Starbucks
Subway
Taco Bell
Tim Hortons
Wendys

CHAPTER 4

Food Retailers Surrounding Schools and Lunchtime Eating Behaviours of Students

ABSTRACT

The primary objective of this study was to examine whether the presence of food retailers within 1 km of Canadian schools was associated with lunchtime eating behaviours of grade 9-10 students. The secondary objective was to determine whether measures of the presence of food retailers assessed using road network buffers were more strongly related to eating behaviours compared to measures obtained using circular buffers. For the circular buffers, students with ≥5 food retailers were 2.94 (95% CI: 1.71-5.09) times more likely to eat their lunch at food retailers compared to students with no nearby food retailers; a finding that was slightly stronger when assessed via road network buffers (OR 3.54, 95% CI: 2.08-6.02). Road network buffers appeared to provide a better measure of the food retail environment, as indicated by lower Akaike's Information Criteria values (3332 vs. 3346), a goodness-of-fit statistic for the regression models.

INTRODUCTION

Poor eating behaviours, defined in this study as eating behaviours that lead to an increased consumption of foods high in calories, sugar, salt and fat, are an important determinant of health among young people. Consumption of these foods is associated with the onset of several adverse health outcomes including obesity [1-3] and early indicators of cardiovascular disease [4,5] and type 2 diabetes [6]. Young people who frequently eat at fast food restaurants have poorer diets than those who eat at these restaurants less frequently [7-9]. Although there is a lack of analogous research on food purchases at convenience stores or coffee/donut shops, the increased consumption of sugar sweetened beverages [10] and snack foods [11] in recent years suggests that these food retailers may also influence eating behaviours.

Since young people spend a large portion of their day at school, the school food environment may impact their eating behaviours and diets. Most research on the school food environment has focused directly on the school itself (e.g., cafeteria, vending machines) [12-14]. However, many students are permitted to leave school grounds during the school day and have access to nearby food retailers. There is sometimes a preponderance of fast food restaurants near schools [15,16], and these types of food retailers sell primarily unhealthy foods. Few studies have considered whether the presence of food retailers near schools negatively influences young peoples' eating behaviours. Existing studies provided weak [17] to no support of this notion [18,19]. A major limitation of these studies is that they measured the overall consumption of specific food items (e.g., fruits and vegetables), and did not consider where or when the food items were obtained. This makes it impossible to distinguish between the contributions of the school food retail environment, the food retail environment surrounding homes, and other environments to overall consumption.

In order to measure the local food retail environment, previous studies have used different types of geographic boundaries, with most relying on either circular buffers [17,19] or road network buffers [15,18]. Circular buffers capture all land within a set distance from a location of interest "as the crow flies", while road network buffers extend outwards from a location of interest by following road networks, and therefore capture what is actually accessible to a person using the roads to travel to and from food retailers. Circular buffers, while easy to create, do not necessarily reflect how people travel. Road network-based buffers address this limitation, but the creation of road network buffers requires more time and expertise in geographic information system (GIS) technologies. Measures of the built environment which use road network buffers have been shown to be more strongly and consistently related to physical activity behaviours compared to circular buffers [20]. There is an analogous need to address this buffer measurement issue for the food retail environment.

The primary objective of this study was to examine the relationship between the food retail environment surrounding Canadian schools and students' lunchtime eating behaviours. This relationship has not been demonstrated convincingly in past studies, potentially due to a lack of precision in the measurement of specific eating behaviours and locations. A second objective was to determine whether measures of the food retail environment obtained by road network buffers were more strongly related to eating behaviours than comparable measures obtained using circular buffers. We carried out these objectives in a large national study. From a public health perspective, findings from this study could support strategies aimed at improving eating behaviours among young people through the development of policies that would address the food retail environment surrounding schools. From a methodological perspective, the findings of this study could provide information on the optimal buffer type to use when conducting research on the food retail environment.

MATERIALS AND METHODS

Overview of Study Design

This study involved a multilevel cross-sectional analysis that examined the relationship between the food environment surrounding schools and the locations where grade 9 and 10 students ate their lunch during the school week. Participants and schools were obtained from the 2009/10 Canadian Health Behaviour in School-aged Children (HBSC) survey. Addresses of food retailers surrounding schools were gathered using an online food retailer database. The presence of food retailers surrounding each school was measured by creating 1 km circular and 1 km road network buffers around schools using the GIS software, then determining the number of food retailers within each type of buffer. Associations between food retailer exposures and individual reports from students about eating their lunch at a food retailer were then assessed.

Study Sample

The HBSC survey is carried out in association with the World Health Organization and was conducted in 43 countries in 2009/10. It includes a student survey completed by grades 6 to 10 students (approximate ages of 11 to 16 years) and an administrator survey completed by a principal or designate at each of the participating schools. The student survey is completed in the classroom and covers a variety of health behaviours and their determinants.(For more detailed information on the HBSC survey methodology, see appendix B). In Canada, a single stage cluster sampling approach was used to obtain participants, in accordance with an international protocol [21]. Classes were the primary sampling unit, and they were stratified by province, with an oversampling of some provinces and the three northern territories. The HBSC survey excludes students in private schools, incarcerated youth, special needs schools and students who are home schooled. In 2009/2010, two Canadian provinces with small populations (New Brunswick and Prince Edward Island) were unable to participate. Ethics approval was obtained from the Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board. Subject consent was obtained at the school board and school levels, as well as from parents or guardians (either explicitly or implicitly, as determined by school board policy). See Appendix A for information on ethics approvals.

The 2009/10 HBSC survey contained a total of 26,078 students in 436 schools across Canada. For our study, analyses were restricted to students attending schools where they were permitted to leave school grounds, thereby making it possible for them to purchase food at nearby food retailers. Because only 1.1% of grade 6 to 8 students reported the study outcome (regularly eating their lunch at food retailers), they were excluded from the analysis, leaving 8,439 students from 169 schools. Students (n=528) from an additional 11 schools were excluded due to missing information on food sources within schools or in the school neighborhoods, and 940 students were excluded because of missing data on key variables. The final analyses involved 6,971 students from 158 schools.

Eating Lunch at a Food Retailer

The outcome of this study was obtained from the response to the following question: "*Where do you usually eat your lunch or mid-day meal on school days?"*. Students who chose the response *"snack-bar, fast-food restaurant, café"* were classified as regularly purchasing their lunch from a food retailer. Those who chose the remaining responses (*"at school", "at home", "at someone else's house", "do not eat lunch/mid-day meal",* or *"other"*) were classified those who typically did not eat their lunch at a food retailer. For a complete description of the HBSC questions used in this Manuscript, see Appendix C.

School Food Retail Environment

The addresses of the 158 HBSC schools were mapped in ArcGIS (ESRI, version 9.3) and 1 km circular and road network-based buffers were constructed. The 1 km distance was chosen because it approximates the distance that can be walked in 10 to 15 minutes [22], a comfortable amount of time for students to walk to and from food retailers during their lunch break. Circular buffers surrounding schools were created by extending a 1 km radius around the schools. Road network buffers were created using a commercial road network database provided by CanMaps Streetfiles (DMTI Spatial Inc., v.2009.4, Markham ON). Roads extending outwards from schools were followed until they reached an endpoint at 1 km. Lines connecting the 1 km endpoints were used to create the border of the road network-based buffers. To illustrate, the Figure shows the characteristics of a circular and road network buffer for one of the participating HBSC schools. For some schools, the 1 km road network buffer may cover a considerably smaller area than circular buffers and therefore capture fewer food retailers.

Convenience stores, fast food restaurants, and coffee/donut shops were included as the primary independent variable of interest. These directly corresponded to the lunchtime eating question used to determine the study outcome. Information on the addresses of these types of food retailers near schools was obtained using an online Yellow Pages directory (www.yellowpages.ca). The Yellow Pages database was chosen because it provided more accurate information on food retailer locations than a commercial database [23]. School addresses were entered into the Yellow Pages directory. The search term ‘convenience stores’ was used to obtain convenience stores. There was no single search term to use for fast food restaurants and coffee/donut shops because many of them were listed under the full service restaurant category. Therefore, we searched for the top 75% of the top 200 chain food retailers in Canada in 2009 [24], which is a similar approach to those used in previous food retail environment studies [25,26]. Names of the 16 fast food restaurant chains and 4 coffee/donut chain restaurants that were included as search terms are shown in Table 1. For detailed information on how food retailers were obtained and mapped, see Appendix F)

All food retailers within the 1 km circular and 1 km road network buffers were mapped using ArcGIS software. For food retailers whose street addresses had a match score of less than 80%, the Street View tool in Google Earth (©2011 Google) was used to confirm the location and obtain latitude and longitude coordinates to map them manually in ArcGIS. The number of food retailers within the buffers was positively skewed, hence the following categories were created: no food retailers present, presence of 1 or 2 food retailers, presence of 3 or 4 food retailers, and presence of 5 or more food retailers.

Confounders

Individual-level variables, including age, sex, and socioeconomic status were considered as potential confounders, since fast food consumption varies by these characteristics [9,27,28]. To obtain information on socioeconomic status, the HBSC survey uses the previously validated family affluence scale (FAS) [29]. Finally, because cafeterias, vending machines, and school snack/tuck shops are associated with students' eating behaviors [12-14], they were considered as potential school-level confounders, as they may have reduced the likelihood of students seeking food from food retailers outside of the school. (See Appendix C for the exact survey questions used in the analysis).

Regression Analysis

All analyses were conducted using SAS statistical software, version 9.2 (SAS Institute, Cary, NC). Multilevel logistic regression was carried out to examine the relationship between the presence of food retailers (convenience stores, fast food restaurants, and coffee/donut shops) and the likelihood of students eating their lunch at these food retailers. A three step modeling procedure was carried out. First, an empty model was used to determine the intraclass correlation coefficient (ICC), which provides an estimate of the proportion of the variation in the study outcome that was due to differences between schools. Second, bivariate relationships were examined between the study outcome and each potential confounder. Finally, the multivariate model building process began with the introduction of the individual-level confounders and proceeded using a backwards elimination approach. Next, the school-level food exposure variables were forced into the model because we were interested in assessing food sources within school as well as those surrounding schools.

Goodness-of-Fit

The Akaike information criterion (AIC) was determined for the final multivariate models. It is a measure of goodness-of-fit when comparing two or more regression models. The AIC value is derived using likelihood theory rather than the more commonly used least squares theory. Likelihood theory estimates the likelihood of an unknown parameter, given the data at hand and a particular model [30]. The AIC value of a model is equal to -2 Log likelihood + 2K, where K is the number of parameters in the model, including the intercept and the variance [30]. It is an estimate of the expected relative distance between a fitted model and an unknown "true mechanism" that generated the observed data. The advantage of the AIC goodness-of-fit value is that the models that are compared do not have to be nested. Rather, the key condition for comparing AIC scores across candidate models is that the models must be obtained from the same data set.

To interpret the AIC values from a set of candidate models, it is not the absolute values of the AIC scores that matter, but rather the difference between them. A lower AIC value indicates better model fit and a difference in AIC values between 2 to 7 indicates a moderate difference in fit of the models, while a difference of 7 or more indicates a large difference in model fit [30]. Using the AIC values, the Akaike weights were calculated, which indicate the probability that a regression model is the best choice among a set of candidate models based on the model fit [31]. After the model with the best fit was determined, the population attributable risk (PAR) was calculated, using the following formula: $PAR = P_{exp}(RR - 1)/(1 + P_{exp}(RR - 1)$, where P_{exp} denotes the prevalence of the exposure [32] and RR represents the relative risk. Since the outcome is rare (<10%), the odds ratio (OR) was used to approximate the RR.

RESULTS

Description of Study Sample

Table 2 shows the individual-level characteristics of the study sample. There was an approximately equal distribution of males and females. Over half of the participants were in the highest family affluence group and only 8.0% were in the lowest. Of the participants who provided self-reported weights and heights, 19.6% were overweight or obese according to the International Obesity Task Force body mass index criteria [33]. During the school week, the majority of students typically ate their lunch either at school (67.7%), at home (15.2%), or in a snack bar, fast food restaurant, or café (7.4%).

Characteristics of the schools involved in this analysis are shown in Table 3. The majority were secondary schools (limited to students in grades 9 to 12) and 39.2% were located within large urban centres. Most schools had cafeterias (76.0%) and vending machines that served sugared drinks (61.4%). Only 33.5% of schools had a snack/tuck shop. Overall, 70.9% of schools had at least one food retailer of any type within the circular buffer, and 61.3% of schools had at least one food retailer within the road network buffer. Convenience stores and fast food restaurants were most prevalent. A total of 648 food retailers were located within the 1 km circular buffers surrounding the 158 schools, and 394 food retailers were located within the 1 km road network buffers.

Association Between Neighborhood Food Environments and Lunchtime Eating Behaviors

The ICC value indicated that 26.3% of the variation in the lunchtime eating outcome was due to school-level factors. The high ICC value provides support for the use of multi-level modeling to examine the relationship between the presence of food retailers near schools and the lunchtime eating outcome. Results of the regression analyses for each buffer type are shown in Table 4. The bivariate analysis showed that the only individual-level confounder related to lunchtime eating was sex, with males nearly twice as likely to obtain their lunch from a food retailer. For the school-level confounders, the presence of a school snack/tuck shop decreased the likelihood of eating at food retailers by nearly half, while the presence of a cafeteria in the school was positively related to students eating lunch at a food retailer.

After adjusting for the relevant individual- and school-level confounders, students exposed to ≥5 food retailers based upon the 1 km circular buffer were 2.94 times (95% CI: 1.71-5.09) more likely to eat their lunch at a food retailer compared to students with no food retailers surrounding their school. For the road network-based buffers, students exposed to 3 or 4 food retailers were 3.19 times (95% CI: 1.66-6.13) more likely to eat their lunch at a food retailer, and students exposed to ≥5 food retailers were 3.54 times (95% CI: 2.08-6.02) more likely to eat their lunch at a food retailer compared to students with no food retailers surrounding their school.

Circular vs. Road Network Buffers

The AIC value for the final road network buffer model was 14 units smaller than the value for the final circular buffer model (3332 vs. 3346), indicating that the road network-based buffers provided a better model fit. In addition, the Akaike weight for the road network buffer was 0.99, indicating that there was a 99% probability that the road network data provided the better model fit.

DISCUSSION

The key findings of our study are as follows. First, by using a focused measure of where students eat their lunch, we were able to demonstrate that the food retail environment surrounding schools is strongly related to student's eating behaviours during the school day. Second, our findings suggest that the geographic boundaries used to assess the food retail environment are better captured using road network buffers rather than circular buffers.

At 26.3%, the amount of variation in students' lunchtime eating behaviours attributable to school-level factors was noteworthy. Although there are currently no studies with a similar lunchtime eating behaviour outcome, another Canadian study of the school food environment and obesity by Leatherdale et al. [34] had an ICC of 5.4%. Our comparatively higher ICC value indicates that the school food environment accounts for a notable proportion of the variation in students' lunchtime eating behaviours. Furthermore, the relationship between food retailers surrounding schools and students' eating behaviors observed in our study were much stronger than those previously reported [17,18]. This difference may partly be explained by our use of a precise measurement of food consumption at food retailers during the school day, rather than a more general measure of food consumption patterns reported for the entire day or week, as has been used in past studies [17,18]. It is important to consider the specific context of food consumption, including where and when the food was eaten, in order to evaluate the importance of a specific food environment. By accounting for the particular context in which food was consumed, the potential for the misclassification in the measurement of the food environment is greatly reduced.

Our comparison of the model fit provided by the circular and road network-based buffers showed findings that were consistent with similar research, despite the fact that previous research has used different behavioural outcomes in different populations. Oliver et al. [20] examined the relationship between land use mix, measured with 1 km circular and road network buffers, and walking behaviour in adults residing in Vancouver, B.C. The road network-based measures were consistently related to walking behaviours, while the circular-based measures were not. Taken together, the findings suggest that researchers should consider investing the time in obtaining road network buffers when they want to measure the association between built environment constructs and health-related behaviours. However, it is important to note that there is a scarcity of studies directly comparing buffer types. Future studies comparing these measures are needed to confirm this observation, particularly when assessing the food environment.

Despite the implementation of a new policy restricting fast food restaurants in a socioeconomically disadvantaged area in California [35], there is currently no evidence evaluating its effectiveness. In fact, to our knowledge, no existing studies have examined whether policies aimed at restricting the number of food retailers that sell primarily unhealthy foods (e.g., fast food restaurants) impacts people's dietary behaviours. However, there is analogous evidence from interventions and policies put in place to address the lack of supermarkets – the main source of reasonably priced fresh fruits and vegetables – in socioeconomically disadvantaged neighbourhoods. For instance, the introduction of a new supermarket in a deprived neighborhood in Leeds, UK positively impacted the fruit and vegetable consumption of the adults residing in that neighborhood, particularly those with the worst diets, whose fresh fruit and vegetable consumption doubled [36]. This demonstrates the potential to influence peoples' eating behaviours by modifying their food environment through policies and interventions. Given the preponderance of unhealthful food retailers near schools [15,16] and the strong associations we found with students' eating behaviours, there is a need for future research to evaluate whether restrictions on food retailers near schools affect lunchtime eating behaviours of young people.

While the food retail environment within the school has an important impact on students' eating behaviors and food choices [12-14], approximately one third of the grade 9 and 10 students in our national study did not usually eat their lunch at school and almost one in ten usually ate their lunch at a food retailer. Interestingly, we observed that the presence of school cafeterias and certain vending machines were positively associated with eating lunch at food retailers, although the relationship was not statistically significant. The positive relationships suggest that despite having the option to purchase food directly within their schools, some students prefer to purchase their lunch at nearby food retailers. Furthermore, the population attributable risk calculations suggest that 58% of the study outcome (eating at food retailers during the school week) was attributable to students being exposed to 3 or more food retailers within a 1 km travel distance of their school. Therefore, policies and programs directed at eliminating unhealthy food choices within school cafeterias and vending machines may be undermined by the availability of less nutritious food at nearby food retailers.

Some important strengths and limitations merit consideration. Key strengths of this study included our specific measurement of eating behaviours during the school day and the large and geographically diverse study sample. A limitation of this study was that the food environment was measured with an online GIS database, which may not provide a completely accurate and up-to-date measure of the food environment. Furthermore, only the top 75% of chain fast food and donut/coffee shops were included in the exposure measure. There was no information from the HBSC survey on which food retailers the students actually went to. Also, all data were obtained by self-report, and may be subject to bias introduced by the social desirability of eating healthy meals. Finally, the study was cross-sectional and therefore temporality between the presence of food retailers and eating behaviours cannot be directly established. However, it is unlikely that students chose to attend schools based on the presence of nearby food retailers.

CONCLUSIONS

In conclusion, this national study provides novel insights into the relationship between the food retail environment surrounding schools and the eating behaviours of students during the school day. It also provided evidence to support the use of network buffers over circular buffers when assessing the food retail environment. Future research needs to evaluate whether policies directed at modifying the food retail environment improve eating behaviours.

ACKNOWLEDGEMENTS

The authors of this study would like to thank Mariane Héroux, Rachel Laxer and Hoda Gharib for their assistance in the collection of the food retailer addresses. The 2009/10 Health Behaviour in School-aged Children Survey (HBSC), a World Health Organization/European Region collaborative study, was funded in Canada by the Public Health Agency of Canada and Health Canada. This study was funded by an operating grant from the Canadian Institutes of Health Research (MOP 97962), and a second operating grant co-funded by the Canadian Institutes of Health Research and the Heart and Stroke Foundation of Canada (PCR 101415). In addition, Laura Seliske was supported by a Frederick Banting and Charles Best Doctoral Research Award from the Canadian Institutes of Health Research. Ian Janssen was supported by a Canada Research Chair and an investigator award from the Ontario Ministry of Research and Innovation. The principal investigators of the 2009/10 Canadian HBSC survey were John Freeman and William Pickett, and the HBSC is coordinated internationally by Candace Currie (University of Edinburgh).

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Figure. A comparison of a 1 km circular buffer and a 1 km road network buffer to measure access to food retailers. The road network buffer is represented by the white area and the circular buffer encompasses both the white and gray areas. The food retailers are represented by the black circles.

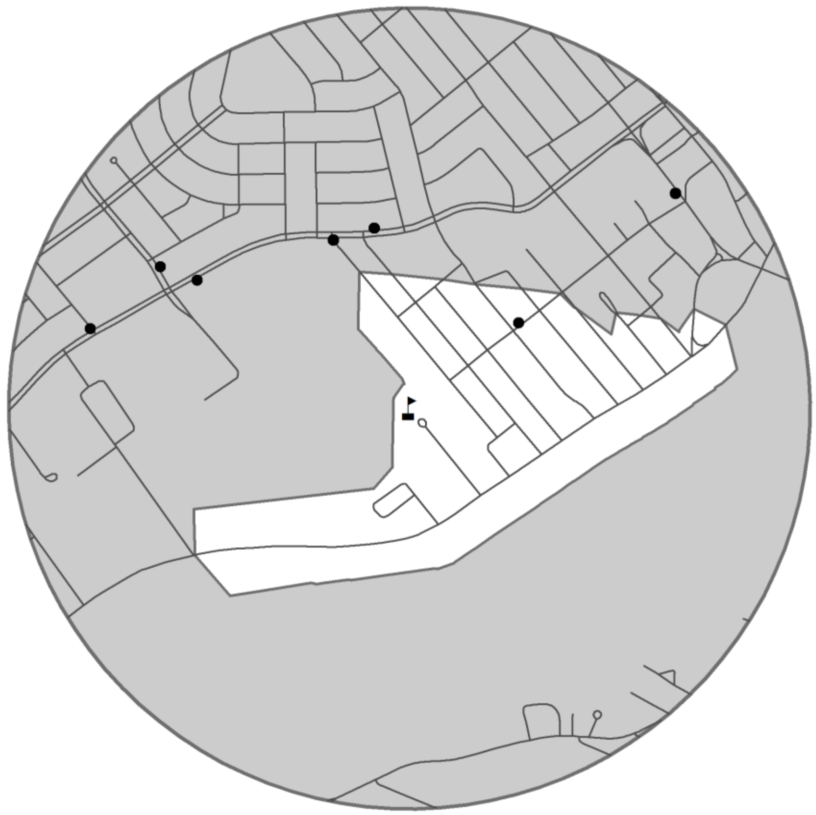

Table 1. Top 75% of chain fast food retailers and coffee/donut shops in Canada according to the number of outlets.

Fast Food Retailers	Number of Outlets	Coffee/Donut Shops	Number of Outlets
Subway	2477	Tim Hortons	3014
McDonald's	1420	Starbucks	1051
KFC	760	Country Style	465
A&W	700	Second Cup	343
Pizza Pizza	590		
Dairy Queen	580		
Quizno's	450		
Mr Sub	400		
Burger King	395		
Wendy's	371		
Pizza Hut	340		
Domino's Pizza	319		
Harvey's	260		
Little Caesar's	191		
New York Fries	180		
Taco Bell	175		

Table 2. Individual-level demographic and health characteristics of the study sample from the 2009/10 Health Behaviour in School Aged Children Survey (N=6,971)

	N	%
Sex		
Male	3381	48.5
Female	3590	51.5
Age (years)		
13	33	0.5
14	2339	33.6
15	3280	47.1
16	1319	18.9
Family Affluence Scale		
Low	560	8.0
Moderate	2531	36.3
High	3880	55.7
Weight Status		
Non-overweight	4823	69.2
Overweight	1018	14.6
Obese	346	5.0
Missing Data	784	11.3
Where Students Eat Mid-day Meal		
At school	4719	67.7
At home	1056	15.2
In a snack bar, fast food restaurant or café	517	7.4
Never eat a midday meal	307	4.4
Somewhere else	209	3.0
At someone else’s home	163	2.3

Table 3. Characteristics of the school and food environment from the study sample obtained from the 2009/10 Health Behaviour in School Aged Children Survey (N=158)

	N	**%**
School Type		
Secondary (grades 9 - 12)	94	59.5
Mixed	64	40.5
Urban Rural Status		
Large urban centre (≥100,000 people)	62	39.2
Medium urban centre (20,000 - 99,999 people)	15	9.5
Small urban centre (1,000 - 19,000 people)	38	24.1
Rural (<1,000 people)	43	27.2
Access to Food Sources Within School		
Cafeteria	120	76.0
Sugared drinks vending machines	97	61.4
Milk vending machines	75	47.5
Candy and potato chip vending machines	64	40.5
School tuck shop/snack bar	51	32.3
≥1 Food Retailer Within 1 km Circular Buffer		
Convenience stores	92	55.2
Fast food restaurants	88	55.7
Coffee/donut shops	53	33.5
All food retailers	112	70.9
≥1 Food Retailer Within 1 km Road Network Buffer		
Convenience stores	73	46.2
Fast food restaurants	65	41.1
Coffee/donut shops	35	22.2
All food retailers	103	61.3

Table 4. Relationship between the presence of food retailers and eating mid-day meal at a café, fast food restaurant or snack bar in the 2009/10 Canadian Health Behaviour in School Aged Children Survey

	Bivariate		***Individual Level Variables***		***Individual and School Level Variables***	
	Circular Buffer	**Network Buffer**	**Circular Buffer**	**Network Buffer**	**Circular Buffer**	**Network Buffer**
Number of Food Retailers						
0	1.00	1.00	1.00	1.00	1.00	1.00
1-2	1.08 (0.57-2.04)	1.24 (0.76-2.02)	1.08 (0.57-2.06)	1.25 (0.76-2.06)	1.10 (0.57-2.11)	1.20 (0.74-1.95)
3-4	1.45 (0.76-2.76)	3.30 (1.71-6.37)	1.45 (0.76-2.79)	3.27 (1.67-6.39)	1.45 (0.75-2.82)	3.19 (1.66-6.13)
≥ 5	3.00 (1.77-5.09)	3.59 (2.13-6.05)	3.08 (1.80-5.27)	3.70 (2.17-6.30)	2.94 (1.71-5.09)	3.54 (2.08-6.02)
Individual-Level Variables						
Age						
1 year increase	1.09 (0.94-1.26)	1.09 (0.94-1.26)				
Sex						
Female	1.00	1.00	1.00	1.00	1.00	1.00
Male	1.91 (1.57-2.33)	1.91 (1.57-2.33)	1.92 (1.57-2.33)	1.90 (1.56-2.32)	1.92 (1.57-2.33)	1.91 (1.57-2.32)
Family Affluence Scale						
Low wealth	1.00	1.00				
Medium wealth	0.99 (0.69-1.42)	0.99 (0.69-1.42)				
High wealth	1.00 (0.70-1.42)	1.00 (0.70-1.42)				
School-Level Variables						
Food Sources in Schools						
Cafeteria	1.79 (1.01-3.15)	1.79 (1.01-3.15)	--	--	1.30 (0.75-2.28)	1.49 (0.88-2.53)
Sugared drinks vending	1.20 (0.76-1.91)	1.20 (0.76-1.91)	--	--	1.36 (0.80-2.32)	1.37 (0.82-2.28)
Milk vending	1.15 (0.74-1.77)	1.15 (0.74-1.77)	--	--	1.19 (0.77-1.83)	1.22 (0.81-1.84)
Candy/potato chip vending	1.13 (0.72-1.76)	1.13 (0.72-1.76)	--	--	0.76 (0.44-1.30)	0.76 (0.45-1.26)
School tuck shop/snack bar	0.57 (0.36-0.91)	0.57 (0.36-0.91)	--	--	0.66 (0.42-1.03)	0.68 (0.44-1.05)

Note: Data are presented as odds ratios (95% confidence interval)

CHAPTER 5

Identification of the Optimal Geographic Boundary Size to Use When Measuring the Food Retail Environment Surrounding Schools

ABSTRACT

The study objective was to identify the optimal geographic boundary or buffer size to use when assessing the food retail environment surrounding Canadian schools. We measured the number of food retailers (fast food restaurants, convenience stores, and cafes) captured by five different road network buffer sizes (500, 750, 1000, 1500, 2000, and 5000 metres) around 158 schools. We then used logistic regression to examine associations between the food retailer measures with the lunchtime eating behaviours of 6,971 students in grades 9-10. The logistic regression model for the 1000 m buffer provided the best fit. At this distance, students with ≥3 food retailers near their schools had a 3.42 times the relative odds (95% CI: 2.12-5.52) of eating their lunchtime meal at a food retailer compared to students with no food retailers near their schools. Future initiatives directed at the food retail environment surrounding schools should consider using a 1000 m road network buffer.

INTRODUCTION

Over the past three decades, the prevalence of childhood and youth obesity has increased dramatically across the globe [1]. There has been a lack of long-term success with its prevention via interventions that focus on individual-level factors [2]. This has resulted in a more comprehensive approach that includes the exploration of food retail environments and their impact on eating behaviours in young people [3]. The food retail environment refers to the availability of food retailers such as fast food restaurants, convenience stores and coffee/donut shops. In general, foods sold at these retailers are of poor nutritional quality [4-6] and excess consumption of these foods is associated with adverse health outcomes such as obesity and cardiometabolic diseases [7-10]. For young people, the food environment includes the food retailers surrounding their homes and schools. Food retailers near schools are readily available to students [11,12] and relationships with students' lunchtime eating behaviours [13] and obesity [14-16] have been identified.

Research on the food retail environment has used both subjective [17,18] and objective [19,20] measures. Subjective measures rely on self-reported availability of nearby food retailers. Objective measures use geographic information systems (GIS) software to map food retailer addresses within a particular geographic area. Subjective and objective measures of the food retail environment are poorly related [21], and therefore objective GIS-based measures are preferred. GIS-based studies have used a variety of boundaries types to capture the food retail environment including census boundaries [22], ZIP codes [16], circular buffers [14], and road network buffers [20]. A limitation of pre-existing census and ZIP code boundaries is that they were designed for administrative purposes and vary considerably in size. Circular buffers overcome this limitation, but unlike road network buffers, they do not necessarily reflect how people travel from one location to another. Road network-based food retailer measures are more strongly related to young peoples' eating behaviours compared to measures that use circular buffers [13].

The next methodological issue to address for GIS-based measures of the food retail environment, as identified in recent literature reviews [3,23], is the appropriate size of the buffer. Some studies that measured food retail environments around schools [14,24] and homes [14,20,24,25] addressed this issue by using various buffer sizes. For instance, for the school environment, Davis and Carpenter [14] found that chain fast food restaurants within 0 to 400 m and 400 m to 800 m of schools, but not 800 m to 1200 m, were associated with students' BMI values. For the home environment, Laska et al. [24] found that food retailers within 1600 m of homes, but not 800 m or 3000 m, were associated with adolescents' sugar sweetened beverage intake and obesity. There are important limitations to these studies [14,20,24,25]. None of them conducted a formal analysis to quantify which buffer distance was the best predictor of eating behaviours or obesity. Many examined only two buffer sizes that were substantially different in size [20,24,25]. Finally, studies took place within a single city [24,25] or state [14,20] and are limited in their representativeness.

The primary objective of this study was to identify the optimal buffer size to use when studying the relationship between the food retail environment around schools and the eating behaviour of Canadian students. To achieve this, we measured the food retail environment surrounding schools using several buffer sizes, and then used regression analysis to examine the associations between the food retailer measures in each buffer size and the lunchtime eating behaviours of students. Comparisons of model fit were used to determine the optimal buffer size. Our study was conducted in a large and diverse sample of students from across Canada.

MATERIALS AND METHODS

Overview of Study Design

This study involved a multilevel cross-sectional analysis of schools participating in the 2009/2010 Canadian Health Behaviour in School-aged Children (HBSC) survey. Addresses of food retailers surrounding schools were gathered using an online food retailer database. Numbers of food retailers surrounding each school were obtained for the following road network-based buffers: 500 m, 750 m, 1000 m, 1500 m, 2000 m and 5000 m. Associations between the presence of food retailers and students' reports of eating their lunch at a food retailer were then assessed.

Study Sample

The 2009/2010 HBSC survey involved 26,078 students from 436 schools across Canada and collected information on a variety of health behaviours in students in grades 6 to 10 (approximate ages 11-16 years). Classes were the primary sampling unit, and they were stratified by province, with an oversampling of some provinces and the three northern territories. Two Canadian provinces with small populations (New Brunswick and Prince Edward Island) were unable to participate in the 2009/2010 survey. The HBSC survey also excludes students in private schools, incarcerated youth, special needs schools and students who are home schooled. Ethics approval was obtained from the Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board. Subject consent was obtained at the school board and school levels, as well as from parents or guardians (either explicitly or implicitly, as determined by school board policy). See Appendix A for more information on the ethics approvals for this Manuscript.

In the current analysis, the sample was restricted to the 169 schools where students were permitted to leave school grounds, making it possible for them to purchase food at nearby food retailers. Because only 1.1% of grade 6 to 8 students reported the study outcome (regularly eating their lunch at food retailers), they were excluded from the analysis, leaving 8,439 students from the 169 schools. Due to missing information on food sources within schools or in the school neighborhoods, 528 additional students from 11 schools were excluded. An additional 940 students were excluded because of missing data on key variables. The final analyses involved 6,971 students from 158 schools.

School Food Retail Environment

The addresses of the 158 eligible HBSC schools were mapped in ArcGIS (ESRI, version 9.3) and road network-based buffers were constructed using the following distances: 500 m, 750 m, 1000 m, 1500 m, 2000 m and 5000 m. These distances were selected based upon existing precedents [19,20,26-28]. Road network-based buffers were chosen instead of circular buffers because they are a better measure of the food retail environment surrounding schools [13]. The road network buffers were created using a commercial road network database provided by CanMaps Streetfiles (DMTI Spatial Inc., v.2009.4, Markham ON). Roads extending outwards from schools were followed until they reached their specified endpoint. Lines connecting the endpoints were used to create the border of the road network-based buffers. See the Figure for an illustration of the multiple road network buffers used in this study.

Convenience stores, fast food restaurants, and coffee/donut shops were included to develop the primary independent variable of interest. These directly corresponded to the lunchtime eating question used to determine the study outcome. Addresses of these specific types of food retailers were obtained using an online Yellow Pages directory (www.yellowpages.ca). The Yellow Pages database was chosen because it provided the most accurate information available on food retailer locations [29]. School addresses were entered into the Yellow Pages directory. The search term ‘convenience stores’ was used to obtain convenience store addresses. There was no single search term to use for fast food restaurants and coffee/donut shops because many of them were listed under the full service restaurant category. Therefore, we searched for the top chain food retailers, as has been done in previous studies [28,30]. The top 75% of the top 200 chain food retailers for Canada in 2009 used in this study were obtained from Technomic Inc [31], and are available upon request. Appendix F provides a detailed description of the methods used to collect food retailer addresses and map their locations.

All food retailers within the road network buffers were mapped using ArcGIS software. The mapping procedure in ArcGIS provided a score evaluating the accuracy of each mapped location. For food retailers whose street addresses had a score of less than 80%, the Street View tool in Google Earth (©2011 Google) was used to confirm the location and obtain latitude and longitude coordinates to map them manually in ArcGIS if necessary. Because the number of food retailers within the buffers was positively skewed, they were categorized into groups. All categories were based on thresholds established for the 500 m network buffer size. At this distance, 74% of schools had no nearby food retailers (categorized as “none”), and the remaining 26% were categorized as having “1 or more” food retailers. For the remaining buffer sizes, a “none” category was created, a threshold of the top ~26% was used to denote the category with the highest number of food retailers. The thresholds for the middle categories were created in a manner which ensured an approximate equal number of schools within each category.

Lunchtime Eating Outcome

The outcome of this study was obtained from the response to the following question: “*Where do you usually eat your lunch or mid-day meal on school days?”*. Students who chose the response *“snack-bar, fast-food restaurant, café”* were considered to regularly purchase their lunch from food retailers. Those who chose the remaining responses (*"at school", "at home", "at someone else's house", "do not eat lunch/mid-day meal",* or *"other"*) were classified as those who did not typically obtain their lunch from food retailers. To see the HBSC survey questions used in this analysis, see Appendix C.

Confounders

Potential confounders were considered at both the individual- and school-levels. Individual-level variables, including age, sex, and socioeconomic status were considered as potential confounders, since fast food consumption varies by these characteristics [6,32,33]. To obtain information on socioeconomic status, the HBSC survey uses the previously validated family affluence scale (FAS) [34]. In addition, because cafeterias, vending machines, and school snack/tuck shops are associated with students' eating behaviors at school [35-37], they were considered as potential school-level confounders.

Regression Analysis

All analyses were conducted using SAS statistical software, version 9.2 (SAS Institute, Cary, NC). Multilevel logistic regression was carried out to examine the relationship between the presence of food retailers near schools (convenience stores, fast food restaurants and coffee/donut shops) and the likelihood of students eating their lunch at these food retailers. For each buffer size, the multivariate model building process began with the introduction of the individual-level confounders and proceeded using a backwards elimination approach. Next, the school-level food exposure variables were forced into the model because we were interested in accounting for food sources within the schools as well as those surrounding schools.

Goodness-of-Fit

The Akaike information criterion (AIC), which is a measure of goodness-of-fit when comparing two or more regression models, was determined for the final multivariate models. The AIC value is derived using likelihood theory rather than the more commonly used least squares theory. Likelihood theory estimates the likelihood of an unknown parameter, given the data at hand and a particular model [38]. The AIC value of a model is equal to -2 Log likelihood + 2K, where K is the number of parameters in the model, including the intercept and the variance [38]. It is an estimate of the expected relative distance between a fitted model and an unknown "true mechanism" that generated the observed data. The advantage of the AIC goodness-of-fit value is that the models that are compared do not have to be nested. Rather, the key condition for comparing AIC scores across candidate models is that the models must be obtained from the same data set.

To interpret the AIC values from a set of candidate models, it is not the absolute values of the AIC scores that matter, but rather the difference between them. A lower AIC value indicates better model fit and a difference in AIC values of between 2 to 7 indicates a moderate difference in fit of the models, while a difference of 7 or more indicates a large difference in model fit [38]. The difference in AIC scores can be used to obtain the likelihood of each model relative to the likelihood of the total set of models. This can be used to calculate Akaike's weight, which expresses the probability that a particular model is the best choice among a set of candidate models based on model fit [38].

The AIC values and Akaike's weights were determined for the original food retailer exposure categories, which differed across buffer sizes. The larger buffer sizes had broader categories of exposure. For example, the 500 m buffer had categories of 0 and 1 or more, while the 1500 m buffer had categories of 0, 1-2, 3-4, 5-6 and 7 or more food retailers. Since the differences in AIC scores may reflect the influence of changing the category sizes in addition to changing the buffer sizes, the regression analyses were repeated using identical exposure categories for all other buffer sizes. The AIC values were then reassessed using the same categorization approach as the 1000 m buffer, since it was near the midpoint of the series of buffer sizes and is a reasonable distance to walk during the time allotted for lunch at school.

RESULTS

The median number of student respondents per school was 37 (interquartile range: 23-55). Table 1 shows the school- and student-level characteristics. Nearly 40% of the schools were located in large metropolitan centres and 59.5% were secondary schools schools (limited to grades 9 to 12). There was an approximately equal distribution of males and females and only 8.0% of the study sample was in the lowest family affluence group. Of the respondents who self-reported their height and weight, 19.6% were overweight or obese according to the International Obesity Task Force body mass index criteria [39]. During the school week, the majority of students typically ate their lunch either at school (67.7%), at home (15.2%), or in a snack bar, fast food restaurant, or café (7.4%).

Table 2 describes the quantity of food retailers within the various buffer sizes. Very few food retailers were obtained within the smallest buffers; only 88 food retailers were located within 500 m buffers for the 158 schools in this study. The median number of food retailers ranged from 0 to 13 across the buffer sizes, and median values were greater than zero for buffers of 1000 m and larger.

Results of the multilevel logistic regression examining the relationship between the number of food retailers in each buffer and students' lunchtime eating behaviours are shown in Table 3. Model 1 shows the bivariate relationships, model 2 controlled for individual-level covariates, and model 3 controlled for individual- and school-level covariates. The left hand side of the table shows the results of the regression when using the different categories of food retailers, whereby broader categories were used for the larger buffer sizes. The strongest relationship appeared to be for the 1000 m buffer, where students who had 3 or more food retailers within 1000 m of their schools had 3.42 times (95% CI: 2.12-5.52) the relative odds of eating lunch at a food retailer compared to students with no food retailers within 1000 m. The smallest two buffer sizes also showed relationships with lunchtime eating behaviours. At buffer sizes greater than 1000 m, these relationships were weaker and, with a couple of exceptions, were not statistically significant (exceptions: 7-10 and 11 or more food retailers for the 2000 m buffer). The right hand side of the table shows the same analysis approach, but with identical food retailer exposure categories for all buffer sizes. The results are similar to the analysis with the different sized exposure categories.

The AIC-related values comparing goodness-of-fit between the final regression models (Model 3 in Table 3) for the different buffer sizes are shown in Table 4. AIC values were calculated for the models which used different food retailer exposure categories as well as the models which used identical food retailer exposure categories for all buffer sizes. For the models with differing exposure categories, the 1000 m buffer had the lowest AIC value (3344). The difference in AIC values between the 1000 m buffer model and all remaining models was greater than the threshold value of 7, which indicated that there was a substantially better model fit for the 1000 m buffer. Results from the Akaike's weights showed there was a 98.8% probability that the 1000 m street network buffer provided the best fit. The AIC values for the differing and identical food retailer exposure categories were quite similar, indicating that the 1000 m road network buffer consistently fit the data better, regardless of the food retailer categorization approach.

DISCUSSION

This study demonstrated that the 1000 m road network buffer provided the best fit for the eating behaviour outcome among the six candidate models with varying buffer sizes. Based upon an average walking speed of 4-5 km/hour in adolescents [40], this is a distance that could be walked in approximately 10-15 minutes. At distances less than 1000 m, less than half of the schools had at least one food retailer present, suggesting these buffers were too small to capture a sufficient number of food retailers. Distances greater than 1000 m may be perceived by students as being too far for them to travel during the time allotted for their lunch break.

Our findings that food retailers measured in 500 m, 750 m, and 1000 m road network buffers around schools were associated with student’s eating behaviours corresponded to observations by Davis and Carpenter [14]. They observed that chain fast food restaurants within 0 to 400 m and 400 m to 800 m of schools were associated with students’ BMI values. An advantage of our study is that it used model fit criteria to determine that the 1000 m buffer size was optimal. It is important to note that the optimal buffer size of 1000 m for schools may differ from non-school settings. Studies of the food retail environment surrounding peoples’ homes have provided mixed results, with two suggesting that a relatively small (i.e., 400 to 800 m) buffer size may be the most meaningful [20, 25], and one study suggesting that larger (i.e., 1600 m) buffer sizes may be most meaningful [24].

Results from this study provide important evidence regarding the appropriate buffer size to use when measuring the food environment surrounding schools. Namely, using a buffer that is either too large or too small may obscure relationships with eating outcomes and result in weakened study findings. Furthermore, having a standardized buffer size measure in studies examining the food retail environment surrounding schools will enhance comparability across studies. Finally, results from studies such as this one are needed to inform the implementation and evaluation of policies aimed at optimizing the built environment surrounding schools. Specifically, our findings suggest that policies that limit the number of food retailers around schools should consider a 1000 m distance and a maximum of 2 fast food restaurants, coffee/donut shops, and/or convenience stores. More than one quarter (28.4%) of the schools studied here would be affected by such a policy.

This study has some key strengths and limitations that warrant consideration. Key strengths include the large and geographically diverse study sample, the wide variety of buffer sizes, and the use of goodness-of-fit statistics to assess the relative contribution of each buffer size to model fit. A key limitation was that the GIS database used to obtain information on the food retail environment does not provide a completely accurate measure of the food retail environment. Furthermore, for practical reasons, only the top chain fast food restaurants and donut/coffee shops were included in the food retail environment measures. In addition, the survey data were obtained by self-report and this may introduce bias due to the social desirability of eating healthy foods. Finally, the cross-sectional nature of this study made it impossible to directly assess temporality between the presence of food retailers and eating behaviours. However, it is unlikely that students chose to attend schools based on the presence of nearby food retailers.

CONCLUSIONS

The results from this study indicated that the optimal road network buffer distance when assessing the food retail environment surrounding Canadian schools was 1000 m. Future studies investigating the school food retail environment should consider using street network buffers of this size. Having a consistent buffer size across studies will not only help inform policies and interventions directed at the modification of the food retail environment surrounding schools, but will also help facilitate comparisons across studies.

COMPETING INTERESTS STATEMENT

The authors declare that they have no competing interests.

ACKNOWLEDGEMENTS

The authors of this study would like to thank Mariane Héroux, Rachel Laxer and Hoda Gharib for their assistance in the collection of the food retailer addresses. The 2009/10 Health Behaviour in School-aged Children Survey (HBSC), a World Health Organization/European Region collaborative study, was funded in Canada by the Public Health Agency of Canada and Health Canada. This study was funded by an operating grant from the Canadian Institutes of Health Research (MOP 97962), and a second operating grant co-funded by the Canadian Institutes of Health Research and the Heart and Stroke Foundation of Canada (PCR 101415). In addition, Laura Seliske was supported by a Frederick Banting and Charles Best Doctoral Research Award from the Canadian Institutes of Health Research. Ian Janssen was supported by a Canada Research Chair and an investigator award from the Ontario Ministry of Research and Innovation. The principal investigators of the 2009/10 Canadian HBSC survey were John

Freeman and William Pickett, and the HBSC Survey is coordinated internationally by Candace Currie (University of Edinburgh).

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Figure. An illustration of the road-network buffer sizes used to measure the food environment. The school is in the centre of the figure and is surrounded by increasing buffer sizes, including: 500 m, 750 m, 1000 m, 1500 m, 2000 m. The 5000 m buffer is omitted due to its large size.

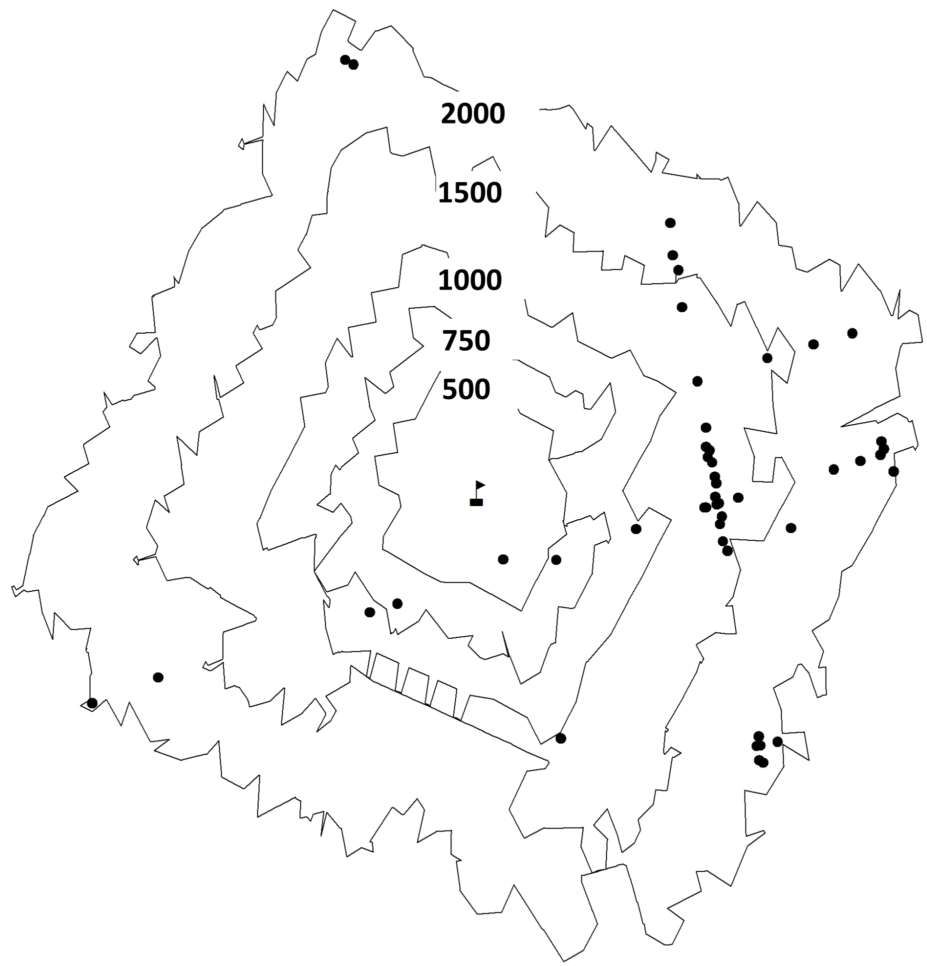

Table 1. Characteristics of the study sample participating in the 2009/2010 Health Behaviour in School-aged Children Survey

	N	%
School-Level Variables		
School Type		
Secondary (grades 9 - 12)	94	59.5
Mixed	64	40.5
Urban Rural Status		
Large urban centre (≥100,000 people)	62	39.2
Medium urban centre (20,000 - 99,999)	15	9.5
Small urban centre (1,000 - 19,000)	38	24.1
Rural (<1,000)	43	27.2
Individual-Level Variables		
Sex		
Male	3381	48.5
Female	3590	51.5
Age (years)		
13	33	0.5
14	2339	33.6
15	3280	47.1
16	1319	18.9
Family Affluence Scale		
Low	560	8.0
Moderate	2531	36.3
High	3880	55.7
Weight Status		
Non-overweight	4823	69.2
Overweight	1018	14.6
Obese	346	5.0
Missing Data	784	11.3
Where Students Eat Mid-day Meal		
At school	4719	67.7
At home	1056	15.2
In a snack bar, fast food restaurant or café	517	7.4
Never eat a midday meal	307	4.4
Somewhere else	209	3.0
At someone else's home	163	2.3

Table 2. The distribution of food retailers within the various buffer sizes surrounding 158 schools from the 2009/2010 Health Behaviour in School-aged Children Survey

Buffer Size	Total Number of Food Retailers	Minimum	25th Percentile	50th Percentile	75th Percentile	Maximum
500 m	88	0	0	0	1	7
750 m	193	0	0	0	2	9
1000 m	349	0	0	1	3	15
1500 m	768	0	0	3	7	27
2000 m	1279	0	1	6	12	53
5000 m	4798	0	1	13	43	275

Table 3. Relationship between the presence of food retailers near schools and students eating lunch during the school week at a café, fast food restaurant or snack bar according to various buffer sizes: different vs. identical exposure categories

No. of Food Retailers	No. of Schools (%)	Odds Ratio (95% Confidence Interval)		
		Model 1	Model 2	Model 3
500 m				
None	117 (74.1)	1.00	1.00	1.00
≥ 1	41 (25.9)	2.15 (1.38-3.36)	2.20 (1.40-3.46)	2.27 (1.46-3.52)
750 m				
None	89 (56.3)	1.00	1.00	1.00
1	26 (16.5)	1.44 (0.82-2.54)	1.50 (0.84-2.66)	1.40 (0.79-2.48)
≥ 2	43 (27.2)	2.84 (1.81-4.47)	2.90 (1.83-4.60)	2.74 (1.75-4.29)
1000 m				
None	62 (39.2)	1.00	1.00	1.00
1-2	51 (32.3)	1.24 (0.76-2.02)	1.25 (0.76-2.06)	1.20 (0.74-1.95)
≥ 3	45 (28.4)	3.49 (2.17-5.61)	3.55 (2.19-5.76)	3.42 (2.12-5.52)
1500 m				
None	43 (27.2)	1.00	1.00	1.00
1-2	25 (15.8)	1.21 (0.60-2.45)	1.20 (0.59-2.45)	1.22 (0.59-2.53)
3-4	20 (12.7)	1.45 (0.71-2.97)	1.43 (0.69-2.97)	1.37 (0.66-2.88)
5-6	26 (16.5)	1.88 (0.97-3.64)	1.91 (0.98-3.74)	1.85 (0.94-3.65)
≥ 7	44 (27.8)	3.06 (1.72-5.44)	3.13 (1.75-5.62)	2.96 (0.64-5.34)
2000 m				
None	34 (21.5)	1.00	1.00	1.00
1-3	28 (17.7)	1.34 (0.64-2.83)	1.32 (0.62-2.82)	1.38 (0.65-2.96)
4-6	25 (15.8)	1.50 (0.71-3.19)	1.54 (0.72-3.30)	1.50 (0.67-3.34)
7-10	22 (13.9)	2.37 (1.16-4.87)	2.43 (1.17-5.04)	2.28 (1.07-4.86)
≥ 11	45 (28.5)	2.56 (1.33-4.93)	2.57 (1.32-5.02)	2.48 (1.23-5.02)
5000 m				
None	30 (19.0)	1.00	1.00	1.00
1-9	35 (22.2)	1.39 (0.65-2.95)	1.38 (0.64-2.96)	1.26 (0.58-2.77)
11-19	31 (19.6)	1.65 (0.77-3.51)	1.69 (0.78-2.65)	1.48 (0.66-3.33)
20-29	11 (7.0)	2.04 (0.75-5.57)	2.01 (0.72-5.57)	1.94 (0.67-5.61)
30-39	11 (7.0)	2.22 (0.82-6.00)	2.18 (0.79-6.01)	1.95 (0.70-5.45)
≥ 40	40 (25.3)	2.09 (1.02-4.29)	2.11 (1.02-4.38)	1.81 (0.83-3.97)

No. of Food Retailers	No. of Schools (%)	Odds Ratio (95% Confidence Interval)		
		Model 1	Model 2	Model 3
500 m				
None	117 (74.1)	1.00	1.00	1.00
1-2	29 (18.4)	1.86 (1.12-3.09)	1.89 (1.13-3.17)	1.98 (1.20-3.27)
≥ 3	12 (7.6)	2.99 (1.48-6.06)	3.08 (1.50-6.31)	3.05 (1.53-6.06)
750 m				
None	89 (56.3)	1.00	1.00	1.00
1-2	37 (23.4)	1.64 (1.00-2.67)	1.69 (1.03-2.79)	1.61 (0.99-2.63)
≥ 3	32 (20.3)	3.11 (1.91-5.09)	3.18 (1.93-5.24)	2.99 (1.83-4.88)
1000 m				
None	62 (39.2)	1.00	1.00	1.00
1-2	51 (32.3)	1.24 (0.76-2.02)	1.25 (0.76-2.06)	1.20 (0.74-1.95)
≥ 3	45 (28.5)	3.49 (2.17-5.61)	3.55 (2.19-5.76)	3.42 (2.12-5.52)
1500 m				
None	43 (27.2)	1.00	1.00	1.00
1-2	25 (15.8)	1.22 (0.59-2.50)	1.21 (0.58-2.51)	1.28 (0.60-2.70)
≥ 3	90 (57.0)	2.30 (1.34-3.92)	2.33 (1.35-4.02)	2.26 (1.25-3.29)
2000 m				
None	34 (21.5)	1.00	1.00	1.00
1-2	23 (14.6)	1.07 (0.47-2.30)	1.04 (0.46-2.36)	1.08 (0.48-2.45)
≥ 3	101 (63.9)	2.24 (1.23-4.10)	2.27 (1.23-4.19)	2.32 (1.21-4.46)
5000m				
None	30 (19.0)	1.00	1.00	1.00
1-2	17 (10.8)	1.14 (0.45-2.89)	1.12 (0.44-2.89)	1.15 (0.45-2.92)
≥ 3	111 (70.3)	1.88 (0.98-3.61)	1.90 (0.98-3.67)	1.66 (0.81-3.42)

Model 1 is the bivariate analysis
Model 2 controlled for individual-level covariates (sex)
Model 3 controlled for individual-level covariates (sex) and area-level covariates (presence of following at school: cafeteria, sugared drinks vending, milk vending, candy/potato chip vending, tuck/snack shop)

Table 4. Comparison of AIC values, relative likelihood, and Akaike's weights across various buffer sizes: different vs. identical exposure categories

Buffer Size	AIC value	Δ AIC vs. 1000 m distance	Relative Likelihood $e^{(-0.5 \times \Delta AIC)}$	Akaike's Weight (%)
Different Exposure Categories				
500 m	3356.64	12.77	0.00169	0.167
750 m	3353.12	9.25	0.00980	0.969
1000 m	3343.87	0	1.00000	98.836
1500 m	3360.21	16.34	0.00028	0.028
2000 m	3366.72	22.85	0.00001	0.000
5000 m	3373.94	30.07	0.00000	0.000
Total			**1.01178**	**100**
Identical Exposure Categories				
500 m	3357.46	13.59	0.00112	0.111
750 m	3353.11	9.24	0.00985	0.974
1000 m	3343.87	0	1.00000	98.894
1500 m	3362.14	18.27	0.00011	0.011
2000 m	3362.26	18.39	0.00010	0.010
5000 m	3368.93	25.06	0.00000	0.000
Total			**1.01119**	**100**

CHAPTER 6

Urban Sprawl and its Relationship with Active Transportation, Physical Activity and Obesity in Canadian Youth

ABSTRACT

Introduction: Urban sprawl is a potential environmental factor associated with youth overweight/obesity. Little is known about the association between urban sprawl and the behavioural determinants of obesity among young people, including physical activity and active transportation. Furthermore, existing studies of this relationship are limited in geographic scope

Methods: The study population consisted of 7,017 youth (aged 12-19 years) from Canada's 33 census metropolitan areas (CMAs) who participated in the 2007-2008 Canadian Community Health Survey. Factor analysis was used to obtain an urban sprawl score for each CMA, incorporating dwelling density, percentage of single or detached dwelling units, and percentage of the population living in the urban core. Multilevel logistic regression examined whether urban sprawl was associated with frequent active transportation (≥30 minutes/day), moderate-to-vigorous physical activity (MVPA, ≥60 minutes/day) and overweight/obesity.

Results: Urban sprawl was not associated with active transportation in 16 to 19 year olds. However, a positive association for active transportation was observed in 12 to 15 year olds, with a relative odds of engaging in frequent active transportation of 1.24 (95% CI: 1.10-1.39) for each standard deviation (SD) increase in the urban sprawl score. Within the entire sample, higher urban sprawl levels were significantly associated with MVPA (odds ratio per SD increase = 1.10, 95% CI: 1.01-1.20) but not overweight/obesity (odds ratio per SD increase = 1.06, 95% CI: 0.94-1.18).

Conclusions: Urban sprawl was associated with active transportation and MVPA in Canadian youth, although in the opposite direction to what has previously been reported in the adult literature.

INTRODUCTION

Over the past 30 years, the prevalence of overweight and obesity has increased dramatically, nearly tripling among Canadian youth aged 12 to 17 years [1]. This is of concern because of the many physical, mental, and social health problems associated with obesity in young people [2-6]. Furthermore, obesity tracks strongly as people age, with 60 to 90% of obese adolescents remaining obese into adulthood [7]. It is important to develop a comprehensive understanding of the determinants of obesity to develop effective public health strategies. A lack of moderate-to-vigorous physical activity (MVPA) is a known determinant of obesity [8-11], and researchers are now interested in studying features of the surrounding environment that influence obesity via mechanisms that inhibit MVPA [12].

Urban sprawl is one potential feature of the environment that may influence obesity. It is a pattern of development whereby metropolitan areas extend over a large geographic region [13]. This pattern of development can make it difficult to travel between destinations by walking or cycling, which can lead to greater driving and commute times and hence less physical activity [14,15]. Evidence from two studies suggests there is an association between urban sprawl and obesity and its causal behaviours in American adolescents [16,17]. Ewing et al. [16] found that 12 to 17 year olds living in a county with greater than average urban sprawl had a 16% (95% CI: 2-31%) increased likelihood of being overweight or obese compared to those who lived in a county with less than average urban sprawl. Similarly, in a study of 8th and 10th grade youth, Slater et al. [17] found that those living in areas with a lower than average urban sprawl had an 11.8% lower prevalence of obesity, but they found no association with MVPA.

Since higher urban sprawl may influence obesity through a greater reliance on automobiles for travel and increased time spent driving, it is important to consider the role of driving age on the association between urban sprawl and the behavioural determinants of obesity. Trowbridge et al. [18] found that youth living in sprawling counties were more than twice as likely to drive >32 km per day than youth living in compact counties. This evidence supports the existence of an association between urban sprawl and driving patterns. However, youth who do not yet have a driver's license may not be influenced by the same driving patterns. Instead, they may be more reliant on physically active modes of transportation such as cycling and walking. Few studies of young people have examined the potential moderating role of driving age, which may have an impact on the associations between urban sprawl and obesity-related behaviours.

Large gaps in knowledge exist surrounding the association between urban sprawl and obesity-related outcomes in youth. Existing studies have been limited to youth from the United States and there is a need for a more generalizable evidence base. Furthermore, the inclusion of active transportation as an outcome may provide a greater understanding of mechanisms surrounding the association between urban sprawl, MVPA, and obesity in youth. It is expected that the more compact a metropolitan area is, the higher the likelihood of engaging in active transportation. The potential moderating role of driving age also requires consideration.

The primary objective of this study was to examine the association between urban sprawl and the outcomes of: (1) overweight/obesity, (2) MVPA, and (3) active transportation in a large sample of youth residing in Canada's metropolitan areas. A secondary objective was to examine the role of driving age as a possible moderator of these associations. This study is important from a public health perspective because it may improve our understanding of the broader environment in which health behaviours occur. Given the negligible impact of interventions that solely focus on changing an individual's behaviours [19-21], there is a need to recognize the importance of modifying our surrounding environments to facilitate healthy behaviours. Sixty eight percent of the Canadian population live within census metropolitan areas (CMAs) [22], which are large urban centres with a population of 100,000 people or more. Therefore, even modest changes in features of the built environment within large urban centres have the potential to affect many people.

METHODS

Study Design

The study consisted of a multi-level cross-sectional analysis and examined the associations between urban sprawl, obesity, and obesity-related behaviours in 12-19 year old youth from Canada's 33 CMAs. Individual-level data on obesity, MVPA, active transportation, and socio-demographic characteristics were obtained from a general health survey. Urban sprawl and climate data were obtained for each CMA. The individual- and area-level data were linked based upon the CMA identifier for each survey participant.

Study Sample

The study sample was obtained from the annual component of the 2007-2008 Canadian Community Health Survey (CCHS). The CCHS is a large nationally representative cross-sectional survey that collects information related to the determinants of health for Canadians 12 years of age and older [23]. The data collection protocol involved use of a complex sampling strategy to ensure that the sample was representative of the health regions within all provinces and territories. For more detailed information on the CCHS methodology, see Appendix D. Demographic and health information was obtained from the survey, and the analysis was restricted to respondents 12 to 19 years old. Since urban sprawl primarily applies to larger metropolitan areas [13], only respondents living in CMAs were included in the present study. For information on ethics approval for this manuscript, see Appendix A.

Outcomes

Self-reported heights and weights were obtained in the CCHS, and these were used to calculate the body mass index (BMI, weight in kg / height in m^2) for each participant. For 18 and 19 year olds, adult BMI thresholds of <25 kg/m^2 (non-overweight), 25-29.9 kg/m^2 (overweight), and ≥30 kg/m^2 (obese) were used to determine weight status. For respondents 12-17 years of age, the age- and sex-specific International Obesity Task Force pediatric BMI thresholds [24], which correspond to adult thresholds, were used to determine weight status. Overweight and obese categories were combined into one group for the regression analyses. For more detailed information on key variables of the CCHS used in this manuscript, see Appendix E.

The CCHS respondents were asked to report the typical frequency of their engagement in common physical activities, by indicating the number of times they participated in the activity over the past 3 months (90 days) and choosing the appropriate category of duration. The midpoints of the duration categories, which were obtained from the CCHS derived variable documentation [25], were used to estimate the total number of minutes for each activity over the 90 days. The average daily duration of the activity was calculated multiplying the frequency and duration and dividing this by 90.

Total MVPA was comprised of all activities, while active modes of transportation were limited to walking, cycling, and rollerblading to work or school, or for leisure purposes. For MVPA, respondents were placed into two groups based upon whether or not they met the current public health guideline of 60 minutes/day of MVPA [26]. Since guidelines do not currently exist for the duration of active transportation, a 30 minute/day cut-point was used to place participants into two active transportation groups. This cut-point corresponded to the top quartile of active transportation, and the proportion of study participants who met this active transportation cut-point was similar to the proportion who met the 60 minute/day MVPA cut-point. Because vehicle use may moderate the association between urban sprawl and obesity-related behaviours, an interaction term between urban sprawl and age group was introduced into the analysis, distinguishing those who were not of driving age from those who were (12-15 years vs. 16-19 years).

Exposure

Urban sprawl was measured for each of Canada's 33 CMAs using an adaptation of the Canadian urban sprawl index developed by Ross et al. [27]. The index incorporated total dwelling density, percentage of single or detached dwellings and the percentage of the population living in the urban core of each CMA. Total dwelling density and the density of single or detached dwelling units in each CMA were obtained using PCensus (2006 Census of Canada Profile Data; Tetrad Computer Applications Inc., Vancouver BC). The percentage of the population living in the urban core was obtained from Statistics Canada [28]. Instead of weighting the 3 urban sprawl components equally to create a summary score, as done by Ross et al. [27], a principal components factor analysis was performed. Results showed that the 3 components comprised a single factor and Cronbach's alpha for this factor was 0.89. The factor loadings were 0.95 for dwelling density, 0.96 for density of single or detached dwellings, and 0.82 for percentage of the population living in the urban core of the CMAs. The three components were used to create a standardized urban sprawl score, with a mean of 0 and a standard deviation of 1.

Covariates

The individual-level covariates were obtained from the CCHS, and included age, sex, socioeconomic status, and the season the survey was completed. Age was considered as a covariate because as age increases, levels of physical activity decrease [29,30] and the prevalence of overweight and obesity increases [7]. Sex was included as a covariate, due to differences in physical activity behaviours in males and females [31]. Obesity is more prevalent in Canadian youth of low socioeconomic status [32]. Therefore, the highest level of household education and household income were included in the analysis as covariates. Responses for household education ranged from less than high school to a post-secondary degree/diploma, while household income was determined by a ratio of the income relative to a low income threshold for a given household and community size [25]. Finally, because physical activity varies by season [33], the season the survey was completed was included as a covariate.

Area-level covariates were also considered; these mainly focused upon climatic variables. In addition to season, climate is a known correlate of physical activity participation in youth [34]. The climate averages for each of Canada's 33 CMAs were obtained from Environment Canada. These were based upon climate averages from 1972-2000 at the international airport or, if unavailable, the municipal airport within each CMA [35], The climate data obtained consisted of average daily temperature, average annual rainfall, and average annual snowfall. These were transformed to have a mean of 0 and a standard deviation of 1 for the regression analyses.

Statistical Analysis

All analyses were conducted using SAS software version 9.2 (SAS Institute, Cary, NC). The complex sampling procedures for the CCHS resulted in individuals within the target population having unequal probabilities of being sampled. To account for this, 500 weighted bootstrap replications were carried out using Statistics Canada's bootstrap weights for the descriptive and regression analyses [36,37]. Multilevel logistic regressions were carried out through a multi-step process to estimate the odds ratio (OR) of reporting: (1) an overweight or obese BMI, (2) the accumulation of 60 minutes/day of MVPA; (3) the accumulation of 30 minutes/day of active transportation-related activities, in association with estimated levels of urban sprawl.

We employed the following modeling strategy. First, an empty model was used to determine the intra-class correlation (ICC) statistic for logistic regression. The ICC value indicates the proportion of the total variation in the study outcome that was due to differences across CMAs. Second, bivariate associations were examined between the study outcome and each covariate. Next, the multivariate model building process began with the introduction of the individual level variables and the interaction term, and proceeded using a backwards elimination approach. The urban sprawl variable was forced into all models. The inclusion of the interaction term at the beginning of the model building process was done to test the *a priori* hypothesis that driving age was a moderator of the association between urban sprawl and the outcome variables. Finally, for the MVPA and active transportation outcomes, the CMA-level climate variables were then entered into the model using a backwards elimination approach. Season and climate variables were not included in the analysis with the overweight and obesity outcome, since there is no evidence of an association. To take into account the possibility that the association between urban sprawl and the study outcomes may have been influenced by participants living in the three largest CMAs (Montreal, Toronto and Vancouver), the analysis was repeated after removing residents from these three cities.

RESULTS

A total of 7,017 respondents from the 2007-2008 CCHS met the inclusion criteria for this study. Descriptive characteristics of the sample are in Table 1. Participants were equally distributed across the two age groups. Of the respondents who provided the appropriate information in the CCHS, approximately one in three met the MVPA guidelines, one in four engaged in active transportation for at least 30 minutes per day. Also, one in four participants in the study sample was either overweight or obese.

Table 2 provides the urban sprawl scores (standardized to a mean of 0 and SD of 1) and the climate characteristics for each CMA. Positive urban sprawl scores indicate higher levels of urban sprawl. Toronto, Montreal and Vancouver are the three largest urban centres, and also had the lowest urban sprawl scores.

The ICC value for active transportation, which was calculated from the empty model, indicated that only 0.21% of the variation in the outcome occurred at the CMA-level. Table 3 shows the results for the frequent active transportation outcome (≥30 minutes/day). The bivariate analysis showed no association between urban sprawl and active transportation in the total sample; however, since the interaction term between age and urban sprawl was statistically significant (β= -0.20, $p<0.01$), separate odds ratios were calculated for the two age groups. After adjustment for the relevant individual- and area-level covariates, the final model suggested that urban sprawl was associated with an increased likelihood of active transportation in 12 to 15 year olds (OR per SD increase = 1.24, 95% CI: 1.10-1.39) but not in 16 to 19 year olds (OR per SD increase = 1.02, 95% CI: 0.88-1.17).

Table 4 outlines the results of the analysis for MVPA (≥60 minutes/day). The ICC was 0.28%. The interaction term between the urban sprawl score and age group was not significant (β = -0.01, p-value = 0.90), so the odds ratio for the urban sprawl score was calculated for the entire study population, rather than by age group. The bivariate analysis suggested that there was no statistically significant association between urban sprawl and MVPA; however, after the relevant individual- and area-level confounders were added to the model, there was a positive association between urban sprawl and MVPA (OR per SD increase = 1.10, 95%: 1.01-1.20). Amongst the covariates, sex, the season the survey was administered, and the average daily temperature were related to MVPA.

Table 5 presents the results of the analysis of the association between urban sprawl and overweight/obesity. The empty model indicated that the ICC was 0.90%. The bivariate analyses indicated that there was no association between urban sprawl and overweight/obesity, and the addition of the covariates into the model did not change this observation. Furthermore, the interaction term between age group and urban sprawl was not statistically significant (β=-0.02, p-value=0.81).

The removal of participants who lived in the three largest CMAs (Montreal, Toronto and Vancouver) did not substantially alter the relationship with overweight/obesity (OR per SD increase = 0.97, 95% CI: 0.86-1.11). However, the association between urban sprawl and MVPA was no longer statistically significant (OR per SD increase = 0.98, 95% CI: 0.88-1.09). In addition, the association between urban sprawl and active transportation changed directions (OR per SD increase = 0.93, 95% CI: 0.82-1.05). Finally, the age interaction term for the active transportation outcome was longer statistically significant (β=0.16, p-value=0.13), suggesting there was no difference in associations between the two age groups.

DISCUSSION

A key finding of this study was that 12 to 15 year olds living in CMAs with high levels of urban sprawl were more likely to participate in frequent active transportation and MVPA compared to those living in relatively compact CMAs. Although the associations between urban sprawl and the physical activity measures were relatively modest, the impact of urban sprawl on the physical activity levels of young people may still be meaningful for the population as a whole. The CMAs with the lowest urban sprawl scores were also the most populated (Toronto, Montreal and Vancouver).

The findings of this study for the overweight/obesity outcome do not agree with the results of previous research by Ewing et al. [16] and Slater et al. [17], who found that increased urban sprawl was associated with a greater prevalence of overweight/obesity in American youth. One possible reason for the discordant findings may be because the sprawl index used by Ewing [16] and Slater [17] applied to counties, whereas our measure applied to CMAs. The larger geographic size of our study areas may have obscured differences in overweight/obesity prevalence. Another possible reason is that information on neighbourhood and traffic safety was unavailable from the annual component of the CCHS, while they were accounted for in previous studies [16,17]. Concerns about traffic safety and crime are negatively associated with active transportation among young people [38,39]. In our study, the CMAs with the lowest levels of urban sprawl were also the largest metropolitan areas, where traffic and safety concerns may be more prevalent. Removal of the participants from the three largest CMAs supported this notion, whereby urban sprawl was no longer positively associated with active transportation or MVPA. This suggests that the increased likelihood of active transportation and MVPA associated with increased sprawl in all 33 CMAs was accounted for in large measure by young people living in Canada's three largest cities.

In contrast to what has been reported in adults from several countries [27,40-44], less compact urban areas may encourage physical activity in young people. Slater et al. [17] found that adolescents living in sprawling counties had higher rates of sports participation, with a 20 unit increase in the county-level urban sprawl score (approximately 1 SD) was associated with a 3.1% increase in sports participation. Furthermore, Mecredy et al. [45] found that Canadian youth exposed to less densely connected streets were 21% (95% CI: 9-34%) more likely to be active for at least 4 hours/week outside of school compared to those exposed to more densely connected streets. Contradictory findings between urban sprawl and physical activity outcomes in adults and youth suggest that the mechanisms explaining these associations vary by age.

Various experts and urban planning groups support initiatives to reduce urban sprawl in Canadian cities [46,47] and worldwide [48]. These viewpoints are based in part on evidence demonstrating various negative effects of urban sprawl, including: increased time spent in cars [49] and elevated levels of air pollution [50]. In adult populations, urban sprawl has been consistently associated with decreased active transportation and overall physical activity [40,43,44]. However, some urban planning experts acknowledge the advantages of a suburban lifestyle over densely populated urban areas, including: more affordable housing [51], aesthetically pleasing green space [13], and decreased crime rates [52]. Clearly, urban sprawl is a complex public health issue, with both positive and negative outcomes for increasing sprawl. The findings of this study contribute to the positive health outcomes associated with urban sprawl.

Strengths of this study include the large and diverse study sample, the examination of the active transportation outcome, and the consideration of age as a moderator. As with any study, this study was not void of limitations. One key limitation was that the ICC values for the outcomes were small, possibly because the geographic area covered by the CMAs was too large and resulted in little variation in outcomes across the CMAs. Furthermore, the CMAs include areas of rural land, and because it was not possible to exclude these areas, some study participants were not influenced by the patterns of development associated with urban sprawl. Therefore, future studies should use urban sprawl measures that apply to smaller geographic areas. A second limitation is that the BMI and physical activity measures were based on self-reports, which likely resulted in an underestimate of the BMI values [53] and an overestimate of the physical activity levels [54], potentially influencing the strength of the observed associations. Finally, since this study used previously collected survey data, information on potentially important covariates was not available. For example, although we determined if participants were of driving age, we did not know whether they had a driver's license and access to a vehicle.

In conclusion, this study provides new insights into the associations between urban sprawl, physical activity, and obesity within Canadian youth. The findings of this study do not correspond with those found in adult populations. This is not unlike some other built environment constructs that are relevant for physical activity, such as street connectivity [45,50], wherein the associations between the built environment construct and physical activity are in opposite directions in youth and adult populations. Therefore, age must be considered when developing strategies around the built environment that are intended to increase physical activity and decrease obesity within the population.

ACKNOWLEDGEMENTS

The authors of this study would like to thank Dr. Miu Lam and Eric Bacon for their technical support with the bootstrapping techniques. Laura Seliske was supported by a Frederick Banting and Charles Best Doctoral Research Award from the Canadian Institutes of Health Research. Dr. Ian Janssen was supported by a Canada Research Chair and an investigator award from the Ontario Ministry of Research and Innovation.

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Table 1. Demographic and health characteristics of the study population (N=6384)

	N	Percent (95% CI)
Sex		
Male	3587	51.3 (50.9-51.8)
Female	3430	48.7 (48.3-49.1)
Age		
12 - 15 years	3522	51.0 (49.4-52.6)
16 - 19 years	3495	49.0 (47.4-50.6)
Household Income		
Deciles 1 - 3	1729	27.4 (25.9-28.9)
Deciles 4 - 6	1747	24.3 (22.9-25.6)
Deciles 7 - 10	1890	23.7 (22.4-25.0)
Not stated	1651	24.6 (23.3-26.0)
Highest Household Education		
Less than secondary school	180	2.8 (2.3-3.4)
Secondary school	659	9.0 (8.0-10.0)
Post secondary	4666	68.6 (67.1-70.1)
Not stated	1512	19.6 (18.4-20.8)
Season Survey Administered		
Winter (Dec - Feb)	1527	23.2 (21.9-24.5)
Spring (Mar - May)	1955	27.4 (25.9-28.9)
Summer (June - Aug)	1489	22.4 (21.1-23.8)
Fall (Sept - Nov)	2046	27.0 (25.6-28.4)
Active Transportation ≥ 30 min/day		
Yes	1669	22.2 (20.9-23.5)
No	4715	68.6 (67.1-70.1)
Not Stated	633	9.2 (8.3-10.2)
MVPA ≥ 60 min/day		
Yes	2402	32.8 (31.3-34.3)
No	3812	56.2 (54.6-57.7)
Not stated	803	11.0 (10.0-12.0)
Weight Status		
Non-overweight	4975	71.7 (70.3-73.2)
Overweight	933	12.1 (11.2-13.0)
Obese	307	4.2 (3.5-4.9)
Not stated	802	11.9 (10.9-13.0)

MVPA = moderate-to-vigorous physical activity.
All N's are unweighted.
The proportions are weighted to take into account unequal sampling probabilities.

Table 2. Urban sprawl scores and climate characteristics for Canada's 33 census metropolitan areas

Census Metropolitan Area	Standardized Urban Sprawl Score	Average Daily Temp (°C)	Average Annual Rainfall (mm)	Average Annual Snowfall (cm)
Montreal, QC	-2.28	6.2	764	216
Toronto, ON	-2.15	7.5	685	115
Vancouver, BC	-1.65	10.1	1155	48
Kitchener-Cambridge-Waterloo, ON	-1.51	6.7	765	160
Hamilton, ON	-1.43	7.6	765	162
Victoria, BC	-1.21	9.7	841	44
Windsor, ON	-0.73	9.4	805	127
Guelph, ON	-0.65	6.5	771	161
Oshawa, ON	-0.45	7.7	760	118
Calgary, AB	-0.35	4.1	321	127
St. Catharines-Niagara, ON	-0.31	8.8	746	137
Quebec City, QC	-0.21	4.0	924	316
Barrie, ON	-0.09	6.7	700	238
Abbotsford-Mission, BC	-0.04	10.0	1508	64
Winnipeg, MB	0.05	2.6	416	111
London, ON	0.05	7.5	818	202
St. John's, NF	0.07	4.7	1191	322
Trois-Rivieres, QC	0.20	4.9	859	241
Regina, SK	0.37	2.8	304	106
Edmonton, AB	0.38	2.4	375	121
Sherbrooke, QC	0.41	4.1	874	294
Ottawa ON-Gatineau QC	0.51	6.0	732	236
Saskatoon, SK	0.65	2.2	265	97
Thunder Bay, ON	0.70	2.5	559	188
Brantford, ON	0.86	8.0	780	113
Kelowna, BC	0.93	7.7	298	102
Halifax, NS	0.96	6.3	1239	231
Moncton, NB	0.98	5.1	865	350
Kingston, ON	1.05	6.7	795	181
Saguenay, QC	1.11	2.3	661	342
Saint John, NB	1.17	5.0	1148	257
Peterborough, ON	1.24	5.9	682	162
Greater Sudbury, ON	1.35	3.7	657	274

Table 3. Multilevel logistic regression examining the association between urban sprawl and active transportation among Canadian youth (N=6384)

	Bivariate Model	*Individual-Level Model*	*Area-Level Model*
Urban Sprawl Score			
1 SD increase in sprawl score:	1.03 (0.94-1.12)		
12 - 15 year olds	--	1.15 (1.03-1.27)	1.24 (1.10-1.39)
16 - 19 year olds	--	0.94 (0.77-1.15)	1.02 (0.88-1.17)
Individual-Level Variables			
Age			
12 - 15 years	1.00	1.00	1.00
16 - 19 years	1.03 (0.88-1.19)	0.84 (0.70-1.00)	0.84 (0.70-1.00)
Sex			
Male	1.00	1.00	1.00
Female	0.74 (0.64-0.87)	0.73 (0.63-0.86)	0.73 (0.63-0.86)
Household Income			
Deciles 1 - 3	1.00	1.00	1.00
Deciles 4 - 6	0.80 (0.65-0.99)	0.77 (0.62-0.95)	0.77 (0.62-0.95)
Deciles 7 - 10	0.72 (0.58-0.90)	0.69 (0.56-0.86)	0.69 (0.56-0.86)
Not stated	0.94 (0.76-1.17)	0.90 (0.72-1.13)	0.90 (0.72-1.13)
Household Education			
Less than secondary school	1.00		
Secondary school	1.62 (0.94-2.80)		
Post secondary	1.32 (0.80-2.20)		
Not stated	1.80 (1.10-2.97)		
Season Survey Administered			
Winter (Dec - Feb)	1.00	1.00	1.00
Spring (Mar - May)	0.92 (0.72-1.17)	0.92 (0.72-1.17)	0.92 (0.72-1.17)
Summer (June - Aug)	1.39 (1.10-1.74)	1.40 (1.11-1.76)	1.40 (1.11-1.76)
Fall (Sept - Nov)	1.16 (0.94-1.44)	1.16 (0.94-1.45)	1.16 (0.94-1.45)
Area-Level Variables			
Avg. temperature (1 SD increase)	1.12 (1.02-1.23)	--	1.18 (1.06-1.32)
Avg. rainfall (1 SD increase)	1.07 (0.97-1.17)	--	
Avg. snowfall (1 SD increase)	0.97 (0.88-1.06)	--	

Data presented as odds ratio (95% confidence interval)

Table 4. Multilevel logistic regression examining the association between urban sprawl and moderate-to-vigorous physical activity among Canadian youth (N=6214)

	Bivariate Models	*Individual-Level Model*	*Area-Level Model*
Urban Sprawl			
1 SD inc in sprawl score	1.01 (0.94-1.09)	1.02 (0.94-1.10)	1.10 (1.01-1.20)
Individual-Level Variables			
Age			
12 - 15 years	1.00		
16 - 19 years	0.93 (0.81-1.07)		
Sex			
Male	1.00	1.00	1.00
Female	0.56 (0.49-0.64)	0.56 (0.49-0.64)	0.56 (0.49-0.64)
Household Income			
Deciles 1 - 3	1.00		
Deciles 4 - 6	0.99 (0.81-1.22)		
Deciles 7 - 10	1.26 (1.04-1.52)		
Not stated	1.05 (0.85-1.29)		
Highest Household Education			
Less than secondary school	1.00		
Secondary school	1.32 (0.74-2.35)		
Post secondary	1.46 (0.87-2.46)		
Not stated	1.63 (0.97-2.73)		
Season Survey Administered			
Winter (Dec - Feb)	1.00	1.00	1.00
Spring (Mar - May)	0.89 (0.73-1.10)	0.89 (0.73-1.10)	0.89 (0.73-1.10)
Summer (June - Aug)	1.34 (1.09-1.65)	1.33 (1.08-1.64)	1.33 (1.08-1.64)
Fall (Sept - Nov)	1.10 (0.90-1.35)	1.09 (0.89-1.33)	1.09 (0.89-1.33)
Area Level Variables			
Avg. temperature (1 SD increase)	1.13 (1.05-1.23)	--	1.18 (1.08-1.30)
Avg. rainfall (1 SD increase)	1.11 (1.02-1.20)	--	
Avg. snowfall (1 SD increase)	1.00 (0.91-1.10)	--	

Data presented as odds ratio (95% confidence interval)

Table 5. Multilevel logistic regression examining the association between urban sprawl and overweight and obesity among Canadian youth (N=6215)

	Bivariate Model	***Individual-Level Model***
Urban Sprawl		
1 SD increase in sprawl score	1.04 (0.94-1.16)	1.06 (0.94-1.18)
Individual Level Variables		
Age		
12 – 15 years	1.00	1.00
16 – 19 years	1.23 (1.04-1.46)	1.25 (1.05-1.49)
Sex		
Male	1.00	1.00
Female	0.52 (0.44-0.62)	0.51 (0.43-0.61)
Household Income		
Deciles 1 - 3	1.00	1.00
Deciles 4 - 6	0.88 (0.69-1.12)	0.85 (0.66-1.08)
Deciles 7 - 10	0.70 (0.55-0.89)	0.67 (0.52-0.85)
Not stated	0.93 (0.72-1.19)	0.88 (0.68-1.14)
Highest Household Education		
Less than secondary school	1.00	
Secondary school	0.54 (0.31-0.95)	
Post secondary	0.42 (0.25-0.71)	
Not stated	0.48 (0.28-0.83)	

Data presented as odds ratio (95% confidence interval)

CHAPTER 7: GENERAL DISCUSSION

7.1 Summary of Key Findings

Findings from each manuscript of this thesis provided new insights into the influence of the built environment on obesity-related behaviours in Canadian youth. Under this theme, key relationships examined include: i) the school food retail environment and its association with lunchtime eating behaviours, ii) urban sprawl and its association with active transportation, physical activity and obesity in young people, and iii) important methodological issues related to assessing the school food retail environment.

In the *first manuscript*, a validation study compared the measurement error present in two geographical information systems (GIS) food retailer databases: an online database (www.yellowpages.ca) and a commercial database (InfoCanada). This manuscript built on previous work by not only considering whether food retailers are present or absent [1-4], but also quantified the positional error of food retailer databases for a 1 km circular buffer surrounding 34 schools within southern Ontario. A greater percentage of food retailer addresses provided by the online database were, in reality, located in the field, but no differences were found for the positional error between the databases. When considering which food retailer database to use for the subsequent two manuscripts, the online source was chosen based on the greater percentage of food retailers identified in the field.

The primary objective of the *second manuscript* was to determine whether there was an association between the presence of food retailers surrounding schools (fast food restaurants, coffee/donut shops and convenience stores) and students' lunchtime eating behaviours. A secondary objective was to determine whether a 1 km circular buffer or a 1 km road network-based buffer was optimal in capturing food retailers near schools. This manuscript also provided new insights into the relationship between the school food retail environment and lunchtime eating behaviours by using context-specific measures which took into account where food was obtained from. The presence of three or more food retailers within a 1 km road network buffer surrounding schools was associated with students typically eating at a snack-bar, fast-food restaurant or café at lunchtime during the school day. Similar associations were demonstrated for the 1 km circular buffer, but only for the presence of five or more food retailers. Model fit statistics confirmed that the 1 km road network buffer provided a more optimal fit compared to the 1 km circular buffer.

The objective of the *third manuscript* was to determine the appropriate distance to use when measuring the school food retail environment. It expanded upon the findings of the second manuscript by creating a variety of road network-based buffers to capture food retailers surrounding schools, ranging from 500 m to 5000 m in size. Results indicated that the 1000 m road network buffer provided the best fit. Establishing a standard buffer size to measure the food retail environment is important for two reasons. First, it would facilitate the comparison of study findings by providing an evidence-based standardized measure of the food retail environment surrounding schools, which is a limitation of the current studies [5,6]. Second, if a study used a buffer that was either too large or too small, it may obscure relationships between the food retail environment and eating behaviours.

Finally, the *fourth manuscript* examined the relationship between urban sprawl and the outcomes of active transportation, moderate-to-vigorous physical activity (MVPA), and overweight/obesity in young people. The inclusion of an interaction term based on driving age (12 to 15 years vs. 16 to 19 years) provided new insights into the role of driving age as a potential moderator of these relationships. Unlike previous studies of urban sprawl in American adolescents [7,8], no associations were found with obesity, and associations with MVPA and active transportation were in the opposite direction: higher levels of urban sprawl were associated with an *increased* likelihood of active transportation, but only in the younger age group. Our findings were consistent with previous research that showed an association between lower levels of street connectivity and increased physical activity in Canadian youth [9].

In summary, the key methodological contributions of this thesis were the identification of the optimal GIS food retailer database, buffer type, and buffer size to use when assessing the food retail environment around schools. Etiologically, this thesis provided new insights into the role of the food environment surrounding Canadian schools and students' lunchtime eating behaviours, as well as the influence of urban sprawl on physical activity in Canadian youth.

7.2 Suitability for a Doctoral Dissertation in Epidemiology

There are several aspects of this thesis that meet the criteria for a doctoral dissertation in epidemiology. First, the candidate demonstrated that she was able to summarize key issues in the built environment literature and identify important gaps in knowledge in order to provide unique contributions to the literature. The candidate was then able to plan, implement and carry out four studies which addressed these gaps and provided a novel understanding of the influence of the built environment on the health behaviours of Canadian youth.

The validation study showed that the candidate had an in-depth understanding of the issues surrounding primary data collection of food retailer locations. She took into account important study design issues such as obtaining an adequate sample size, ensuring sufficient variability within the study sample and also showed an appreciation of how the accuracy of food retailer databases affects the internal validity of studies of the food environment. Issues of internal validity were also addressed in her second and third manuscripts, where she answered important methodological questions regarding the size and type of buffer to use when measuring the school food retail environment. Also, the focus on context-specific behavioural outcomes (e.g. eating behaviours while at school) allowed her to show strong and consistent relationships which had not been previously demonstrated in the food retail environment literature due to the potential misclassificiation of the study outcomes.

Throughout the course of her thesis, the candidate showed an understanding of key epidemiological issues surrounding confounding and effect modification. Careful consideration was given to selecting the potential confounders to include in her analyses. In addition, the candidate showed insights into potential biases introduced by the confounders that she was unable to control for in her analyses. The exploration of the role of driving age as a potential effect modifier in the relationship between urban sprawl and active transportation provided a novel contribution to the urban sprawl literature. The analysis of large national survey data provided more generalizable findings relative to some of the previous studies of the food retail environment. Finally, the candidate demonstrated the mastery of complex epidemiological analytical techniques, including multilevel modeling and bootstrapping.

7.3 Strengths and Limitations

There are several key strengths to this thesis. Each of the manuscripts surpasses many existing studies with respect to sample size and geographic scope. The first manuscript improved upon previous field validation studies by including 973 food retailers from the commercial source and 676 food retailers from the online source in 22 cities and towns. The second and third manuscripts had larger sample sizes and stronger associations compared to existing studies of the food retail environment [10-12]. Finally, the sample size in the fourth manuscript was sufficiently large to allow for the examination of driving age as a potential effect modifier, which has not been done in previous research.

Obtaining a sufficient sample size is important in order to be able to detect relationships, if they exist, and not all studies are adequately powered to do so. For example, Laska et al. [10] were unable to find consistent relationships between the food retail environment surrounding schools and obesity-related behaviours. This may be due to the fact that only 349 adolescents within a single city were included in this study, and it was likely that many of them attended the same schools. A study of the school food environment by van der Horst et al. [12] examined a larger number of students (n=1,293), but only 15 schools were included in their study, which may have explained the lack of notable relationships between the food environment surrounding schools and students' eating behaviours. Therefore, it appears that an insufficient number of study participants and schools prevent some studies from detecting relevant associations. In addition, having sufficient geographical variation in study locations is important for recommending standardized methods of measuring the food retail environment. Allowing for adequate variability in food retail environments ensures the recommendations reflect the food environment in a variety of locations, rather than being influenced by a small number of food environments.

A second key strength of this thesis was related to the importance of context. For the second and third manuscripts, information was included on where food was obtained, which had not been done in previous studies. For example, measures such as 24 hour dietary recalls [10,13] or questions on typical weekly food and drink intake [12] did not consider where the foods or drinks are obtained. This made it impossible to attribute eating behaviours to specific environments, and previous studies may have introduced misclassification into their study outcomes by using these measures. The stronger findings within the second and third manuscripts of this thesis highlight the importance of using context-specific measures of the food retail environment and may guide future studies to consider similar outcome measures.

In addition to the importance of context within study measures, this thesis provided insights on the influence of the built environment on obesity-related behaviours within the broader Canadian context. There were contradictory findings between urban sprawl, MVPA and active transportation between American and Canadian adolescents. Both Ewing et al. [7] and Slater et al. [8] found that increased urban sprawl was associated with higher levels of obesity among American youth. In contrast, findings from the fourth manuscript of this thesis showed no relationship between urban sprawl and obesity, and greater urban sprawl was associated with increased active transportation among 12 to 15 year olds, as well as increased MVPA among 12 to 19 year olds. This suggests there may be a different mechanism underlying this relationship between the two countries. However, more research is needed to provide a detailed understanding of this mechanism. Finally, this thesis examined the influence of the food retail environment in Canada, which is important since there may be differences in the availability of food retailers compared to other countries.

There were also some key limitations of this thesis which warrant discussion. One of the main limitations was the reliance on cross-sectional data, which can make it difficult to establish causal relationships. This is due to the uncertainty regarding whether the exposure preceded the outcome or vice versa if they are measured at the same point in time, which is a typical characteristic of cross-sectional studies. However, given that young people do not have a great deal of autonomy in determining where they live and go to school compared to adults, it is more likely that their environments influence their health behaviours rather than the opposite.

There are other characteristics of the relationships found in this study that do support a causal relationship. The strength of the associations and the dose-response pattern seen for the relationship between the food retail environment and eating behaviours in the second and third manuscripts add further support for a causal relationship. These patterns are important because having strong relationships supports the notion that the results are not due to some other confounding factor. Having a dose-response pattern is important because when an increase in exposure is followed by a proportional increase in the outcome, it suggests the presence of a relationship between them. Support for a causal relationship was not as strong in the fourth manuscript, since the relationship between active transportation is in the opposite direction compared to previous studies [7,8]. However, the lack of consistency with previous research does not necessarily discount the study findings, and may guide future research dedicated to gaining a greater understanding the mechanism of this relationship.

A second limitation was the reliance on self-reported data provided by surveys. For physical activity and dietary intake among young people, evidence suggests that physical activity is overreported and poor eating behaviours are underreported due to biases towards socially desirable behaviours [14]. For the second and third manuscripts, it is possible that students underreported the frequency of eating lunch at a food retailer because it may be perceived as an unhealthy behaviour. This may have varied by exposure status. For example, students with a greater exposure to food retailers may have eaten out more often, and they may have underreported this to a greater degree than students with fewer nearby food retailers. However, it is also possible that the misclassification of eating behaviours was non-differential. Regardless, the multiple exposure categories make it difficult to determine the direction of the misclassification. For the fourth manuscript, misclassification may also have been present for self-reported heights and weights, resulting in underestimates of BMI [15]. It is likely that this misclassification is non-differential, since it was not expected to differ for areas of high and low urban sprawl. This non-differential misclassification may have partly explained the lack of an association between urban sprawl and obesity.

There are some other important limitations regarding food retailer measures used in the second and third manuscripts. Only the top chain fast food and coffee/donut retailers were used in the food retail environment studies. This excluded the smaller non-chain food retailers that may also have been accessible from schools. In addition, only the top 75% of the chain food retailers were used in this study and regional variations in smaller chains may not have been reflected in the food retailer measures. The exclusion of the non-chain food retailers is particularly problematic for the northern schools, which were oversampled within the Health Behaviours in School-aged Children Survey. These regions may have a greater number of non-chain food retailers that were not captured, resulting in an underestimation of the relationship between food retailers and eating out for lunch during the school day.

Finally, there are some variables that have not been accounted for in the analyses and may be suspected confounders. For example, peer influence is an important determinant of fast food consumption in young people. Those who frequently eat at fast food restaurants are more likely to report that their friends were not concerned about healthy eating [16,17]. However, peer influence is not a likely confounder because no association is expected between the presence of food retailers near schools (exposure) and peer influence (potential confounder).

There is some evidence to suggest that there are differences in the availability of food retailers based on area-level socioeconomic status (SES). In the US, Great Britain and Australia, fast food restaurants are more prevalent in areas with a high proportion of racial minorities [18] and low SES [19,20]. In addition, areas with low SES tend to have fewer supermarkets [21,22]. In Canada, however, the evidence to support this relationship is mixed. Seliske et al. [23] found no relationship between the SES of the areas surrounding Canadian schools and the presence of various food retailers. Apparicio et al. [24] also found no differences in access to supermarkets by area-level SES in Montreal, QC. However, Smoyer-Tomic [25] et al. found a greater prevalence of fast food restaurants in areas of low SES in Edmonton, AB. Thus, two of the three Canadian studies found no association between area-level SES and access to food retailers. This suggests that the relationship between area-level SES and the presence of certain food retailers may not be as strong in Canada, particularly for areas surrounding schools. Therefore, area-level SES measures were not considered as confounders in the second and third manuscripts. However, it is possible that not accounting for school-level SES may have confounded the relationship between exposure to food retailers and eating out during lunchtime at school.

7.4 Methodological Contributions

This thesis provided some important methodological contributions to studies using GIS-based measures to assess the food retail environment. Current studies typically did not include the use of handheld global positioning systems (GPS) devices to record and compare accuracy of food retailer listings, which was one of the methodological limitations of studies of the food retail environment [26]. The GPS devices provided data on the actual locations of food retailers, rather than simply identifying them as present or absent. This is important because it quantified the level of error present in studies which rely on secondary databases for food retailers.

A second major measurement issue that was addressed was the evaluation of the buffer type (circular vs. road network) and size used to capture the food retailers surrounding a specific geographic location. Previous research has compared the type of buffer used to measure the physical activity environment [27], and this thesis addressed the need for analogous research for the food retail environment. In addition, the third manuscript addressed a key methodological limitation regarding the optimal buffer size to measure the food retail environment. New insights were gained by including model fit criteria, and the findings provided important information to guide future studies regarding the choice of buffer.

7.5 Public Health and Policy Contributions

In spite of some modest relationships between aspects of the built environment and obesity-related outcomes, the potential public health implications of this thesis are important. In the fourth manuscript, a one standard deviation increase in the urban sprawl score was associated a moderately increased likelihood of engaging in active transportation (OR=1.24, 95% CI: 1.10-1.39) among 12 to 15 year olds. However, the urban sprawl score was the lowest in the largest metropolitan areas (Montreal, Toronto and Vancouver), which suggests that a substantial number of young people living in those locations could benefit from interventions directed at increasing active transportation. Additional research is needed to understand the mechanism of the relationship between urban sprawl and active transportation prior to implementing interventions. However, the benefits of modifying the built environment in order to support active transportation in young people may also have a positive effect on other age groups.

With respect to the food retail environment, interventions directed at improving eating behaviours among young people have a great deal of potential to influence health outcomes at the population level due to the large effect sizes observed in the second and third manuscripts. In the second manuscript, relationships were relatively strong, with exposure to 5 or more food retailers associated with a 3.5-fold increased likelihood of eating at a snack bar, fast food restaurant or café, and it resulted in a population attributable risk of 58%. The large population attributable risk suggests that changing lunchtime eating behaviours through the modification of the food retail environment near schools could have a large impact. The concept of population attributable risk is an important one for the built environment, where relatively modest effects can have important public health implications due to the large number of people affected by the features of the built environment [28].

The results of the research on the food retail environment could also have some important policy implications. The third manuscript identified the appropriate buffer size to use to identify food retailers when assessing their influence on eating behaviours. Knowledge of the appropriate buffer size may play an important role in determining where to implement interventions directed at the modification of the food retail environment. For example, it may not be feasible for provincial and/or municipal policies, for example, to apply across the board restrictions on the number of food retailers that sell primarily unhealthy foods. However, it may be feasible to apply such restrictions in specific areas. For instance, policies may be able to restrict the number of food retailers to no more than three for the 1 km road network distance surrounding schools. This may be met with less opposition compared to large-scale restrictions on food retailers. A second benefit of having a clear and specific definition of the size of the food retail environment is that it informs policymakers of the relevant area to evaluate the effectiveness of policies directed at changing students' eating behaviours.

7.6 Future Research

Further research is needed to build upon the findings of this thesis. For etiological studies of the food retail environment, there is a need for more detailed information on the lunchtime eating behaviours of students. The amount of agreement between self-reported and actual lunchtime eating behaviours is currently unknown. There is also a need for more detailed information on the specific food retailers that students visit during breaks in the school day, as well as the food items that are purchased. Such information would help researchers gain a better understanding of the health implications of eating at food retailers that are located off school grounds. Finally, as more information is gained about relationships between the food retail environment and eating behaviours, there is a need for studies to examine the feasibility and effectiveness of policies that modify the food retail environment in order to change eating behaviours. In spite of the growing body of research on the influence of the food retail environment on obesity-related behaviours, there is a dearth of evidence assessing whether policies that address these environments are feasible or effective in changing people's behaviours.

The low ICC values (< 1%) obtained for the fourth manuscript of this thesis indicated that there was very little variation in the obesity and physical activity outcomes across census metropolitan areas. Therefore, the association between urban sprawl and active transportation within Canadian youth should be explored on a smaller geographic scale in order to obtain sufficient variation in outcomes. Also, findings from this study indicated that urban sprawl had the opposite effect on young Canadians compared to other populations of young people [7,8] and adults [29-31]. There is a need for future research to provide a more detailed understanding of the mechanism behind this relationship in order to explain the divergent associations, and also to help inform interventions directed at increasing the proportion of youth who frequently engage in active transportation and moderate-to-vigorous physical activity.

There are also some measurement issues which could expand upon the findings of this thesis. First of all, since the second and third manuscripts are among the first to examine the size and type of buffers surrounding schools using model fit criteria, there is a need for other studies to replicate these studies in other populations in order to establish whether the relationships are consistent. Second, there is a need for analogous research to address the measurement issues regarding buffer size and type for the food retail environments surrounding the homes of young people. This would help make it possible to conduct studies that incorporate the home and school food retail environments within the same study sample, which would provide a more comprehensive assessment of the food retail environment. Finally, due to the lack of a proper distinction between full service and fast food restaurants in the online food retailer database, only chain food retailers were considered within this thesis. It may be worth examining whether students purchase foods mainly from chain food retailers, or whether non-chain food retailers have an important role in young peoples' food choices.

7.7 Conclusions

Given the lack of success of interventions focused individual-level factors, this thesis provided important insights into the relationship between the built environment, eating behaviours and active transportation among Canadian youth. It not only demonstrated associations between the built environment and obesity-related behaviours, but it also addressed important questions regarding how to measure the food retail environment. Understanding the context in which health behaviours occur is important because interventions directed at modifying the built environment have potentially wide-ranging public health implications due to the large number of people they can affect. However, there is a need for a greater understanding of how to effectively implement policies designed to facilitate healthy lifestyle choices through the modification of the built environment.

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APPENDIX A

Ethics Approval

QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD-DELEGATED REVIEW
September 15, 2011

Ms. Laura Seliske
Department of Community Health and Epidemiology
Queen's University

Dear Ms. Seliske
Study Title: EPID-359-11 Measuring access to food retailers surrounding schools and the relationship to eating patterns and obesity in Canadian youth
File # 6006285
Co-Investigators: Dr. Ian Janssen

I am writing to acknowledge receipt of your recent ethics submission. We have examined the protocol for your project (as stated above) and consider it to be ethically acceptable. This approval is valid for one year from the date of the Chair's signature below. This approval will be reported to the Research Ethics Board. Please attend carefully to the following listing of ethics requirements you must fulfill over the course of your study:

Reporting of Amendments: If there are any changes to your study (e.g. consent, protocol, study procedures, etc.), you must submit an amendment to the Research Ethics Board for approval. Please use event form: HSREB Multi-Use Amendment/Full Board Renewal Form associated with your post review file # **6006285** in your Researcher Portal (https://eservices.queensu.ca/romeo_researcher/)

Reporting of Serious Adverse Events: Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information. Serious Adverse Event forms are located with your post-review file **6006285** in your Researcher Portal (https://eservices.queensu.ca/romeo_researcher/)

Reporting of Complaints: Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. Note: All documents supplied to participants must have the contact information for the Research Ethics Board.

Annual Renewal: Prior to the expiration of your approval (which is one year from the date of the Chair's signature below), you will be reminded to submit your renewal form along with any new changes or amendments you wish to make to your study. If there have been no major changes to your protocol, your approval may be renewed for another year.

Yours sincerely,

Albert F. Clark.

Chair, Research Ethics Board
September 15, 2011

Investigators please note that if your trial is registered by the sponsor, you must tale responsibility to ensure that the registration information is accurate and complete

QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD

The membership of this Research Ethics Board complies with the membership requirements for Research Ethics Boards as defined by the Tri-Council Policy Statement; Part C Division 5 of the Food and Drug Regulations, OHRP, and U.S DHHS Code of Federal Regulations Title 45, Part 46 and carries out its functions in a manner consistent with Good Clinical Practices.

Federalwide Assurance Number: #FWA00004184, #IRB00001173

Current 2011 membership of the Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board:

Dr. A.F. Clark, Emeritus Professor, Department of Biochemistry, Faculty of Health Sciences, Queen's University (Chair)

Dr. H. Abdollah, Professor, Department of Medicine, Queen's University

Dr. R. Brison, Professor, Department of Emergency Medicine, Queen's University

Dr. M. Evans, Community Member

Dr. S. Horgan, Manager, Program Evaluation & Health Services Development, Geriatric Psychiatry Service, Providence Care, Mental Health Services, Assistant Professor, Department of Psychiatry

Dr. B. S. Kisilevsky, Professor, School of Nursing, Department of Psychology and Obstetrics & Gynaecology, Queen's University

Ms. D. Morales, Community Member

Ms. P. Newman, Pharmacist, Clinical Care Specialist and Clinical Lead, Quality and Safety, Pharmacy Services, Kingston General Hospital

Dr. W. Racz, Emeritus Professor, Department of Pharmacology & Toxicology, Queen's University

Ms. S. Rohland, Privacy Officer, ICES-Queen's Health Services Research Facility, Research Associate, Division of Cancer Care and Epidemiology, Queen's Cancer Research Institute

Dr. B. Simchison, Assistant Professor, Department of Anesthesiology, Queen's University

Dr. A.N. Singh, WHO Professor in Psychosomatic Medicine and Psychopharmacology
Professor of Psychiatry and Pharmacology, Chair and Head, Division of Psychopharmacology, Queen's University, Director & Chief of Psychiatry, Academic Unit, Quinte Health Care, Belleville General Hospital

Dr. E. Tsai, Associate Professor, Department of Paediatrics and Office of Bioethics, Queen's University

Rev. J. Warren, Community Member

Manuscript 4

QUEEN'S UNIVERSITY HEALTH SCIENCES & AFFILIATED TEACHING HOSPITALS RESEARCH ETHICS BOARD

February 1, 2011

This Ethics Application was subject to:

☐ Full Board Review
Meeting Date:
☒ Expedited Review

Ms. Laura Seliske
Department of Community Health & Epidemiology
Queen's University

Dear Ms. Seliske,

Study Title: **Relationship between urban sprawl and physical activity and obesity among Canadian youth**
Co-Investigators: **Dr. I. Janssen and Dr. W. Pickett**

I am writing to acknowledge receipt of your recent ethics submission. We have examined the protocol for your project (as stated above) and consider it to be ethically acceptable. This approval is valid for one year from the date of the Chair's signature below. This approval will be reported to the Research Ethics Board. Please attend carefully to the following list of ethics requirements you must fulfill over the course of your study:

- **Reporting of Amendments:** If there are any changes to your study (e.g. consent, protocol, study procedures, etc.), you must submit an amendment to the Research Ethics Board for approval. (see http://www.queensu.ca/vpr/reb.htm).

- **Reporting of Serious Adverse Events:** Any unexpected serious adverse event occurring locally must be reported within 2 working days or earlier if required by the study sponsor. All other serious adverse events must be reported within 15 days after becoming aware of the information.

- **Reporting of Complaints:** Any complaints made by participants or persons acting on behalf of participants must be reported to the Research Ethics Board within 7 days of becoming aware of the complaint. Note: All documents supplied to participants must have the contact information for the Research Ethics Board.

- **Annual Renewal:** Prior to the expiration of your approval (which is one year from the date of the Chair's signature below), you will be reminded to submit your renewal form along with any new changes or amendments you wish to make to your study. If there have been no major changes to your protocol, your approval may be renewed for another year.

Yours sincerely,

Albert Clark
Chair, Research Ethics Board

Feb 3, 2011
Date

ORIGINAL TO INVESTIGATOR - COPY TO DEPARTMENT HEAD- COPY TO HOSPITAL – BINDER COPY - FILE COPY

Study Code: EPID-338-11

- **Investigators please note that if your trial is registered by the sponsor, you must take responsibility to ensure that the registration information is accurate and complete**

Health Behaviour in School Aged Children (HBSC) Survey Ethics Approval

January 6, 2011

Queen's UNIVERSITY
OFFICE OF RESEARCH SERVICES
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Dr. John Freeman
Faculty of Education
Duncan McArthur Hall
Queen's University

GREB ref. #: GEDUC-430-09
Title: "Health Behaviour in School-Aged Children (HBSC) Study: 2009-2011"

Dear Dr. Freeman:

The General Research Ethics Board (GREB) has reviewed and approved your request for renewal of ethics clearance for the above-named study. This renewal is valid for one year from February 21, 2011. Prior to the next renewal date you will be sent a reminder memo and form to reapply.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB if applicable, of any adverse event(s) that occur during this one year period (details available at webpage http://www.queensu.ca/ors/researchethics/GeneralREB/forms.html - Adverse Event Report Form). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example you must report changes in study procedures or implementations of new aspects into the study procedures on the Ethics Change Form that can be found at http://www.queensu.ca/ors/researchethics/GeneralREB/forms.html – Research Ethics Change Form. These changes must be sent to the Ethics Coordinator, Gail Irving, at the Office of Research Services or irvingg@queensu.ca prior to implementation. Mrs. Irving will forward your request for protocol changes to the appropriate GREB reviewers and / or the GREB Chair.

On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

Joan Stevenson

Joan Stevenson, Ph.D.
Professor and Chair
General Research Ethics Board

c.c.: Dr. William Pickett, Matt King, Wendy Craig, Ian Janssen, Frank Elgar, Co-investigators
Dr. Lesly Wade-Woolley, Chair, Unit REB
E-REB: c/o Graduate Studies & Bureau of Research, Attn.: Celina Caswell

think Research
think Queen's

JS/gi

APPENDIX B

Health Behaviour in School-aged Children (HBSC) Survey Methodology

Overview

The second and third manuscripts of this thesis were based on data collected from the 2009/2010 Canadian Health Behaviour in School-Aged Children (HBSC). The HBSC survey is a cross-sectional survey that obtains information on a variety of health behaviours, health determinants, and personal characteristics of students in grades 6 to 10 (approximate ages of 11 to 16 years old). It is carried out in affiliation with the World Health Organization, and 43 countries in Europe and North America participated in the 2009/2010 survey. In addition to the student questionnaire, the HBSC collects information on school characteristics using an administrator survey that is completed by the principal or designate at each of the participating schools.

Sampling Strategy

In Canada, a single stage cluster sampling approach was used to obtain participants, in accordance with an international protocol [1], with an oversampling of youth from some of the provinces and the northern territories. In 2009/2010, New Brunswick and Prince Edward Island did participate; all other provinces and territories were included. There were a total of 26,078 respondents from 436 schools in the 2009/2010 Canadian HBSC, and the overall response rate was approximately 75%. The sample was weighted to account for oversampling of certain provinces and territories.

The primary sampling unit of the HBSC survey is the classroom, with eligible classrooms in each school having the same probability of being selected for the survey. Classes were systematically selected from an ordered list based on school jurisdiction, province or region, language, public/roam Catholic designation, community size, and community location. Youth attending private schools, incarcerated youth, students from special needs schools and home schooled students were excluded. Together, these youth represent <10% of Canadian youth in the studied age range. Permission to participate in the survey was obtained from the school board and school, as well as from parents or guardians (either explicitly or implicitly determined by school board policy) and individual students. Participation in the survey was voluntary. Permission to carry out the survey was obtained from the Queen's University General Research Ethics Board (see Appendix A for ethics permission).

Administration of the Survey

The HBSC is a classroom-based survey which is conducted during the school day and which is administered by the classroom teachers. Having students seal un-signed surveys in enveloped ensured anonymity. The survey takes approximately 45 minutes for students to complete. There are core questions within the HBSC that must be asked in all participating countries, as well as optional themed modules that are completed in some but not all countries, as well as country specific items. Core information includes demographic information (e.g. age, sex, grade), as well as health behaviours (e.g. diet, physical activity, drug and alcohol use), health outcomes (e.g. physical and emotional well-being) and social support (e.g. family, peer and teacher support). The administrator survey contains information on school policies (e.g. whether students are permitted to leave school grounds during the school day) and resources (e.g. nutritional programs, condition of sports fields, presence of bicycle racks, etc.). For the 2009/2010 survey, data collection occurred from October 2009 until May 2010.

School Administrator's Survey

The Canadian HBSC also includes an 8 page survey completed by the school principal or designate to collect information on school characteristics, school built environment features, and school policies and programs that may influence the health of students. This includes policies and programs to promote physical activity, such as the amount of class time allotted for physical education, the promotion of active transportation (e.g. presence of bike racks), and the availability of physical activity facilities (e.g. running track, gymnasium, indoor swimming pool, etc.). In addition, information on food sources within schools (e.g. cafeterias, snack/tuck shops, vending machines) is collected, along with healthy eating programs, such subsidized access to fruits and vegetables. Finally, the survey also gathers information on the overall school climate through questions on student absenteeism, conflict among students, as well as overall crime and safety issues in the surrounding school neighbourhood.

Reference

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APPENDIX C

Relevant Questionnaire Items from the Student and Administrator Health Behaviour in School Aged Children (HBSC) Surveys

The following HBSC survey questions were used for Manuscripts 2 and 3

HBSC STUDENT SURVEY QUESTIONS

Outcome: Lunchtime Eating Behaviour

Where do you usually eat your lunch or mid-day meal on school days?

1☐ *at school*

2☐ at home

3☐ somewhere else. *Please write down where:*___________________________

4☐ I never eat a lunch or mid-day meal

5☐ at someone else's home

6☐ in a snack-bar, fast-food restaurant, cafe

Student-Level Covariates

a) Age & Sex

Are you male or female?

1☐ Male

2☐ Female

What month were you born?

1☐	2☐	3☐	4☐	5☐	6☐	7☐	8☐	9☐	10☐	11☐	12☐
Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec

What year were you born?

1☐	2☐	3☐	4☐	5☐	6☐	7☐	8☐
1991	1992	1993	1994	1995	1996	1997	1998

b) Family Affluence Scale

The Family Affluence Scale is derived from the following four questions below. The values beside the selected answers (1, 2 or 3) are added up to receive a total score. Respondents who receive a score of 3 or less are categorized into the low affluence group. The medium affluence group is comprised of those with a score of 4 or 5, while those with a score of 6 or more are categorized into the high affluence group.

Do you have your own bedroom for yourself?

0☐ No 1☐ Yes

Does your family own a car, van or truck?

0☐ No 1☐ Yes, one 2☐ Yes, two or more

During the past 12 months, how many times did you travel away on holiday (vacation) with your family?

0☐ Not at all
1☐ *Once*
2☐ *Twice*
3☐ *More than twice*

How many computers does your family own?

0☐ None
1☐ *One*
2☐ *Two*
3☐ *More than two*

HBSC ADMNISTRATOR SURVEY QUESTIONS

<u>School-Level Covariates</u>

20. Do students have access to the following facilities where they can buy foods or drinks?

	Yes	*No*
a. Cafeteria	☐	☐
b. School shop	☐	☐
c. Candy and potato chips vending machine	☐	☐
d. Drinks vending machine (e.g., coke, soft drinks, orange juice)	☐	☐
e. Milk vending machine/ milk program (e.g., milk, chocolate milk)	☐	☐

APPENDIX D

Canadian Community Health Survey (CCHS) Methodology

Overview

The CCHS is a large cross-sectional survey of the determinants of health of Canadians. It was first conducted in 2000/2001 and was carried out every two years until 2005. Beginning in 2007, the survey was changed to include a core annual component which remains relatively consistent across all years of the survey. The core annual component collects information on demographic characteristics, socioeconomic status, self-rated health and health care utilization, as well as selected health behaviours (e.g. smoking, diet, physical activity, etc.). The 2007-2008 annual component was comprised of 131,061 respondents [1]. In addition to the core annual component, data are collected on particular themes. For example, the theme for the 2007-2008 CCHS was based on healthy living. There are also different themes that are collected each year of the survey. For 2007, the theme was health services and access, and in 2008 it was prevention of chronic illnesses. Finally, there is also optional content that can be administered by different regions in Canada. For more details on the health data collected in the 2007-2008 CCHS, see the overview provided by Statistics Canada [2]. The fourth manuscript of this thesis used data from the core annual component of the 2007-2008 CCHS.

Sampling Strategy

The target population for the CCHS includes Canadians 12 years of age and older. The survey covers a large geographic area, with coverage at 98% for the provinces, 90% in the Yukon, 97% in the Northwest Territories and 71% in Nunavut [1]. The CCHS obtains participants from all 121 health regions in Canada. A complex multi-stage sampling process is used to select participants, whereby the number of respondents selected is proportional to the size of the province/territory they live in as well as their health region. In order to acquire the survey sample, 49% of the respondents are obtained by the area frame, 50% from a telephone list and 1% from random digit dialing. The number of people contacted is inflated in order to take into account non-response.

Administration of Survey

Participation in the CCHS is voluntary and interviews are conducted either in person or by telephone. The survey is administered by trained interviewers who use computer-assisted interview (CAI) software to conduct the survey. The CAI software allows the interviewer to be directed through the survey questions based on the respondent's personal characteristics (e.g. age, sex, etc) as well as answers to previous questions. The CAI also provides built-in checks for implausible or inconsistent answers, which can be corrected immediately.

Access to Data

Some of the data collected from the CCHS is available through Public Use Microfiles, which can be accessed through the Statistics Canada. Steps have been taken to ensure that privacy and confidentiality standards are met prior to the data being made available to the public. These data are available free of cost to universities and also to the general public for a fee [1]. In order for researchers to gain access to the full dataset from Research Data Centres (RDCs) across Canada, they must submit a proposal to be approved by Statistics Canada. Researchers must also have their study results reviewed prior to release from the RDCs in order to ensure that there are no violations of privacy or confidentiality.

Limitations

The CCHS has some limitations that warrant consideration. First, the target population excludes individuals living on Indian Reserves or Crown Land, full-time members of the Canadian Forces, as well as individuals living in remote regions. Second, because the survey is cross-sectional, it is not possible to directly determine causality. Finally, because the survey data are obtained through self-report, it is likely that some bias is present in the study responses.

References

1. Statistics Canada. 2007-2008 CCHS Microdata File User Guide. http://www.statcan.gc.ca/imdb-bmdi/document/3226_D7_T9_V6-eng.pdf. Accessed November 2011.
2. Statistics Canada. Canadian community health survey (CCHS). Content overview for 2007, 2008 and 2007-2008. http://www.statcan.gc.ca/imdb-bmdi/document/3226_D45_T9_V1-eng.pdf. Accessed November 2011.

APPENDIX E

Relevant Questionnaire Items from the Canadian Community Health Survey (CCHS)

<u>Outcome Variables:</u>

Overweight and Obesity: This variable was derived from self-reported heights (which could be provided in cm or inches/feet)and weights (which could be provided in kg or lbs). For youth aged 12 to 17 years, the International Obesity Task Force thresholds were used (shown below). For youth aged 18 and 19 years, adult body mass index (BMI) thresholds of <25 kg/m^2 (non-overweight), 25-29.9 kg/m^2 (overweight), and ≥ 30 kg/m^2 (obese) were used to determine weight status. To maintain consistency between the age groups the underweight and normal weight were both considered non-overweight or obese.

The description of how this variable was derived is for 12 to 17 year olds is provided below:

Canadian Community Health Survey (CCHS) Cycle 4.1 *Derived Variable Specifications*

Reference: For more detailed information see Canadian Guidelines for Body Weight Classification in Adults, Health Canada, 2003

5) BMI classification for children aged 12 to 17 (self-reported) - Cole classification system

Variable name: HWTDCOL

Based on: HWTDBMI, DHH_SEX, DHHYOB, DHHMOB, DHHDOB, ADM_YOI, ADM_MOI, ADM_DOI

Description: This variable classifies children aged 12 to 17 (except female respondents aged 15 to 17 who were pregnant or did not answer the pregnancy question) as "obese", "overweight" or "neither obese nor overweight" according to the age-and-sex-specific BMI cut-off points as defined by Cole et al. The Cole cut-off points are based on pooled international data (Brazil, Great Britain, Hong Kong, Netherlands, Singapore, and United States) for BMI and linked to the widely internationally accepted adult BMI cut-off points of 25 (overweight) and 30 (obese).

Note: Respondents who do not fall within the categories of "Obese" or "Overweight" (as defined by Cole et al.) have been classified by CCHS as "neither obese nor overweight".

This variable excludes respondents who are 18 years old or over (216 months).

The description of how this variable was derived for 18 to 19 year olds is provided below:

4) BMI classification for adults aged 18 and over (self-reported) - international standard

Variable name:	HWTDISW
Based on:	HWTDBMI, DDH_AGE
Description:	This variable assigns adult respondents aged 18 and over (except pregnant women) to one of the following categories, according to their Body Mass Index (BMI): underweight; acceptable weight; overweight; obese class I; obese class II; and, obese class III. Here, the BMI categories are adopted from a body weight classification system recommended by Health Canada and the World Health Organization (WHO) which has been widely used internationally.

Note:	According to Health Canada, this BMI classification system can be used as a screening tool to identify weight-related health risks at the population and individual levels. The following health risks are associated with each of the BMI categories for adults aged 18 and over:
	normal weight = least health risk;
	underweight and overweight = increased health risk;
	obese class I = high health risk;
	obese class II = very high health risk;
	obese class III = extremely high health risk
	
	At the population level, the BMI classification system can be used to compare body weight patterns and related health risks within and between populations and to establish population trends in body weight patterns. The classification should be used with caution at the individual level because the health risk associated with each BMI category varies considerably between individuals. Particular caution should be used when classifying: adults who are naturally very lean, very muscular adults, some ethnic and racial groups, and seniors.
	
	This variable excludes female respondents aged 18 to 49 who were pregnant or did not answer the pregnancy question (i.e. MAM_037 = don't know, refusal, not stated).

Internet site:	http ://www.hc-sc.gc.ca/hpfb-dgpsa/onpp-bppn/weight_book_f.pdf

2) Moderate to Vigorous Physical Activity (MVPA) and Active Transportation

Minutes spent participating in MVPA was a derived variable. First, participants were asked if they participated in a particular physical activity over the past 90 days, with response options of: yes, no, don't know, refuse to answer, or not stated. An example is shown below for walking for exercise.

(The sum of individual rounded items in the "Population" column may not necessarily equal the total)

Variable Name	PAC_1A	Length	1	Position	914
Question Name	PAC_Q1				
Concept	Activity / last 3 months - walking				
Question	Have you done any of the following in the past 3 months? - Walking for exercise				
Universe	All respondents				
Note	Includes only leisure time activities. The "not stated" category includes people who did the interview by proxy				

Content		Code	Sample	Population
YES		1	91,163	18,831,500
NO		2	37,649	8,455,500
DON'T KNOW		7	94	19,500
REFUSAL		8	131	25,000
NOT STATED		9	2,922	700,000
	Total		131,959	28,030,943

For respondents who answered yes, don’t know or refused to answer, they were asked follow up questions to obtain the frequency and duration of the activity, which were both close-ended categorical variables. The frequency of walking for exercise is shown below, with the number of times permitted to range from 1 to 270.

Variable Name	PAC_2A	Length	3	Position	939 - 941
Question Name	PAC_Q2A				
Concept	Number of times / 3 months - walking for exercise				
Question	In the past 3 months, how many times did you [participate in identified activity]? - Walking for exercise				
Universe	Respondents who answered PAC_1A = (1,7 or 8)				
Note					

Content		Code	Sample	Population
NUMBER OF TIMES		1 - 270	90,108	18,661,000
NOT APPLICABLE		996	37,649	8,455,500
DON'T KNOW		997	1,046	168,500
REFUSAL		998	9	2,000
NOT STATED		999	3,147	744,500
	Total		131,969	28,030,943

Next, information is obtained on the typical duration of the activity:

Variable Name	PAC_3A	Length	1	Position	942
Question Name	PAC_Q3A				
Concept	Time spent - walking for exercise				
Question	About how much time did you spend on each occasion? - Walking for exercise				
Universe	Respondents who answered PAC_1A = (1,7 or 8)				
Note					

Content		Code	Sample	Population
1 TO 15 MINUTES		1	8,575	1,745,500
16 TO 30 MINUTES		2	35,578	7,504,500
31 TO 60 MINUTES		3	34,541	7,012,000
MORE THAN ONE HOUR		4	11,159	2,362,500
NOT APPLICABLE		6	37,649	8,455,500
DON'T KNOW		7	252	36,000
REFUSAL		8	3	1,000
NOT STATED		9	4,202	914,500
	Total		131,969	28,030,943

To obtain the total number of minutes of walking for exercise over the past 3 months, the frequency is multiplied by the number of minutes assigned to the duration categories. The duration categories were used in the National Population Health Survey [1]. The number of minutes corresponding to each category is provided in the Table 1 below:

Table 1. Duration of physical activity assigned to response categories in the CCHS

Category	Duration
0 to 15 minutes	13 minutes
16 to 30 minutes	23 minutes
31 to 60 minutes	45 minutes
More than 60 minutes	60 minutes

The number of minutes of physical activity over the 3 month period was then divided by 90 to get the average daily physical activity. This was used to categorize participants based on whether they obtained at least 60 minutes per day, which is in accordance with the Canadian Physical Activity Guidelines [2].

To determine the total MVPA among participants, the responses to all physical activity questions were used. Active transportation contained a subset of the activity. The specific activities included in both outcomes are listed in Table 2.

Table 2. Activities used to determine MVPA and active transportation for Manuscript 4

MVPA			Active Transportation
Walking for exercise Gardening or yard work Swimming Bicycling Popular/social dance Home exercises Ice hockey Ice skating Inline skating or rollerblading	Jogging or running Golfing Exercise class or aerobics Downhill skiing or snowboarding Bowling Baseball or softball Tennis Weight training	Fishing Volleyball Basketball Soccer Other #1 Other #2 Other #3 Walked to work or school Bicycled to work or school	Walked to work or school Bicycled to work or school Walking for exercise Bicycling Inline skating or rollerblading

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APPENDIX F

Geographical Information Systems (GIS) Methodology

Overview

In this Appendix a detailed description of the GIS-based measures used for Manuscript 1 is described in detail, followed by a similar description for the GIS-based measures used Manuscripts 2 and 3. Next, key limitations inherent to GIS-based measures of the food retail environment are outlined. Finally, the specific protocol that I developed to obtain food retailer addresses and map the food retailers using GIS is included at the end of this Appendix.

Manuscript 1

Mapping School Locations

CanMaps Streetfiles (DMTI Spatial Inc., v.2009.4, Markham ON) was the source of geographic data used. It provided information on features of the surrounding environment, including: bodies of land and water, road networks, and schools. A GIS software program (ArcGIS: ESRI, version 9.3) was used to create a 1 km circular buffer surrounding each of the 34 schools included in the field validation study. Contained within the 1 km buffer were: the school, roads, and bodies of water.

Obtaining the Food Retailer Addresses

The addresses for the food retailers within 1 km of schools were obtained from an online database (www.yellowpages.ca) and a commercial database (InfoCanada). Spreadsheets containing the addresses of full service restaurants, limited service restaurants, and convenience stores were created in Microsoft Excel. The relevant fields included the food retailer name, street address, city, province and postal code. If any of the address fields were missing (i.e., not provided by yellow pages), an online search was conducted to obtain the missing information.

Mapping the Food Retailer Addresses

The completed Excel spreadsheets were then uploaded into ArcGIS software and the software's address locator tool was used to map the food retailers surrounding each of the 34 schools. When the initial mapping process was complete, the address locator provided a match score out of 100, which indicated how accurate the mapping process was for each food retailer. For food retailers with a score of less than 80, an online search was conducted to check whether the address information was complete and accurate. If it was still not possible to improve the match score to a value greater than 80, the Google Earth Street View tool (©2011 Google) was used to visually locate the food retailer and to obtain the latitude and longitude coordinates that could be used to manually map the food retailer.

Field Validation

For each of the 34 schools included in the validation study, a list of the food retailers to be measured was generated along with a map of the roads within the school's 1 km buffer. Two researchers (the PhD candidate and an undergraduate research assistant that was supervised by the candidate) conducted the validation study, with each researcher responsible for one of the databases (e.g., the commercial or yellow pages directory).

Once the food retailers were located within the field, their street entrances were recorded using a handheld Global Positioning Systems (GPS) device (Garmin Dakota 10). If a food retailer was not initially found, a phone call was made to the retailer to obtain information on its location. GPS devices use satellites to obtain the longitude and latitude coordinates of a given geographic location [4]. The Garmin 10 GPS device is accurate within 3 to 5 metres under optimal conditions [5]. However, the presence of tall buildings and other obstructions to satellite communications can affect accuracy [4].

After the field work was complete, the longitude and latitude coordinates recorded by the GPS devices were then transferred to ArcGIS. For each food retailer found within the field, the Euclidian distance (also referred to "as the crow flies" or the straight line distance) between the GPS-recorded location and the listed address was calculated. The proportion of the listed food retailers that were found in the field was obtained.

Manuscripts 2 and 3

Mapping School Locations

Similar to Manuscript 1, the locations of the 158 schools in Manuscripts 2 and 3 were identified within the CanMaps Streetfiles databases. The location of each school was also verified within Google Earth Street View (©2011 Google). For remote locations where Street View was unavailable, the principal or other staff member was contacted to help identify the school's location and map it using a satellite image. For Manuscript 2, a 1 km circular and 1 km road network buffer were created around each school using ArcGIS. For Manuscript 3, six road network buffers of varying sizes were created (500 m, 750 m, 1000 m, 1500 m, 2000 m and 5000 m).

Obtaining the Food Retailer Addresses

Since there was a higher proportion of food retailers located using the online databases (www.yellowpages.ca), it was used as the source of food retailers for both the second and third manuscripts. The food retailer types were chosen to correspond to the Health Behaviour in School-Aged Children survey question which formed the outcome of both manuscripts. They included fast food restaurants, coffee/donut shops and convenience stores.

Mapping the Food Retailers

The mapping procedure was similar to the process described for Manuscript 1, whereby spreadsheets were created containing the name of the food retailer as well as the address information (street address, city, province, and postal code). Efforts were made to find missing information by carrying out online searches of food retailers. The locations of food retailers with a match score of less than 80 were visually confirmed, and corrected if necessary, using Google Earth Street View (©2011 Google). After the food retailers were mapped, the number of food retailers within the buffer of interest was obtained using ArcGIS.

Limitations of GIS Measures of the Food Retail Environment

Although GIS-based measures of the food retail environment may avoid the biases associated with subjective observations, they have some limitations which warrant consideration. First, there is the possibility that the food retailer databases are not up to date. New food retailers may not be listed or food retailers that have closed may not have been removed from the databases. Secondly, there is the possibility that the address information is not accurate. Although efforts were made to ensure that the address information was complete as possible, it is possible that incorrect information was included, such as the wrong street number or street type (e.g. avenue, street, road, boulevard, etc), which would not be detected by the match score. Finally, for the online database, food retailers were obtained through an advertisement subscription, so food retailers whose owners choose not to advertise within it are excluded.

COLLECTING ADDRESSES FOR MANUSCRIPT 1

Classifying Food Retailers:

Step 1: Setting Up Spreadsheets
In Excel, set up a spread sheet for each school with the following column titles: Food Retailer Name, Category, Address, Postal Code, Distance From School. At the lower left hand corner of the spread sheet, there are tabs labeled as 'Sheet1', 'Sheet2', and 'Sheet3'. Rename them as Full Service Restaurants, Ltd. Service Chain Restaurants, and Convenience Stores and type in the column headings described above for each of the sheets.

Step 2: Gathering Location Data for Restaurants

Go to www.yellowpages.ca and choose 'Search by Proximity'. Type in the school address and the following key words (1 at a time):
- Restaurants
- Ice cream & frozen desserts
- Sandwiches
- Donut

For the first 4 key words, cut and paste the names of the restaurants, the location (street address), postal code and distance from the school on the 'Restaurants' sheet. Do this for the restaurants 1.2 km or closer. I'm unsure of the accuracy of the distance from school in the yellowpages website, so I want to overshoot the 1 km by a small margin for the time being.
Step 3: Copying and Pasting Selected Food Retailers into the Limited Service Spreadsheet
The next step is to review the restaurants found and identify limited service restaurant chains.

These include:
-Burger King
-Domino's Pizza
-McDonald's
-Wendy's
-Subway
-241 Pizza
-Tim Horton's
-Harvey's
-A&W
-Double Double Pizza Chicken
-Pizza Pizza
-Mr. Sub
-KFC
-Arby's
-Pita Pit
-Starbucks
-Baskin Robins
-Dairy Queen

-Country Style Donuts

At this point in time, this is an evolving list, so if you come across any others you think are missing, email me and I'll add it to the list

-Currently, I am still waiting for a commercial list of food retailers around schools (i.e. we pay to get a list created for us). Because I'm unsure comparable they will be to the yellowpages, I just want colour coded in the main "Restaurants" list so I can go back and retrace my steps if I need to.

- Limited Service listed under Restaurant = Purple
- Limited Service listed under Sandwiches = Green
- Limited Service listed under Ice cream & Frozen Desserts = Orange
- Limited Service listed under Donuts = Blue

- Take all the highlighted food retailers and copy and paste into Ltd. Service Restaurants. Change the colour of the restaurants back to white.

Step 4: Gathering Location Data for Convenience Stores

- Go back to www.yellowpages.ca and choose 'Search by Proximity'. Type in the school address and the key word "Convenience Stores". Copy the name, address and distance from the school for each convenience store. For the time being, collect information for all convenience stores within 1.3 km.

<u>GIS FOOD RETAILER PROTOCOL</u>

COLLECTING ADDRESSES FOR MANUSCRIPTS 2 & 3

A) Convenience Stores

<u>Step 1.</u> Go to www.yellowpages.ca and click on the 'By proximity' Tab

<u>Step 2.</u> Fill in the school address information in the relevant boxes.

Tip*: If you are performing multiple searches for the same school (i.e. later on, when you're looking for the location of multiple fast food restaurants), leave the "What?" box blank. For the next step, the website will highlight the missing field and ask you to fill it in. If you use your back button on your browser, then all you need to do is fill in different food retailer names without typing in the school address over and over. This will save you some time.*

<u>Step 3:</u> Click the 'Find' button to obtain your results.

<u>Important Note</u>: If you're collecting data for a small town and entering the street address does not give you any results, then use the town name, and not the postal code. You will know the street address is not coming up with results because it will say something to that effect. If there are simply no restaurants within range, then generic web search results will come up (similar to a Google search results page).

For my work with the food retailers surrounding schools, I am interested in the food retailer addresses around a 5 km circular buffer. However, the distance information is not as precise when I start mapping them in ArcGIS. For example, when I map in ArcGIS, the food retailer within 5.2 km actually falls within the 5 km circular buffer created in ArcGIS. Therefore, I overshoot a bit and include all the food retailers within a 5.5 km distance from the schools.

Back to the Montcalm Secondary School example, I need all the addresses from page 1 and the first 7 from page 2.

A modified web browser should come up, and that is where I paste the website address for page 1 of my search results. After the result page loads, click 'Import'.

<u>Step 4.</u> Cleaning up the Data

You will notice that there is a lot of extra info in the header of the website (about 50ish lines worth). I've deleted all that and come to the first convenience store.

Keep the first 5 lines of text (the unusual numbering scheme here is due to a process in SAS). Delete the intervening lines. This will make sense later when I process the Excel spreadsheet in SAS.

I find it helpful here to check to see if there are any intervening lines of text that should not be there.

When you're finished, save your work and make a note of the file location. Create a file for each province with the type of food retailer in the name. Then save the results under the school name

e.g.

F:\Ontario - Convenience Stores\Montcalm SS.xlsx

Step 5. Importing & Processing Data into SAS

```
PROC IMPORT OUT= WORK.test
        DATAFILE= "C:\Documents and Settings\Laura\My Documents\PhD
Thesis\Manuscripts 2 and 3\Ontario – Convenience Stores\Montcalm SS.xlsx"
        DBMS=EXCEL REPLACE;
    RANGE="Sheet1$";
    GETNAMES=NO;
    MIXED=NO;
    SCANTEXT=YES;
    USEDATE=YES;
    SCANTIME=YES;
RUN;
```

This is where you import the file you just created in Excel.

```
*creating a variable x1 numbering the lines from 0 to 4;
data new;
set test;
x1 = mod(_n_, 5);
run;
```

This is where I tell SAS to number the lines from 0 to 4.

```
*deleting the lines numbered 0, 2 and 4, and keeping lines 1 and 3 (=name/distance & address);
data new2;
set new;
if x1 = 0 then delete;
if x1 = 2 then delete;
if x1 = 4 then delete;
run;
```

Next, we only want lines 1 and 3 (food retailer name and address), so the above code deletes the other lines. The rest of the code in my SAS program is data management where I merge name and addresses together into 1 dataset and get rid of extra variables I no longer need.

The one problem with the address field as given from the yellow pages website is that the relevant info (street name, city, province, postal code) is separated by commas. I need each piece of information as its own variable. The code below accomplishes this.

```
data nameadd3;
set nameadd2;
delim=',';
street_name = scan(address,1,delim);
city = scan(address,2,delim);
prov = scan(address,3,delim);
post_code=scan(address,4,delim);
run;
```

Note: For schools in Quebec, I needed to add another field for street number because they are often separated by a comma from the street address. (e.g. Depanneur 7 Jours address: 8864, rue Centrale, Lasalle, QC, H8P1P4). I commented this out in the SAS code as well, and that code will be used instead of the above code in Quebec.

Finally, if everything is working properly in the SAS program, we can export our SAS file back into Excel. The code below does that. For naming the file to send it out, I created a file with the province name, two letter abbreviation for the food retailer type, followed by the word geocode. This is the file I will use to geocode in ArcGIS.

```
PROC EXPORT DATA= WORK.NAMEADDFINAL
        OUTFILE= "C:\Documents and Settings\Laura\My Documents\PhD Thesis\Manuscripts 2 and 3\Ontario CS geocode\Montcalm SS.xls"
        DBMS=EXCEL LABEL REPLACE;
    SHEET="5km CS";
RUN;
```

Open the new excel file you have created, and you will need to do a few things

- Rename the F1 column as ‘name’. For whatever reason, I could not properly rename it in SAS

- Check for duplicate entries for food retailers. Delete any duplicates you come across (duplicate = same address & postal code, same or very similar names).

- Some postal codes may be missing from some retailers. Look up the food retailer address from the food retailer’s website. If that doesn’t work, use Canada Post’s online postal code finder (www.canadapost.ca).

- Check to see if some entries have mall/shopping plaza addresses. If they do, look up the street address of the mall/shopping plaza online and put that in the spreadsheet instead.

When you’re finished, save your changes and start the next school

GEOCODING INSTRUCTIONS

General concepts for ArcGIS

- Working with layers. Need to be in a logical order, starting with land and water at the bottom, street layer next, and school on top.

- Can drag layers to change their order, change colours (right mouse click) and shape (left mouse click) and turn them off and on using the checkboxes.

- If you ever get lost somewhere in the map, right click the 5 km circular buffer layer and select 'Zoom to Layer'

Step 1: Adding the appropriate layers to ArcGIS

i) Map Layers

You will find the layers stored in a similar way for each school. For example, for school number 388, which is Gleneagle Secondary School, located in Coquitlam, BC. Work with the data in the Projected folder only.

E:\PhD Thesis\Manuscripts 2 and 3\5 km buffers\BC schools\388 Gleneagle SS\Projected

For this step, I have created the map layers that you will need. The layers that you will be using are:

- school
- roads
- water (if appropriate)
- 5 km buffer (edu_123), where 123 is the school ID number

You will need to add the layers mentioned above using the 'Add Data' button and change the colours as appropriate. Hold down the 'Ctrl' button to select multiple layers at the same time.

ii) Food Retailer Addresses

The default view of the far left window in ArcGIS is the 'Display' view. To add the spreadsheet information to the map, switch to the 'Source' tab.

Add in the spreadsheet with addresses for each food retailer type (coffee donuts, convenience stores, limited service using the 'Add Data' button as you did for the map layers.

Step 2: Geocoding the Addresses

Go to Tools → Geocoding → Geocode Addresses

A box will come up, prompting to you to select an Address Locator. This will be found in the files Andrei put on your computer using the large USB device.

Go to the CanStreets file, and navigate your way to the provincial street file. The last 2 files you'll go to are the province folder and the street folder. The address locator is the two letter province followed by 'rte'. E.g. for British Columbia roads, the Address Locator is BCrte. You'll only need to do this for the first food retailer type you geocode.

Click OK. A dialog box like this will then come up:

- Click the name of table you wish to geocode (coffee donuts in this example)

- Select 'street_name' for the 'Street or Intersection' box. 'City' should already be selected.

- Choose a name for the resulting layer within the 'Projected' file of the school you are geocoding: 'coffee donuts', 'convenience stores' or 'limited service'.

- Click on the Advanced Geometry Options button and switch from the 'Use the address locator's spatial reference' (top option) to 'Use the map's spatial reference' (middle option). When you're done, click OK

Always click 'Rematch' when you receive the summary box.

To determine if the addresses have been geocoded adequately, you will need to check by clicking the 'Rematch button'. The Match Score is provided in the Interactive Rematch box below. The match score is a rating out of 100, with 100 indicating a perfect match. Scores above 80 will be deemed adequate for the purposes of my study.

Step 3: Fixing Unmatched Addresses:

There are 4 problems that usually arise when geocoding addresses.

<u>Problem #1: Municipality does not correspond to one given in the address.</u>

This is usually an issue with larger cities. For example, a street address from the Yellow Pages might be given as 'Toronto', but in the road network layer, the street address corresponds to a smaller municipality such as Etobicoke, Mississauga, Vaughan, etc.

To fix this, right click on the road layer and select 'Open Attribute Table'. A spreadsheet should come up listing all the streets. To sort them alphabetically, right click on the column with the street name and select 'Sort Ascending'. Scroll through the list until you find the street name in question. Look at the nearby municipality and if this differs from the one circled in red in the address rematcher. If it is different, type the correct municipality in the Zone box, and hit the search button at the bottom of the rematcher. If a match comes up with a score of 80 or above, then select it and hit the 'Match' button.

Problem #2: Yellow Pages Street address Number out of Range of the Geocoder

This is by far the most common source of unmatched addresses. The address geocoder for the road networks is almost always incomplete. For example, say you have an address of 160 Main Street, but the road network only has addresses locations available for 100 – 120 Main Street. Although 160 Main Street is a completely valid address, it won't geocode properly. Instead, the address matcher will pick the closest address it can find, and then assign it a score usually in the mid 60 range.

To get a more precise location, we will need to use Google Earth:

- Type in the unmatched address in the 'Fly to' box of Google Earth. This will centre your screen over the address you're looking for

- Go to the Add menu bar and select Placemark. This will give you the Latitude and Longitude coordinates of the address.

- We will be cutting and pasting the Latitude and Longitude coordinates into ArcGIS. **NOTE**: The order of the latitude/longitude coordinates are the opposite in ArcGIS and Google Earth, so ensure you cut and paste in the correct order. Degrees West are first in ArcGIS.

- To cut and paste the coordinates into ArcGIS, go to the XY box on the top menu bar in ArcGIS

Press the blue bull's eye button to put a point on that address on your map, and then select the magnifying glass to zoom to it. I also like to use the dialog box (the one with XY in the square box) to type in the address of this point in case the same address comes up later (i.e. a plaza with multiple food retailers). Use the black arrow on the upper menu bar to double click to edit the contents of the dialog box to change it from lat/long to a street address).

Bring up the Interactive Match dialog box again with the address you looked up highlighted in bright blue and select the 'Pick Address from Map' button (shown on the next page). Right click the location you marked with the XY coordinates button.

Problem #3: Ties

Sometimes there will be a tie in address candidates, and 2 candidates will appear nearly identical in the Candidate list box. In this case, use Google Earth to find the address. Select the candidates one at a time in ArcGIS, and click the Zoom to Candidates button (just to the left of the 'Pick Address from Map' button). Choose the location that matches most closely to what you see in Google Earth. These locations are usually quite close together.

Problem #4: Numbered Streets

For some reason, the address locator does not recognize numbered street names (i.e. 450 9th Street). Andrei is working on fixing this. For now, I am not going to geocode addresses where this is a predominant street address type (i.e. Alberta), but for the few streets like this that come up, treat it as you would for problem #2 I outlined above.
Miscellaneous tips:

1. ArcGIS always goes to the last folder you were working in. When you start geocoding for the next school, make sure your new layer is saved in the CORRECT folder

2. When you’re finished geocoding and want to work with the next map, ArcGIS will ask you to if you want to save your map as a .mxd file. You can go ahead and do this if you want to access the map on your own computer. However, when I put the files on my computer, I will be adding the layers (school, water, roads, buffer, food retailers) individually and those are always saved properly regardless if the map is saved as a .mxd file or not.

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APPENDIX G

Power and Sample Size

Manuscript 1

A priori sample size calculations were carried out in the planning stages of this study using the tabulations for screening tests provided by Flahault et al. [1]. Estimated sensitivity values were based on the relatively conservative findings reported by Paquet et al. [2]. An expected sensitivity of 0.70 was chosen for the online food retailer database, with a lower acceptable confidence value of 0.60. For the commercial database, the expected sensitivity was 0.85, and a lower acceptable confidence value of 0.75 was selected. Power was set at 80% and the alpha value was equal to 0.05. The table below compares the target sample size and the actual sample size.

Table. Comparison of the actual versus required sample sizes for Manuscript 1

Database	Full Service (N)	Fast Food (N)	Convenience (N)	Total (N)	Required (N)
Online	368	140	87	**595**	**248**
Commercial	338	326	85	**749**	**176**

Although the required sample sizes were not met for the individual food retailer types, the total sample size for the total number of food retailers exceeded those suggested by the sample size estimates.

Manuscript 2

The *a priori* sample size calculation for this study was based on the presence or absence of food retailers within approximately 1 km of schools. Studies have found that at this distance, food retailer exposure ranged from 30 percent [3] to 58 percent [4]. Based on this range, an exposure prevalence of 50% was used in the sample size calculation. At the time the sample size calculation was carried out, the available literature suggested there were relatively modest associations between the food retail environment and obesity outcomes, with odds ratios ranging from 1.07 [5] to 1.30 [6]. Therefore, an estimated odds ratio of 1.20 was used, along with 80% power and an alpha value of 0.05. The initial sample size calculated for this study was 2,844. However, due to the clustered nature of the data, a design effect of 1.4 for the HBSC was used to inflate the required sample size to 3,982 [7]. The sample size of 6,971 obtained in the second manuscript demonstrated that the study was adequately powered.

It is important to note that when this study was carried out, having four exposure groups rather than a dichotomous exposure may have influenced study power. However, the magnitude of the relationships was also stronger than expected. Therefore, *a posteriori* calculations were conducted to verify that sufficient study power was obtained. For the 1 km road network buffers, study power was 65.9%. It increased and it increased to over 99% for the 3 to 4, and $\geq$ 5 food retailer exposure categories. For the circular buffers, study power was 2.6% for the 1 to 2 food retailer exposure category, 91.8% for the 3 to 4 food retailer exposure category, to >99.9% for the $\geq$ 5 food retailer exposure group.

Manuscript 3

For the third manuscript, it was expected that associations between food retailers surrounding schools and students' eating behaviours would not be strong for buffer sizes greater than 1 km. For the distances of 500 m, 750 m and 1 km, the prevalence of exposure to all food retailer types was estimated to be 20, 30 and 50 percent, respectively. Incorporating the same power, alpha values and design effect as the second manuscript, the sample sizes obtained ranged from 3,982 to 5,572. For the larger distances, exposure was anticipated to be measured in quartiles, rather than a dichotomous exposure and the required sample size was calculated to be 5,688.

The primary objective of this manuscript was to determine the optimal buffer size rather than to demonstrate etiological associations. Therefore, it was expected that associations between the presence of food retailers and eating behaviour outcomes would be weak to non-existent for distances greater than 1 km. Furthermore, at the smallest distances, there may not have been a sufficient number of food retailers present to demonstrate an association. Since it was determined that there was adequate power for the *a posteriori* calculations for the 1 km network distance, a lack of power to detect associations with the largest and smallest buffer sizes is not a concern and therefore *a posteriori* calculations were not conducted.

Manuscript 4

In the planning stages of this study, an expected odds ratio of 1.2 was used, which corresponded to the associations between urban sprawl and obesity in American youth found by Ewing et al. [8]. The prevalence of overweight and obesity included in the sample size calculation was 25%, which corresponded to the levels found in Canadian youth [9]. Exposure to urban sprawl was expected to be in tertiles. The initial sample size calculated with power set at 80% and an alpha value of 0.05 was 4,266. However, the design effect was not taken into account because the issue of clustering was not immediately apparent. However, because of the complex sampling design used for the 2007-2008 CCHS, a design effect of 2.25 required for the sample size calculation [10], and resulted in a final sample size of 9,600. Since only 7,017 participants were included in the study, it is clear that there may be insufficient study power in this manuscript.

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