ACTIVE TRANSPORTATION TO SCHOOL AMONG CANADIAN YOUTH: AN EXPLORATION OF CORRELATES AND ASSOCIATED INJURY

by

Kathleen Mary Gropp

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Abstract

Background: Active transportation refers to methods of travel that involve physical activity, such as walking and bicycling. For students, characteristics of both individual and contextual environments are likely associated with active transportation to school. Furthermore, injury is one possible but overlooked outcome of active transportation to school.

Objectives: To examine among urban Canadian youth in grades 6-10: 1) associations between individual- and area-level factors and active transportation to school and 2) the relationship between active transportation to school and active transportation injury.

Methods: Individual-level data were obtained from the 2009/2010 Canadian Health Behaviour in School-Aged Children (HBSC) survey. Active transportation to school was measured via student's report of their usual method of travel to school. Active transportation injury was assessed via self-report for a one-year recall period. Area-level data were obtained from a school administrators' survey and from various geographical sources. Multi-level logistic regression was used to examine the associations of interest.

Results: Multiple correlates of active transportation to school were identified from the individual/family, school, and neighbourhood. Correlates possessing a potential for intervention and a relatively high population impact were identified: gender (female: relative risk, RR=0.86, 95% CI: 0.80-0.91, population attributable risk, PAR: 7.1%), perception of neighbourhood safety (disagree *vs.* strongly agree: RR=0.83, 95% CI: 0.70-0.95, PAR: 2.3%), percentage of roads with sidewalks (quartile 3 *vs.* quartile 1: RR=1.17, 95% CI: 0.96-1.34, PAR: 9.5%), and the total length of streets (quartile 4 *vs*. quartile 1: RR=1.23, 95% CI: 1.00-1.42, PAR: 6.9%). A positive association between active transportation to school and active transportation injury was identified; the risk for injury increased as walking or bicycling increased (short distance: OR=1.17, 95% CI: 0.92-1.50; long distance: OR=1.56, 95% CI: 1.10-2.21).

Conclusions: Many factors are associated with active transportation to school. While active transportation is associated with the potential for improved health, it also likely increases the risk for active transportation injuries. Interventions to increase active transportation to school should also consider potential negative outcomes. Future studies in this research area could focus on qualitative measures of the environment and school programs, in addition to the etiology of injuries experienced during school travel.

Co-Authorship

This thesis is the work of Kathleen Gropp under the supervision of Dr. William Pickett and Dr. Ian Janssen. The idea to use the HBSC survey to investigate the correlates of active transportation to school and injury as an outcome of active transportation to school was a collaborative effort between the three authors. The collection of geographic data was coordinated by Dr. Ian Janssen and Andrei Rosu (GIS Technician, Queen's University). The collection of HBSC data in Canada was coordinated by Matthew King, while Dr. William Pickett and Dr. John Freeman were the principal investigators.

Kathleen Gropp performed the primary statistical analyses, interpretation of results, writing of the thesis chapters, and a portion of the geographic data collection. Both Dr. Pickett and Dr. Janssen revised this thesis and its associated papers extensively.

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Third, I want to thank my classmates that that were around every step of the way and making my graduate experience very memorable. I especially want to thank my lab mates for their support, thoughts, and sense of humour. I believe very few people enter their work/learning place expecting to make forts, learn how to do cryptic crosswords, organize and participate in a 26.2 metre ‘fun run for the cure and other good stuff’, learn the importance of locking your computer when away, and make lifelong friends.

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List of Abbreviations

CI – Confidence Interval

IQR – Interquartile Range

ENACT – Nutrition and Activity (program)

GIS – Geographic Information Systems

HBSC – Health Behaviour in School-Aged Children

ICC – Intra-class Correlation

IR – Incidence Rate

LEAP – Lifestyle Education for Activity Program

OR – Odds Ratio

PAR – Population Attributable Risk

RR – Relative Risk

SES – Socio-Economic Status

Chapter 1

General Introduction

1.1 General Overview

Active transportation refers to modes of travel that involve physical activity such as brisk walking and cycling.[1,2] For children, walking to school has historically been a common source of active transportation. However, the percentages of school-aged children that walk or cycle to school are decreasing.[3,4]

In general, school-aged children engage in far less physical activity than the current national public health recommendation of a daily minimum of 60 minutes of moderate to vigorous activity.[1] It is possible that the recent decline in walking and biking to school may contribute to the low overall physical activity levels in child populations.[5] Indeed, children that walk or bicycle to school have higher cardiorespiratory fitness levels,[6] healthier body compositions,[6] higher amounts of physical activity,[7] and are also more likely to use active transportation to destinations other than school.[7] In addition to the personal health benefits, active transportation also reduces traffic congestion and pollution,[2] and could possibly reduce family and school expenditures on gasoline and bussing.

Characteristics of the individual and their family, school, and neighbourhood are potential determinants of active transportation within populations of children. Individual and family factors associated with active transportation to school include living in close proximity to school,[8-11] male gender,[8,11-13] and a non-traditional family structure.[14] There is little information on which characteristics of the school are related to active transportation, however, students who attend public school are more likely to report engaging in active transportation to school compared to those that attending private school.[11,15] Neighbourhood factors associated with active transportation to school include living in densely populated areas[16] and the presence of sidewalks in the school neighbourhood.[12,15,17-19] Existing studies on this topic have generally been conducted within small geographic areas[8,10,12,18,20,21] and have not focused simultaneously on all factors at the various levels.[8-10,12,19,20,22-26]

Studies of active transportation in school-aged children have focused on its positive contributions to the maintenance of a healthy body weight and overall physical activity[27] however, negative effects of active transportation are also possible. One such effect is unintentional injury. Injury is the leading cause of death in youth after the age of one, accounting for more deaths in children than all other causes combined.[28] There is considerable interest in the promotion of active transportation as a source of physical activity for children. In order to create sound policy around active transportation to school, society needs to understand its benefits and potential harms, one of which is injury. Studying injury as an outcome of active transportation to school could help to determine the etiology of the injury (e.g., caused by traffic, violence, poor infrastructure). A further understanding may also alleviate the safety concerns of parents of school-aged children when the negative outcomes can be compared to negative outcomes of other activities.

1.2 Focus of this Thesis

This thesis has two study arms that are related thematically. The first arm examines potential correlates of active transportation among populations of young people in Canada. This arm addresses a recognized gap in the existing biomedical literature, in that few comprehensive and population-based analyses have been conducted to describe factors that contribute to the engagement of students in this type of physical activity. The second arm of this thesis quantifies one potential negative health consequence of active transportation to school in urban environments, that being injury.

Two manuscripts were produced in this thesis, one per study arm. These were organized conceptually around the framework described in **Figure 1-1**. The first manuscript was a full research article that employed a descriptive approach. In this article, I examined factors associated with decisions to engage in active transportation to school (as per the left side of the conceptual framework, **Figure 1-1**). This manuscript has been accepted, pending revisions in the *International Journal of Behavioural Nutrition and Physical Activity*. The second manuscript focused specifically on the relationship between active transportation to school and injuries that occur in such environments (as per the right side of the conceptual framework, **Figure 1-1**). This manuscript is written in short report format, and has been accepted, pending revisions, in *Injury Prevention (BMJ Publications)*. The manuscripts attempt a more thorough understanding of the correlates and outcomes of active transportation to school.

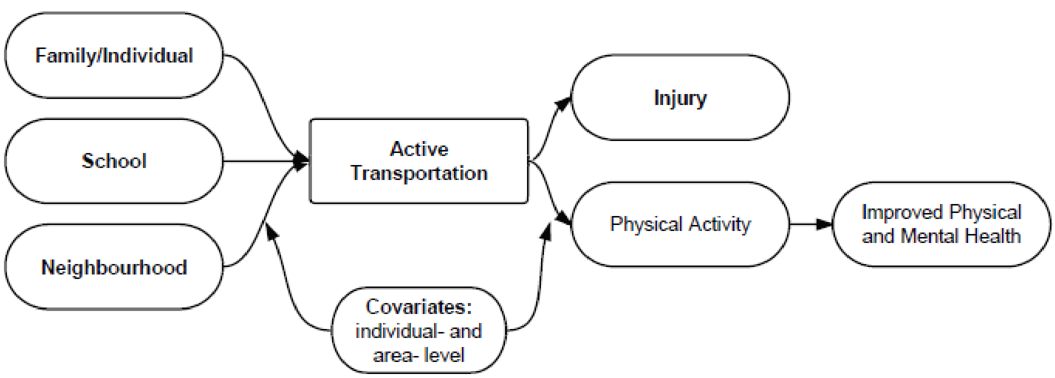

Figure 1-1 Conceptual framework of thesis

Manuscript 1 (left side) examines characteristics of the family/individual, school and neighbourhood that are correlated with active transportation to school among school-aged children. Manuscript 2 (right side) examines one potential negative consequence of active transportation, that being injury associated with such physical activity practices.

1.3 Study Purpose and Population

The objective of this thesis research was to investigate the determinants and outcomes of active transportation to school among Canadian youth in grades 6 to 10. I had the opportunity to examine this association using a large national data set, the 2009/2010 Canadian HBSC. This survey cycle included reported health behaviours for 26 078 Canadian students from 436 schools, across the provinces and territories (with the exception of New Brunswick and Prince Edward Island). I was able to link the individual student surveys to area-level data obtained from school administrator surveys and various geographical information systems (GIS) sources.

1.4 Objectives and Hypotheses

1. In a descriptive and hypothesis-generating analysis, I examined the associations between aspects of the individual and family (*demographics, the number of vehicles per household, distance to school*, *family structure*, *perceived safety of the neighbourhood*), school (*active transportation programs, the availability of bicycle facilities*), and neighbourhood environments (*sidewalks, road types, street connectivity, road lengths, speed limits, and regional climate*) and active transportation to school among urban Canadian youth living in proximity to that school. The purpose of this analysis was to identify which aspects of the individual and area levels are most strongly associated with active transportation to school. This research could set the stage for a more definitive etiological analysis. As this manuscript is descriptive and exploratory in nature, no *a priori* hypotheses were assumed.

2. In an etiological analysis, I examined the focal association between active transportation to school and injury among Canadian youth. I hypothesized that active transportation was associated with an increase in related injury, although most likely few and minor in nature, and that features of the individual and neighbourhood environment, particularly safety features, may confound or modify this relationship.

1.5 Scientific Importance

Potential determinants, or correlates, of active transportation to school are not well established. In addition, the association between regular active transportation to school and its possible negative effects in terms of injury has not yet been examined. Furthermore, Canadian research in this field of study is lacking, while such studies are stated priorities of the Canadian Institute of Health Research (CIHR)[29] and the Heart and Stroke Foundation.[30] This thesis aims to fill these gaps in the literature by 1) using an existing national survey to conduct a large-scale study of this issue; 2) examining multiple determinants from different conceptual levels simultaneously (using multi-level logistic modeling); and 3) examining factors and associations that are, as of yet, unstudied.

1.6 Public Health Importance

Many of the correlates of active transportation to school are modifiable, such as school policies, and sidewalk infrastructure. Information from this thesis may help to inform the content of targeted interventions and policies that can be implemented in order to increase safe active transportation to school. This may lead to an increase in overall physical activity and a reduction in injury related to active transportation. These results will be relevant to officials both in public health and urban planning and directors of schools and school boards. Even if only small effect estimates are calculated in this sample, there could still be a wide impact on the entire population of school-aged children. For example, the population attributable risk (PAR) likely remains high for built environment correlates of active transportation to school; even with small effects, the prevalence of common exposures remains high and can affect many individuals (e.g. all students attending a particular school, or living in a certain city or town).

A further understanding of the negative outcomes of active transportation to school may help alleviate parental concerns of safety. Addressing these concerns, such as injury (whether trips or falls, or motor vehicle collisions), bullying, crime, abductions, and comparing these risks to the benefits of active transportation to school would be beneficial and has not yet been accomplished. The injury portion of this thesis begins to address this issue.

1.7 Thesis Organization

This thesis conforms to the guidelines and recommendations for a manuscript-based thesis as per the "General Forms of Theses" published by the Queen's School of Graduate Studies and Ressearch.[31] This first chapter is a general introduction to the subject areas of this thesis. The second chapter summarizes current literature examining the determinants and outcomes of active transportation to school and injury in the street as an outcome related to active transportation to school. The third chapter is composed of the first manuscript: a descriptive, exploratory analysis of the correlates of active transportation to school among urban Canadian youth. The fourth chapter is the second manuscript, a brief report examining the relationship between active transportation to school and injuries occurring in the street among Canadian youth. The fifth chapter consists of a summary of the findings, a general discussion, and conclusions. A series of appendices are attached that contain additional information regarding the study methodology.

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Chapter 2

Literature Review

2.1 General Overview

This chapter has two purposes: (1) to discuss the existing evidence surrounding potential factors (characteristics of the individual and family, school, and neighbourhood) that may be correlated with active transportation to school among Canadian youth; and (2) to further examine evidence surrounding one potential negative outcome of active transportation, that being injuries.

This literature review begins by describing the key terms and constructs used in this thesis, followed by a brief explanation of the importance of studying active transportation to school. The next two sections discuss literature describing (1) correlates of active transportation to school, and (2) injuries as an outcome of active transportation to school. Next, the potential application of research in this area to development of the content of public health interventions is discussed. The review then concludes with a summary of the literature and a rationale for the thesis.

The following search strategy was used to identify important literature for each of the two study foci. Studies published as recent as January 2012 were identified using the OvidSP/Medline database and search tools. In the searches for research surrounding the correlates of active transportation to school, “schools,” “walking,” and “bicycling” were included in combination with one of “child,” “youth,” or “adolescent”. In order to search for studies examining active transportation injuries, the search terms included “school,” “transportation,” and “injury” in combination. Additional studies were identified by examining reference lists of the studies obtained through the OVIDSP/Medline database and through Google searches for potential school-based interventions for active transportation to school (e.g., identification of safe transportation routes, the walking school bus).

2.2 Definitions of Key Terms

Several key terms are central to this thesis. *Active transportation to school* is the engagement in different forms of physical activity (e.g., walking, cycling) in order to travel from home to school.[1] The WHO defines *injury* as the physical damage that results from sudden or brief intolerable levels of energy (including mechanical, radiant, thermal, electrical, and chemical); this definition excludes chronic stress injuries.[2] An *active transportation injury* is operationally defined as an injury that is obtained while engaged in the act of active transportation. A *walking school bus* is an intervention to promote active transportation to school. A walking school bus involves at least two adult volunteers that walk along a designated route to school, with regular stops along the route that function as regular bus stops. Children join the walking school bus from the designated stops, allowing them to walk to school in a supervised environment.[3] *Geographic information systems (GIS)* refer to software and hardware used to capture and analyze spatial information.[4] The *built environment* includes the man-made structures in communities, including structures such as homes, neighbourhoods, schools, road networks, and commercial areas.[5] Throughout this thesis, reference will be made to both individual- and area-level factors that potentially affect decisions to engage in active transportation. *Individual-level* factors are those that are measured on an individual basis (e.g., gender, age), while *area-level* factors (sometimes called contextual factors) are measured on a group basis (e.g., climate, school policy, neighbourhood built environment). *Street connectivity* refers to the directness of a route from point A to point B and can be measured with variables such as intersection density and average block length.[6] Throughout this thesis, different terms such as youth, adolescents, school-aged children, and young people are used interchangeably to refer to individuals attending grades 6 to 10 (approximately aged 11-15 years in Canada). For manuscript 1, an odds ratio >1 indicates a potential positive relationship with active transportation to school (e.g., active transportation increases), whereas an odds ratio <1 indicates a negative relationship with active transportation to school. For manuscript 2, an odds ratio >1 is indicative of a risk for injury, whereas an odds ratio <1 indicates a protective effect against the occurrence of injury.

2.3 Importance of Studying Active Transportation to School

Active transportation to school (e.g., walking and bicycling) is a source of physical activity for youth.[7] It incorporates forms of moderate intensity physical activity and places them in a context with purpose and routine. A recent systematic review suggests that students who engage in such forms of transportation to school have healthier body compositions and higher cardiorespiratory fitness levels.[8] In addition, those who walk or bicycle to school are also more likely to walk or bicycle to other destinations as well.[9] This is important, as physical activity helps protect against obesity and its related physiological impacts.[10]

The rates of active transportation to school have decreased in recent decades. In the greater Toronto area, rates fell from 53% in 1986 to 43% in 2006.[11] Steeper declines have been reported in the United States, from 42% in 1960 to 16.2% in 2000.[12] A more recent study using 2009 survey data found that 47% of elementary students and 23% of high school students engaged in active transportation to school in Ontario.[13] This downward trend of walking and bicycling to school may have contributed to the similar downward trend in the overall physical activity levels of children.[14]

2.4 Correlates of Active Transportation to School

There are many potential correlates of active transportation to school. Because this thesis research and much of the existing literature have utilized cross-sectional analyses, I have referred to these potential determinants as "correlates" due to the lack of confirmation of the temporal direction of the relationships under study. This research also involves a population health approach, which recognizes that determinants of health operate at both individual- and area-levels.[15] Correlates of active transportation to school have been identified at multiple levels, although rarely have characteristics of the individual and their contexts (e.g., family, school, and neighbourhood) been examined simultaneously in a single analysis. The risk estimates provided in prose typically refer to fully-adjusted odds ratios from models considering multiple correlates of active transportation to school. The summary charts only consider the fully-adjusted odds ratios. Correlates of the individual and family will be reviewed initially, followed by evidence surrounding contextual factors in schools and neighbourhoods.

2.4.1 Individual and Family Characteristics

2.4.1.1 Distance and Travel Time

Within the existing literature, the distance between home and school has consistently been identified as a strong correlate of active transportation to school.[13,16-28] A cross-sectional study performed in California found that students living within 800 m of school were more likely to walk or bicycle to school than those that lived more that 3 200 m from school (OR=11.99, CI: 6.97-20.63); in addition, there was a dose-response relationship between distance and the categories of distance to school (including <800 m, 800 – 1 599 m, 1 600 – 3 199 m, and ≥3 200 m).[21] However, the magnitude of the effect of distance to school is likely to vary between different communities, as suggested by a cross-sectional study in Switzerland that found varying odds ratios for active transportation outcomes associated with distance to school across four different communities.[25] Reductions in the proportion of students that use active transportation to school in the United States have typically been attributed to increased commuting distances.[12] In addition, travel distance has been identified as the most common barrier to active transportation by parents of school-aged children.[29] Similar to the findings for travel distance, travel time also has a negative association with walking and bicycling to school.[28,30]

2.4.1.2 Demographic Information

Various demographic factors are correlated with the decisions to engage in active transportation to school. Race/ethnicity has been identified as a relatively consistent correlate of walking and bicycling to school in the United States; Caucasian students are less likely to engage in active transportation to school than students of other racial backgrounds.[16,17,21,31,32] To illustrate, Babey et al. found that students identified as Latino and of a mixed race were 37% more likely to walk to school and 71% more likely to bicycle to school.[21] Evenson et al. found that African Americans and 'other' races were more likely to walk or bicycle to school (middle school: OR = 4.29; 95% CI: 2.11-8,75; and high school: OR=2.76; 95% CI: 1.66-4.59). Both Baby et al. and Evenson et al. used Caucasian students as the referent category.[21,31] However, McDonald found the opposite association in a recent study of the trends of active transportation to school in the United States.[16] The birthplace of parents was included in the model, a variable that is likely to be related to the child's declared race. The resulting associations were opposite to those expected for race: African-American (OR=0.68; p=0.012) and Hispanic students (OR=0.77; p=0.025) were less likely to walk or bicycle to school than Caucasian students.[16] It is possible that differences in walking and bicycling in these groups of individuals may be attributed to socio-economic or cultural differences associated with parents that were not born in the United States. Supporting this theory that cultural differences may play a role in the decision to engage in active transportation, a Swiss study found differences in rates of active transportation to school between the German speaking and French speaking populations of the same town.[25]

The association between age, or grade level, and active transportation to school is less consistent across different populations. Many studies have identified a significant association; however, the effect estimates vary such that some studies find younger students more likely to engage in active transportation to school,[21,30,31,33] while others find that older students are more likely to do so.[16,17,22,25,27,32,34] The effect of age may itself be affected by differing school policies, the location of elementary, middle, and high schools, and the access to vehicles for older students. In addition, the referent group for age often differs amongst the studies, and it is possible that the relationship between age and active transportation to school is not linear. For example, Martin et al. (N = 7 433) included children ages 9 to 15 in their study of active transportation to school, revealing a U-shaped relationship: 12 and 13 year olds reported significantly more active transportation to school than did 9 year olds (12 years old: OR=1.45, 95% CI: 1.08-1.95; 13 year olds: OR=1.72, 95% CI: 1.27-2.33) with the rate of engagement decreasing across the 14 and 15 year age groups.[35]

Throughout the literature, young boys are reported to be more likely to walk or bicycle to school than young girls.[13,16,20,21,30,31,33,34,36] The effect estimates are relatively strong, and range up to an OR of 2.69 (95% CI: 1.63-4.43) for males compared to females.[36] McDonald et al. suggested that gender differences may be related to different aspects of safety, in particular "social control" which was defined as the "expectation that neighbourhood residents can and will intervene on behalf of children".[37] Findings showed that in neighbourhoods with low "social control", 30% of boys and 19% of girls engaged in active transportation to school, while in neighbourhoods with "high social control", 37% of boys and 38% of girls engaged.[37]

Most studies that have included a measurement of family income or socioeconomic status found that students from lower income households are more likely to engage in active transportation to school.[21,24,27,28,30,38] For example, Babey et al. reported that children in the United States from families with income less than 200% of the poverty threshold were more likely to use such methods of transport to school, compared to those with incomes greater than or equal to 200% of the poverty threshold (OR= 1.84, 95% CI = 1.41-2.41).[21] Silva et al. reported a similar relationship in Brazilian students; children from households with a higher income were more likely to use passive transportation (e.g., car, or bus) to get to school.[30] However, one American study found the opposite association, suggesting that students from households with an income greater than $100 000 per year engaged in more active transportation to school than those from a household with income less than $30 000 per year (OR=1.56, p=0.002).[16] These results differ from other studies by the same author; however, they all use the same data source. It is possible that the difference in risk estimate may be associated with the control for many other variables associated with family SES, more than other studies of the correlates of active transportation to school (e.g., the number of vehicles, the number of vehicle per driver, whether the household is rented, the presence of a homemaking adult, parental education, and the number of parents in the household).[16] Similar variables that are measures of family socio-economic status include parental education levels[13,16,31,33,35,39] and parental employment.[19,39] The relationships between these variables and active transportation to school in children are inconclusive, not standardized, and not as commonly investigated.

2.4.1.3 Family and Parental Characteristics

Measurements of the number of family members and family structure (e.g., number of siblings, number of parents, and parental marital status) are commonly included in studies of active transportation to school. The number of parents and parental marital status is not always included in final models of correlates of active transportation, due to removal for lack of statistical significance.[16,19,20,22] If there is a true association between the number of parents and marital status and active transportation to school, it is likely that children of single parents are more likely to do so than children with non-single parents. Babey et al. found that children from a family with no adult home after school are more likely to engage in active transportation to school (OR=1.77; 95% CI: 1.33-2.35)[21] and Fulton et al. found that children with parents that were currently unmarried were more likely to walk or bicycle to school (OR=4.3 95% CI: 1.8-10.0), a finding similar to that other studies.[35] This association may be attributable to the availability of parents to drive children to school. Studies that measure the number of siblings suggest a positive association with active transportation to school,[17,24,38] (e.g., 1 or more siblings vs. no siblings OR=1.14; 95% CI=1.04-1.25)[38] or that there is no association, or the variable is left out of the final model.[19,35]

Most studies that include the number of vehicles per household, vehicles per capita in the household, or vehicles per driver have identified no association, or do not include one of these variables in the final model due to lack of statistical significance.[16,17,19,20,22,24,27,32] However, there are two studies that found a negative association with family vehicle ownership and active transportation to school,[13,25] along with one of the final models from another study for walking to school.[28] To illustrate, Wong et al. found that elementary school students in Ontario that came from a home with a car were less likely to walk or bicycle to school (OR = 0.22; 95% CI: 0.08-0.61) when compared to those students from families without a car.[13]

Parental habits, such as the use of public transit, or the engagement in active transportation as correlates of active transportation to school are currently inconclusive. Findings from Merom et al. suggest that children's commuting habits may mirror that of their parents; compared to children with parents that do not work, those with parents who travel by car to work were less likely to walk or bicycle to school regularly (OR=0.68; 95% CI: 0.44-0.92).[22] In addition, children of parents that use other methods to get to work (e.g., walk, bicycle, bus) may be more likely to regularly walk or bicycle to school (OR=1.64; 95% CI: 0.99-2.75).[22] One other study investigated parental transportation habits, yet found no statistically significant association (OR=1.03; 95% CI: 0.83-1.29).[21]

2.4.1.4 Perceptions of Safety

Few studies have demonstrated a relationship between perceptions of neighbourhood safety and active transportation to school. Safety variables are mostly based on parental reports; however, there are a few studies that measure child perception of safety. Most of these analyses either show no association between perception of safety and active transportation to school,[19,21,25,33,40] or that there is a positive association with such modes of travel.[16,22,24] With further scrutiny, it is found that child perceptions of safety have less of an effect on active transportation to school than do parental perceptions of safety: half of the studies examining parental perceptions found a positive association with walking and bicycling to school.[16,19,21,22,24,25] An American study included parental concerns of crime, weather, and traffic/speed, and found no statistically significant association between concerns of crime and active transportation to school (OR=1.04; p=0.14), whereas there was a negative association between having concerns about weather (OR=0.90; $p<0.001$) and traffic/speed (OR=0.73; $p<0.001$) with relation to active transportation to school.[16] McDonald et al. found that gender differences in rates of active transportation to school did not differ in neighbourhoods with high “social control”, when compared to neighbourhoods with “low social control” where more boys walked or bicycled to school than girls.[37] This suggests that perception of safety may be a determinant of active transportation to school in females, but not males, or, that gender may be an effect modifier. However, Evenson et al. investigated many aspects of perceived safety in relation to active transportation to school in a sample of female school-aged children, and none of these measures were retained in the final model.[40] Variables such as whether it was safe to walk, jog, or ride a bike, whether one could be seen by others, traffic safety, crime, the presence of other children playing, the presence of loose dogs, and lighting in the neighbourhood were all investigated in relation to active transportation to school.[40] The association between perceived neighbourhood safety and active transportation to school is difficult to assess, as safety is a wide construct and may include many different aspects of the neighbourhood (e.g., traffic, strangers, lighting) and involves non-standardized measurements.

Overall, characteristics of the individual and family are the most understood as the correlates of active transportation to school. However, there are still several inconsistencies in the literature. As noted in **Table 2-1**, the relationship between age and active transportation to school is one of the most inconsistent correlates. Although more studies find a positive association between age and active transportation to school when included in a final model, four studies finding positive associations were performed by the same researcher, hence the results are likely to suffer from the same biases. A further understanding of age may be gained with future focus on wider age ranges. There are various measures of family SES that are examined in terms of walking and bicycling to school, and these measurements and their effects remain inconsistent across the literature. Despite the inconsistencies, there are several correlates that show more consistent and relatively strong relationships, such as distance to school or travel time and gender. In addition to the variables discussed in this section, some studies have measured behavioural attitudes as correlates. These were not thoroughly examined, as they are difficult to group together upon examination. Although some studies paint a clear picture between the covariates of the individual and family, many do not control for other aspects, such as characteristics of the school and the neighbourhood. Without controlling for these variables, there is likely to be residual confounding, masking the true relationships between the exposures and active transportation to school

2.4.2 School Characteristics

School-based measures are rarely included in studies examining possible determinants of active transportation to school. The type of school (e.g., private versus public) has been found to be a factor in both the United States and Australia. In Australia, students attending private school were less likely (OR=0.60; 95% CI: 0.37-0.96)[22] to be regular active commuters, while in the United States a similar relationship was found: students attending public schools were more likely to walk or cycle to school (OR=1.97; 95% CI: 1.27-3.07).[21] This association between school type and active transportation may reflect the relationship between family SES and active transportation to school, and not distance, as Merom et al. ruled out distance to school as a contributing factor of smaller rates of active transportation to school by private school students.[22] In addition, it is possible that this relationship may reflect school bussing policies and perhaps parental availability to drive children to school, or other parental habits.

The existence of an opposing school policy is likely to have a negative effect on active transportation to school (such as disallowing children to walk certain distances, or cross busier roads, by implementing bussing for those affected). This barrier was identified by 7% of parents of school-aged children in the United States.[29]

The institution of health promotion programs and policies are known to affect rates of active transportation to school. To illustrate, the *Safe Routes to School* program held at several schools in Marin County, California incorporated a number of school-based interventions to increase active transportation and carpooling as methods of school travel.[41] These interventions consisted of mapping safe routes to school, walk and/or bike to school days, a frequent rider miles contest, classroom education, "walking school buses" and "bike trains", newsletters and promotions, and finally presentations and networking at both the state and national levels.[41] Although this study did not include multivariate analyses, results showed increases in walking trips to school (64%), increases in bike trips (114%), increases in carpooling trips (91%), and a decline in the number of trips made by cars carrying only one student (39%).[41]

The effect of implementation of a walking school bus program was assessed in a quasi-experimental study in low-income urban settings in Seattle, WA.[42] The Seattle Public Schools and Feet First obtained funding to implement one program in an elementary school. This intervention school was compared to two control schools. However, the intervention school was not picked randomly and was based on "school readiness," referring to the support of the principal, staff, and parents to implement a walking school bus program. By the end of the 12 month follow-up period, the total number of students walking to the intervention school rose from 56 to 75 students, while the number of students walking to the control schools fell from 54 to 24 students ($p<0.0001$ by McNemar's test). This study suggests that the walking school bus program may help increase the number of students walking to school, but requires further confirmation from other studies, as the school sample size was very small (only 2 control schools and 1 intervention school), it did not control for any possible covariates, and assignment to control and intervention groups was biased.[42]

There is a large gap in the literature surrounding aspects of the school and active transportation to school, such that aspects of the school are rarely included in multivariate analyses determining the correlates of active transportation to school. This is reflected in **Table 2-2**, in comparison to **Table 2-1** and **Table 2-3**. In addition, of the studies that do include aspects of the school, none have been conducted in a Canadian setting. A further understanding of the association between characteristics of the school and active transportation to school, such as active transportation infrastructure (e.g., availability of bicycle racks, the presence of car- and bus-free zones around schools), and school programs (e.g., the walking school bus, the identification of safe routes to school, other campaigns, and even school bussing policies) would help direct interventions aiming to increase active transportation to school, and overall physical activity. Finally, there is a lack of control for school bussing policies across the literature examining active transportation to school; it is likely that some associations may be masked without the control for school bussing policy.

2.4.3 Neighbourhood Characteristics

A larger body of research has examined neighbourhood factors and how they correlate with active transportation to school. Most of these have focused upon different attributes of the built environment.[23] The built environment may impact people's lifestyles and physical activity behaviours,[43] and hence is a possible determinant of active transportation decisions. To illustrate, a well-connected trail system throughout a city may encourage people to bicycle or walk to destinations rather than driving. Standard measures of built environments include aspects such as geographic factors, types of street networks, and population density within communities.

Findings surrounding the importance of sidewalks in the neighbourhood are inconclusive with relation to active transportation to school. Several studies did not include this variable in a final model but solely examined the bivariate relationship, or there was no significant association in the final model.[20,24,26,28,40,44] However, Fulton et al. found that the presence of sidewalks in the neighbourhood compared to a lack of sidewalks (yes versus no) was associated with higher rates of active transportation to school (OR = 3.4 95% CI: 2.3-5.1).[33] In addition, Ewing et al. found that the average sidewalk coverage for origin and destination areas was the most important correlate of the built environment in their study with relation to active transportation to school (coefficient=1.48 from multinomial logistic regression).[28] To illustrate further, Boarnet et al. found that the increased availability of sidewalks was associated with higher participation in active transportation to school in California (e.g., 7 - 28% increase across five different schools).[45] Although there is some inconsistency, the true relationship between the presence of sidewalks and active transportation to school is likely positive.

Street connectivity is another variable with an inconsistent association with active transportation to school. Bungum et al. did find a positive association with “street connectedness,” or the number of intersections for a given geographic area, and active transportation to school. Students that attended the school in the area with the highest connectedness were more likely to engage in active transportation than students at the other three schools (OR=2.08, 95% CI: 1.19-3.65).[36] Similarly, Schlossberg et al. measured a variety of factors associated with street connectivity including intersection density, dead end density, and route directness.[18] Although a high dead end density was the only statistically significant variable (OR=0.37 $p<0.05$), the associations with the other measurements of street connectivity suggest a positive association as well.[18] In contrast, Timperio et al. objectively measured the directness of the route to school; students with a direct route to school were less likely to walk or bicycle to school (OR=0.70 95% CI: 0.50-0.98), compared to those that had an indirect route to school.[19] Further examples of street connectivity can be drawn from the physical activity literature. Mecredy et al. found that lower street connectivity was associated with higher levels of physical activity in school-aged children (quartile 4 versus quartile 1 OR=1.21; 95% CI: 1.09-1.34).[46] One of the possible reasons for the inconsistency across the literature may be the method by which street connectivity is measured and whether it is measured objectively or subjectively. Street connectivity has been measured objectively using measures such as average block length, intersection density, and connected node ratio, and subjectively through survey questions inquiring about the degree of the street connectedness in the neighbourhood. Due to the inconsistencies, the relationship between street connectivity and active transportation to school warrants further study.

The effect of neighbourhood aesthetics has been investigated in a limited number of studies. Larsen et al. found that students who had more trees along their route to school (within 5 meters of the street edge) were more likely to engage in active transportation to school (OR=1.30 95% CI: 1.03-1.63). However, Evenson et al. measured several aspects of neighbourhood aesthetics in environments affecting school-aged girls; the presence of trees and garbage had no effect on active transportation to school, but girls who disagreed that their route to school was "smelly" also reported less active transportation to school (OR= 0.42 95% CI: 0.24-0.75) than those who agreed that the route to school was "smelly".[40] The presence of trees along the route to school, was also left out of the final model by Dalton et al.[47] The relationship between neighbourhood aesthetics and active transportation to school may be related to other variables, such as neighbourhood SES, and urbanicity.

Road danger was identified as a barrier to active transportation to school in 40% of a national sample of US parents.[29] To illustrate, the need to cross streets with speed limits higher than 30 miles per hour (~50 km/h) in order to get to school reduces the likelihood that children will engage in active transportation (OR=0.36; p=0.002).[24] However, the consistency of the effects of road busyness tend to differ based on whether measures are objective or subjective. Most measures of subjective road danger and busyness show a negative relationship with active transportation to school,[16,19,22] whereas studies including objective measures of the road report inconsistent associations between road busyness and active transportation to school.[19,25,26] These inconsistencies are likely due to road danger/busyness being related to more urban areas, as urbanicity has been shown to be associated with active transportation to school.[13,16,21,30,33-35]

The urbanicity of the school's location is commonly associated with active transportation to school; those who attend schools in urban communities are more likely to actively commute to school.[13,16,21,33,34] There appears to be a consistent trend of participation in active transportation across the levels of urbanicity, with the lowest amounts of active transportation in rural areas, followed by suburban areas, with the most walking and bicycling to school occurring in urban areas even while controlling for distance to school. To illustrate, Babey et al. found that those students attending school in suburban areas and rural areas were less likely to walk or bicycle to school than those living in urban areas (suburban: OR=0.69, 95% CI: 0.52-0.91; rural: OR=0.58, 95% CI: 0.43-0.79).[21] Many other measures of the built environment are tied to urbanicity, such as road density, intersection density, traffic volumes, speed limits, and prevalence of sidewalks. An investigation of the correlates of active transportation performed only in rural communities found that factors associated with urbanicity were still associated with active transportation to school (e.g., building continuity and residential housing density).[47]

Area-level SES has been investigated as a correlate of active transportation to school in several studies. When area-level SES is included in a final model that controls for other correlates of the individual- and area-levels, there typically is a positive association with active transportation to school. Panter et al. in the UK found that students living in the most deprived neighbourhoods were less likely to walk to school than those living in the least deprived neighbourhoods (quartile 4 versus quartile 1: OR=0.45, 95% CI: 0.29-0.70) with a similar relationship for bicycling to school.[26] Timperio et al. in Australia did not have statistically significant findings of this association, but found similar effect estimates: those living in neighbourhoods with a higher SES were more likely to engage in active transportation to school (medium *vs.* low SES: OR=1.3, 95% CI: 0.8-2.1; high SES: OR=1.5, 95% CI: 0.8-3.0).[19] Measures of neighbourhood SES, such as educational attainment of adults and median household income have been studied in relation to active transportation to school in London, Ontario, however, these variables were left out of the final model due to lack of statistical significance.[20] The association between area-level SES and active transportation to school is possibly related to other measurements of the neighbourhood, such as neighbourhood aesthetics, perceived safety, and parental employment.

Other variables are likely to have a positive association with active transportation to school at the neighbourhood level including higher road density (highest versus lowest quartile: OR=3.22, 95% CI: 2.09-4.94),[26] higher population density,[17,27] and more land-use mix.[20,24] Some of these variables have rarely been studied, have inconsistent relationships across the literature, or have not been included in final models due to lack of statistical significance.

Climate and weather are potential correlates of active transportation to school, with rainfall, snowfall, extreme heat, or extreme cold being possible limiting factors.[48] However, few studies investigate the effect of climate on active transportation to school. The lack of interest in climate measures is likely due to the limited geographic focus of most studies (i.e., most studies are conducted within a single city), leading to a lack of variation in climate. Adverse weather conditions were reported by 24% of parents of school-aged children in the United States as a barrier to active transportation to school.[29] In addition, McDonald et al. found that in the United States, parental reports of concern about weather was associated with less walking and bicycling to school (OR=0.90 $p<0.001$).[16] Robertson-Wilson et al. did investigate the association between objective measures of the weather and active transportation to school.[34] There was no statistically significant difference in active transportation to school across the fall, winter, and spring seasons, across the tertiles of average temperature, and across the tertiles of days of precipitation.[34]

Although this relationship was not statistically significant, there may be a trend across the tertiles of average temperature, suggesting a lower average temperature in the United States may be associated with more active transportation to school (urban: mid tertile versus lowest tertile OR=1.44, 95% CI: 0.24-8.46; highest tertile versus lowest tertile=2.24, 95% CI: 0.80-6.28).[34] It is possible that this relationship may vary in Canada, due to the differing climate.

When compared to correlates of active transportation to school at the school level, the neighbourhood level is more thoroughly researched. However, there are several inconsistencies, as can be seen in **Table 2-3**. Studies that have measured aspects of weather and climate with relation to active transportation to school have found no effect. However, climate and weather have not been examined in the Canadian context with active transportation to school, and as there is a difference between Canadian and American climates, there is likely to be some effect. There are also gaps in the literature surrounding aspects of neighbourhood aesthetics as correlates. Neighbourhood aesthetics that have been examined most thoroughly are the presence of trees. The presence of litter or garbage has only been included in one study of active transportation to school in female school-aged children, and other measures of aesthetics, such as graffiti and vacant housing or buildings have not been investigated. In addition, most investigations of the correlates of active transportation to school have included quantitative measures of the environment, but have not included qualitative measurements. For example, the presence of sidewalks is commonly studied as a correlate of active transportation to school, but as of yet, no study has investigated the relationship between the quality of sidewalks and walking to school.

2.4.3.1 Measuring the Built Environment

Most of the measures of the road environment can be obtained three different ways; using Geographical Information Systems (GIS), direct observation, or through collection of a self-report of the neighbourhood condition from survey participants.[4] GIS is the most practical measure of the built environment in particular, for large studies that span large areas, however, the databases may not be complete or accurate, introducing error.[4] Direct observational audits will provide more current data for the area, however, this is difficult for studies covering a wide geography. With the introduction of Google Street View (Google Inc., Mountain View, CA), direct observational audits may be unnecessary for certain variables, given that the collection date is somewhat recent.[49] The largest difficulty with self-report data of the built environment of an individual's neighbourhood is that these reports may be subject to accrual and response bias; however, this method of data collection has been shown to be near perfect in terms of reliability.[4]

2.5 Active Transportation to School and other Health Outcomes

Studies investigating the outcomes of active transportation to school have primarily focused on its effects on body composition and overall physical activity levels. For example, participation in active transportation to school is not only associated with an increase in physical activity levels,[9] but a healthier body composition and higher cardiorespiratory fitness levels.[8] In addition, adolescents who engage in regular active transportation to school are more likely to walk and bicycle to other destinations, further increasing amounts of physical activity.[9] Although most studies focus on the positive outcomes of active transportation to school, there are likely some negative outcomes, in particular injuries, which will be further discussed.

2.5.1 Active Transportation to School and Related Injuries

One negative effect of increased physical activity is the potential for more injuries.[50] From a public health perspective, this is an important health outcome because injury is the leading cause of injury in Canadian youth, and is also a cause of much other pain and suffering.[51]

However, little research has quantified the strength and statistical significance of these associations. Thus, many of the relevant findings need to be drawn from research in general pedestrian injuries in children.

The most relevant study in the literature compared crude rates of injuries across the different modes of transportation to school in New Zealand. Bicycling was reported as the most risky form of transportation to school with 46.1 injuries per million trips compared to 10.3 injuries per million trips for walking and 6.1 injuries per million trips for motor vehicle transport.[52] Although this study suggests that walking and bicycling to school may be riskier forms of transportation, there were no covariates included in this analysis and the study did not consider the type and severity of the injuries.

Mueller et al. studied some aspects of the road environment in association with child pedestrian-motor vehicle collisions. Although there was no statistical significance across increasing levels of traffic volumes (mean weekday traffic volume), the risk estimates suggest that there may be a positive relationship with such injuries (5 000-9 000: OR = 1.2, 95% CI: 0.4-3.4; 10 000-14 999: OR=2.0, 95% CI: 0.4-9.1; ≥15 000: OR=3.1, 95% CI: 0.9-10.8).[53] Posted vehicle speeds appear to be more strongly associated with child pedestrian injuries (45-55km/h: OR = 3.2, 95% CI: 1.2-8.8; ≥64 km/h: OR = 6.0, 95% CI:1.4-26.9). Other variables, such as sidewalks, marked cross-walks, and curb parking were investigated but, at least within this study, did not show a relationship with child pedestrian-motor vehicle collisions. These similar relationships may be implicated in active transportation to school.[53]

An investigation in Florida found that almost 35% of child pedestrian crashes occur at intersections and 71% of crashes occur within a half-mile of a school.[54] This points to child pedestrian and motor vehicle crashes as an important issue associated with active transportation to school. An age-specific rate of 28 children per 10 000 were involved in a child pedestrian–

vehicular collision was calculated in Connecticut, with specific geographical and temporal patterns (e.g., higher amounts of collisions surrounding schools shortly following school hours).[55] Similar to active transportation injuries, there is a lack of information on non-vehicular related pedestrian injuries.

Findings from Licaj et al. suggest that the risks for child pedestrian injury vary across levels of SES.[56] The incidence of injury was compared among different modes of transportation in areas with differing levels of deprivation in France.[56] The incidence of injury was higher in deprived areas compared to non-deprived areas for walking female youth (in all age groups): incidence rates (IR) range from 1.72-2.56 per 1000 young habitants per year. There were similar findings for young males that bicycled (14-17 year olds: IR=1.71, 95% CI:1.14-2.57; 18-24 year olds: IR= 1.67, 95% CI: 1.14-2.45) or walked (10-13 year olds: IR=2.81, 95% CI:1.60-4.97; 14-17 year olds: IR=4.74, 95% CI:2.19-10.3).[56] When inquiring about travel, travel to school was not specifically asked, however, travel outside of weekends and school holidays was excluded.[56] The findings suggest that children walking or bicycling to school in areas of lower SES are at higher risk of active transportation injuries, and that these risks vary with age.

In urban India, Dandona et al. investigated the risk factors for non-fatal road traffic injuries among children aged 5-14. Findings suggested that males are more likely to incur road traffic injuries while cycling compared to females (OR=1.94, 95% CI: 1.16-3.25), and that a higher household income is associated with fewer pedestrian road traffic injuries (quartile 4 versus quartile 1: OR=0.26, 95% CI: 0.08-0.86). In addition, as both the number of trips per day on the road, and the number of hours spent on the road increased, there was also an increase in non-fatal road traffic injuries.[57]

Based on current literature surrounding the association between active transportation to school and active transportation injury, one can infer that there is a positive relationship. Most of the studies mentioned do not take into account many possible covariates in these relationships, and only compare incidence rates. There are many possible covariates in this relationship, including aspects of the built environment (e.g., street speeds, street networks, the urban/rural status of the school location) that have not been investigated with school travel and injuries. In addition, these associations have not been thoroughly examined in Canada.

2.6 Implications of Active Transportation Research for Applied Health Interventions and Policy

Physical activity and injuries are commonly identified issues in the health of youth. It is possible that urban design and school policies can be modified to not only increase active transportation to school, but also decrease the risks for injury. In addition, targeted interventions may be needed given the association between individual and family characteristics with active transportation to school.

2.6.1 Individual and Family Interventions

As gender is a consistent correlate of active transportation, programs directed towards female school-aged children may encourage such behaviours. For example, interventions could follow similar existing programs, such as LEAP (Lifestyle Education for Activity Program) that was implemented in South Carolina and aimed to help girls to develop and maintain a healthy lifestyle by providing physical education classes, health education, a healthy school environment, school health services, faculty and staff health promotion, and family and community involvement all within regular school hours.[58] Additionally, other programs, such as ENACT (Nutrition and Activity), suggest that resident-led neighbourhood programs are effective at increasing active transportation to school by improving perception of neighbourhood safety, with safety in numbers.[59] That is, the more children there are walking to school, the safer active transportation will be perceived by parents and children, which will further increase the number who engage in active transportation. In order to increase active transportation to school with fewer injuries, these programs could be implemented with an added element of pedestrian safety.

2.6.2 School Interventions

Current research suggests that there are interventions at the school level that are effective at increasing participation in active transportation to school. The Safe Routes to School program, implemented in some Californian schools, includes the walking school bus, walk and bike to school days, competitions for the most miles traveled (using active transportation), and the identification of safe routes to school.[45] Typically, more than one intervention is employed when aiming to increase active transportation to school, for example, schools in Marin County California implemented many interventions including mapping safe routes to school, walk/bike to school days, frequent rider miles contest, classroom education, walking school bus and bike trains, and newsletters and promotional material.[41] It is possible that interventions, such as the walking school bus, may help to decrease injury occurrence through parental supervision. However, walking school buses are more likely to be implemented and maintained in neighbourhoods of a higher SES, and children of lower SES are more likely to experience injuries.[60] Though there is a lack of etiological studies surrounding the relationship between each of these interventions and active transportation, one study examined the difference in participation in active transportation to school after implementing a walking school bus: participation in walking to the intervention school increased by approximately 50% while the percentage of those walking to the control school fell by approximately 50% ($p<0.0001$) over the span of 12 months.[42]

In addition, school boards and municipalities could review the existing policies regarding the siting and construction of new schools. Rather than only considering the short-term budget benefits of building a school on land that is inexpensive, the long-term benefits of constructing a school closer to existing homes and road and sidewalk infrastructure resulting in reduced spending on bussing, and the many other benefits of active transportation to school should also be considered.[61]

2.6.3 Neighbourhood Interventions

Several aspects of the built environment are associated with an increase in active transportation to school, for example, the presence of sidewalks[28,33,45] and the urban/rural status of the neigbourhood.[13,16,21,33,34] Interventions at the neighbourhood level would not only affect school-aged children, but there may be a positive effect on the health of the general population, as individuals of all ages would be exposed to the changes to the environment. Improvements to the existing active transportation infrastructure surrounding schools (e.g., traffic calming strategies, cross-walks, bicycle paths, new sidewalks and traffic diversion efforts), such as done by the Safe Routes to School intervention in California, would likely increase rates of active transportation to school.[62] Not only could improvements to existing active transportation infrastructure increase rates of active transportation, but it is likely that these may decrease the amount of associated injury; a recent literature review concludes that clearly marked bicycling infrastructure, such as bike routes, lanes, and paths, provide safer means of bicycling than on-road, or alongside pedestrians.[63] Although the studies were not exclusive to children, it is possible that these interventions may have the same results in young populations.

2.7 Summary of Literature

Rates of active transportation to school have been decreasing over time, as noted in the greater Toronto area[11] and the United States.[12] Correlates of active transportation to school have been investigated in terms of factors of the individual and family, the school, and the neighbourhood. Some key correlates of active transportation to school are identified consistently within and across the literature, including distance to school, gender, race, and urban/rural status. There are major gaps in the literature surrounding qualitative measures of neighbourhood environments, school programs, and other school factors in relation to active transportation to school. In addition, few studies consider multiple factors of the individual/family, the school, and the neighbourhood simultaneously in multivariate analyses of active transportation to school. Furthermore, a small number of the studies that include factors of the individual/family, school, and neighbourhood also use multi-level modeling techniques; the large amount of studies that did not use appropriate multi-level modeling produced inappropriate confidence intervals due to the under-estimate of standard errors. Most of these studies based modeling decisions on statistical significance alone. This body of literature could benefit from studies including factors of the school in multivariate models of the correlates of active transportation to school.

Several positive health outcomes of active transportation to school have been investigated, including overall physical activity levels and obesity. However, potential negative outcomes of active transportation to school remain unstudied. There is a dearth of information surrounding injury as an outcome of active transportation to school. Current studies in this area only compare incidence rates of injury across modes of transportation, and there is a lack of control for important covariates. A more thorough understanding of the relationship between active transportation to school and related injuries could help to understand the magnitude of these associations and the severity of these injuries. This information could also be incorporated into interventions to promote active transportation to school.

2.8 Thesis Rationale

Some correlates of active transportation to school are identified consistently across the literature, however, there are gaps surrounding characteristics of the school and a lack of consistency across neighbourhood characteristics. Thus, multi-level studies that simultaneously investigate correlates of the individual/family, school, and neighbourhood that appear to be relevant to active transportation to school are warranted. In addition, very little research has examined child injury as an adverse outcome of active transportation to school. There are parental concerns about childrens' safety while engaging in active transportation to school, some of these have been reported as concerns of road danger, crime, and 'other' concerns.[29] Part of this thesis aimed to determine whether such concerns were warranted about one aspect of these concerns, that being unintentional transportation injury, in order to more fully inform active transportation initiatives. Furthermore, Canadian research in this field of study is lacking, while such studies are stated priorities of the Canadian Institute of Health Research (CIHR)[64] and the Heart and Stroke Foundation.[5] This thesis aims to fill these gaps in the literature by 1) using an existing national survey to conduct a large-scale study of this issue, 2) examining multiple determinants and one outcome from different conceptual levels simultaneously (using both descriptive analyses and multi-level logistic modeling), and 3) examining school factors related to active transportation. Information from this thesis will help inform the content of targeted policies that can be implemented in order to increase active transportation to school, increasing overall physical activity, and, when done safely, potentially decrease the amount of injuries related to active transportation.

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Table 2-1 Summary of literature examining individual/family correlates of active transportation to school

	Referent	Positive (p<0.05)	No association, or not included in final model	Negative (p<0.05)
Gender	Males		[13][g] [17][a] [27] [31][h] [34][f] [35] [38]	[13][h] [16] [20] [21] [30] [31][g] [33] [34][e] [36]
Age -	Youngest/Increasing	[16] [17][a] [22] [25] [27] [32][a] [34][f] [38]	[13] [31][bg] [31][h] [34][e]	[21] [30] [31][cg] [33]
Race	Caucasian	[16] [17][a] [21] [31] [32][a]	[33] [35]	
Foreign-born parent	None	[16] [24][a]	[13][g]	
Family SES	Lowest/Increasing	[16]	[17][a] [28][ac] [32][a] [35]	[21] [24][a] [27] [28][ab] [30] [38]
Number of siblings/children living in household	None/Increasing	[17][a] [24][a] [32][aj] [38]	[19] [32][ai] [35]	
Parents marital status/number of parents	Single/One		[16] [19] [22]	[33] [35] [38]
Number of vehicles	None/Increasing		[16] [17][a] [19] [20] [22] [24][a] [27] [28][ac] [32][a]	[13][g] [25] [28][ab]
Child perception of safety	Not safe/Increasing		[19] [33] [40][d]	
Parental perception of safety	Not safe/increasing	[16] [22] [24][a]	[19] [21] [25]	
Distance to school/Travel time	Shortest/Increasing		[32][aj]	[13] [16] [17] [18] [19] [20] [21] [22] [24][a] [25] [26] [27] [28][a] [30] [32][ai]
Parental education	Least/Increasing	[16]	[31][g] [31][ch] [33] [39]	[13][g] [31][bh] [35]
Parent walks for transportation/uses public transit	No	[22]	[21] [40][d]	

Only the fully-adjusted associations in a final model appear in this table. In addition, if there were two separate models for trips TO and FROM school, only the model containing the trip TO school was considered. Some relationships were described in the opposite direction, i.e., more likely to engage in passive transportation to school., or a different referent was used. In these cases, the odds ratio was inverted.

[a]Not recorded as an odds ratio
[b]Recorded for walking to school only
[c]For cycling to school only
[d]In young girls, only
[e]Urban schools only
[f]Rural schools only
[g]Middle school only
[h]High school only
[i]Living within 1.6 km of school only
[j]Living farther than 1.6 km from school only

Table 2-2 Summary of literature examining school correlates of active transportation to school

	Referent	Positive (p<0.05)	No association, or not included in final model	Negative (p<0.05)
Private vs Public	Public		[34]	[21] [22]
Walking School Bus	No		[26]	
Walk/bike to school days	No		[26]	
Entrances for pedestrians/cyclists	No		[26]	
Presence of bicycle racks	No	N/A	N/A	N/A

Only the fully-adjusted associations in a final model appear in this table. In addition, if there were two separate models for trips TO and FROM school, only the model containing the trip TO school was considered. Some relationships were described in the opposite direction, i.e., more likely to engage in passive transportation to school., or a different referent was used. In these cases, the odds ratio was inverted.

Table 2-3 Summary of literature examining neighbourhood correlates of active transportation to school

	Referent	Positive (p<0.05)	No association, or not included in final model	Negative (p<0.05)
Urban/Rural Status	Rural	[13][g] [16] [21] [30] [33] [35] [38]	[26] [13][h]	
Sidewalks	None/Increasing	[28][ab] [33] [47][a]	[20] [24][a] [26] [28][ac] [40][d] [44]	
Pedestrian crossings	None/Increasing	[19] [44][a]		
Street Connectivity/Route Directness	Lowest/Increasing	[18]b [36] [39]	[18][c] [20] [26][c] [32][a] [47]	[19] [26][b]
Road Density/Length of streets	Lowest/Increasing	[26][b]	[26][c]	
Neighbourhood Aesthetics: presence of trees	Lowest/Increasing	[20]	[40][d] [47]	
Neighbourhood SES	Lowest/Increasing	[26]	[19] [20] [32][a]	[27]
Street Speeds	Lowest/Increasing			[24][a]
Main or busy roads present	No/Increasing	[26]	[18]	[19]
Land Use Mix	Lowest/Increasing	[20] [24][a]	[26]	
Traffic accidents (e.g., per kilometre of roads)	Fewest/Increasing		[26]	
Population density	Lowest/Increasing	[27] [17]a	[25]	
Average temperature	Lowest/Increasing		[34]	
Precipitation	Lowest/Increasing		[34]	

Only the fully-adjusted associations in a final model appear in this table. In addition, if there were two separate models for trips TO and FROM school, only the model containing the trip TO school was considered. Some relationships were described in the opposite direction, i.e., more likely to engage in passive transportation to school., or a different referent was used. In these cases, the odds ratio was inverted.

[a]Not recorded as an odds ratio
[b]Recorded for walking to school only
[c]For cycling to school only
[d]In young girls, only
[e]Urban schools only
[f]Rural schools only
[g]Middle school only
[h]High school only
[i]Living within 1.6 km of school only
[j]Living farther than 1.6 km from school only

Chapter 3

Multi-level Examination of Correlates of Active Transportation to School among Canadian Youth: A Cross-Sectional Study

Abstract

Background: Active transportation to school is a method by which youth can build physical activity into their daily routines. We examined correlates of active transportation to school at both individual- (characteristics of the individual and family) and area- (school and neighbourhood) levels.

Methods: Using the 2009/10 Canadian Health Behaviour in School-Aged Children (HBSC) survey, we selected records of students (n=3 997) from 161 schools that (1) resided in an urban core; and (2) lived within 1.6 km from their school. Student records were compiled from (1) individual-level HBSC student questionnaires; (2) area-level administrator (school) questionnaires; and (3) area-level geographic information system data sources. The outcome, active transportation to school, was determined via a questionnaire item describing the method of transportation that individual students normally use to get to school. Analyses focused on factors at multiple levels that potentially contribute to student decisions to engage in active transportation. Multi-level logistic regression analyses were employed.

Results: Approximately 18% of the variance in active transportation was accounted for at the area-level. Several individual and family characteristics were associated with engagement in active transportation to school including female gender (RR vs. males = 0.86, 95% CI: 0.80-0.91), having ≥2 cars in the household (RR vs. no cars = 0.87, 0.74-0.97), and family socioeconomic status (RR for 'not well off' vs. 'very well off' = 1.14, 1.01-1.26). Neighbourhood characteristics most strongly related to active transportation were the length of roads in the 1 km buffer (RR in quartile 4 vs. quartile 1 = 1.23, 1.00-1.42), the amount of litter in the neighbourhood (RR for 'major problem' vs. 'no problem' = 1.47, 1.16-1.57), and relatively hot climates (RR in quartile 4 vs. quartile 1 = 1.33 CI, 1.05-1.53).

Conclusion: Engagement in active transportation to school was related to multiple factors at multiple levels. We identified gender, perception of residential neighbourhood safety, the

percentage of streets with sidewalks, and the total length of roads as the most important correlates of active transportation to school.

Key Words: active transportation, adolescent, school, neighbourhood

Background

Active transportation is the engagement in physical activity specifically for travel and includes methods such as walking and bicycling.[1] Active transportation is one means by which children and youth can incorporate physical activity into their daily routines. Indeed, children and youth who walk or bicycle to school have higher overall physical activity[2] and cardiorespiratory fitness levels[3] and a healthier body composition.[3] Unfortunately, the proportion of children and youth who engage in active transportation to school has decreased by 8-10% in Canada over the last two decades[4] and by 25% in the United States over the last four decades,[5] which is of obvious concern to public health. Evidence about the various factors that lead to decisions to engage in active transportation to school is fundamental to the development of effective health promotion strategies.

Correlates of active transportation to school likely exist at multiple levels, including characteristics of individual students and their families (individual-level) and characteristics of the students' schools and their neighbourhoods (area-level). Yet, there is a dearth of multi-level research on this topic. Existing studies have generally been conducted within small geographic areas[6-11] and have not simultaneously considered multiple factors at the various levels.[7-10,12-18] Several positive correlates do exist at the individual-level, such as living in close proximity to school,[8,10,13,19] male gender,[7,8,19,20] races other than Caucasian,[16,19,21] low family socio-economic status,[22] and a non-traditional family structure.[22]

There is little information about the influence of schools and school policies on active transportation to school. One school-based active transportation study found that students attending private school were less likely (odds ratio (OR)=0.60, 95% confidence interval (CI)=0.37-0.96) to engage in regular active transportation.[23] At the neighbourhood-level, students who live in densely populated areas are more likely to engage in active transportation to school.[21] Another neighbourhood factor is the presence of sidewalks, which has consistently been shown to be a strong correlate.[6,7,15,23,24] Associations between active transportation and the design of road networks are less clear. A recent systematic review reported varying associations for intersection density, block length, and route directness.[25] Despite the interest in characteristics of the neighbourhood, certain variables have not been examined, including neighbourhood aesthetics (e.g., litter, condition of houses and buildings) and safety features (e.g., speed limits of roads surrounding the school).

We conducted a national analysis of possible individual-level and area-level correlates of active transportation to school among urban Canadian youth aged 11-15 years. Our goal was to identify major factors that govern decisions to engage in active transportation using contemporary multi-level methods and approaches. This study was exploratory and no *a priori* hypotheses were assumed, although our choices of variables for study were governed in part by existing literature. Our analyses suggest a number of modifiable factors that, in the short-term may be identified for more focused study, and in the long-term may be addressed via preventive interventions.

Methods

Overview of Study Design and Measures

The basis for this study was the 2009/10 Canadian Health Behaviour in School-Aged Children (HBSC) Survey. HBSC is a general health survey of grades 6-10 students conducted in affiliation with the World Health Organization. The 2009/10 Canadian HBSC, or the 6th Canadian cycle, consisted of three main components: (1) a questionnaire completed by students that asked about their health behaviors (such as active transportation), lifestyle factors, and demographics, (2) an administrator questionnaire distributed to each school principal that inquired about school demographics, policy, infrastructure, and about the school neighbourhood setting, and (3) geographic information systems (GIS) measures of built and social features in the school neighbourhoods that were later linked with the HBSC data.

Participants

In Canada, the HBSC survey follows a systematic multi-stage cluster sample where individual students are nested in school classes, which in turn are nested within schools, followed by school boards. This sampling approach adheres to the standard international protocol.[26] In 2009/10 the HBSC survey was administered to 26 078 Canadian students in grades 6-10 from 436 schools in 11 territories and provinces (all jurisdictions with the exception of Prince Edward Island and New Brunswick participated). With respect to human subjects, consent to participate was obtained from school boards, individual schools, parents or guardians (either explicitly or implicitly determined by school board policy), and from individual students. Ethics approval for the Canadian HBSC was granted by the General Research Ethics Board of Queen's University.

For this study, we only included participating students who attended school in an urban core, as indicated by the school postal codes. An urban core is defined as a "large urban area that has a population of at least 50 000 in the urban core in the case of a Census Metropolitan Area, or a population of at least 10 000 in the urban core for a Census Agglomeration".[27] In Canada, postal codes provide specific indicators of location of residence in urban core settings, but not in rural locations.[28]

To be included in this study we required that the participants lived within a standard walking distance of their school, estimated at 1.6 kilometers or less as per existing precedents.[29] Walking distances were conservatively estimated using direct distance from the geographical centre of their postal code to the school address.[30] The inclusion criteria limited the study base to students who had a realistic opportunity to regularly engage in active transportation to school. By school policy, students who live more than 1.6 kilometers from school are typically offered transportation by school bus, although this distance can vary.[31-33] A large percentage (43%) of urban students did not report their postal code in the HBSC survey, and to increase the study sample size, for these students we used their answers to questions about "travel time to school" and "usual mode of transportation to school" to estimate whether they lived within the 1.6 km distance. Students who reported that their travel time to school was 15 minutes or less by walking, or less than 5 minutes for every other mode of transportation (bicycle, car, bus, etc.), were therefore also included. The final sample size of urban youth available for analysis was 3 997 (see **Figure 3-1** for a participant flow diagram).

Outcome – Active Transportation to School

The outcome of interest was regular engagement in active transportation to school, either via walking or bicycling. Participants answered the following HBSC survey question: "On a typical day, the MAIN part of your journey TO school is made by…" with the following options: 1) walking; 2) bicycle; 3) bus, train, streetcar, subway, or boat/ferry; 4) car, motorcycle, or moped; 5) other. Responses were grouped dichotomously: those who answered "walking" or "bicycle" were categorized as students that regularly engage in active transportation to school, while those who answered 'bus, train, streetcar, subway, boat/ferry, car, motorcycle, moped' were categorized as individuals that do not. Participants who answered 'other' to this question were excluded to minimize possible misclassification. Intra-rater reliability analyses for the HBSC active transportation question suggest there is an excellent level of agreement (Cronbach's alpha ≥0.80) between multiple student reports, including reports examined across seasons.[34]

Possible Correlates of Active Transportation to School

We constructed a list of possible correlates of active transportation to school based on the evidence in existing literature, and HBSC and GIS data available to our research team.

Individual and Family Correlates (Individual-Level Data)

Eight items describing potential correlates of the individual participants and their families were obtained via the HBSC student questionnaire: gender (male or female), grade (6-8 and 9-10), race (four composite categories consisting of Caucasian only, Caucasian and other, Aboriginal, and other), number of siblings (0, 1, 2 or more), family structure (living with both parents, living with one parent and a step-parent, living with a single parent, and all other living situations), family socio-economic status (SES) as measured by perceived relative affluence (5 categories from “very well off” to “not well off at all”), the number of cars in the household (0, 1, 2 or more), and perceived residential neighbourhood safety (where you live, is it safe for children to play outside? (5 categories: “strongly agree” to “strongly disagree”).

School Correlates (Area-Level Data)

Three items of the school were measured using the HBSC administrator questionnaire. These items focused on school active transportation policies, programs, and infrastructure. A series of questions inquired about whether the school promoted active transportation by (1) having walk and/or bike to school days or walking school buses; (2) identifying safe routes to walk or bicycle to school; and (3) providing bicycle racks in safe locations. All three of these items were dichotomized as “yes” or “no” for analytical purposes. Schools with administrators who answered “don’t know” to these questions were classified as “no”.

Neighbourhood Correlates (Area-Level Data)

<u>Aesthetics</u>: Two items that reflect neighbourhood aesthetics were measured using the HBSC administrator questionnaire: (1) presence of litter in the school neighbourhood; and (2) vacant or shabby housing in the school neighbourhood. Four possible response categories were available, ranging from “no problem” to “major problem”.

Twelve items of the neighbourhood were measured with GIS using the CanMap Route Logistics database (DMTI Spatial Inc., Markham, ON) in ArcView version 9.3 software, PCensus for MapPoint software (Tetrad Computer Applications Inc., Vancouver, BC), Google Earth and Google Street View software (Google Inc., Mountain View, CA), and Environment Canada data (National Climate Data and Information Archive). Some of these variables were obtained from a 1-km radius circular buffer surrounding the school, some were obtained at the exact school address, and others were obtained for the municipality where the school was located.

Sidewalk measures: The first of the GIS measures consisted of whether there was at least one sidewalk leading directly to the school. This was measured using Google Street View. If the Google Street View image confirmed that there was a sidewalk on either side of the street on which the school was located, this variable was categorized as "yes", otherwise it was categorized as a "no". The use of Google Street View as an alternative to physical audit has been validated, and measures (such as the presence of recreational buildings and parks) have produced observed agreement correlations of 0.92 and 0.95, respectively.[35]

The percentage of roads with sidewalks in the 1 km buffer surrounding each school was obtained from Google Earth and ArcGIS. The length of roads with a sidewalk (on either side) was gathered and divided by the total length of roads. This variable was then categorized into quartiles. This was done by first calculating the distance of roads in the buffer using the CanMap Route Logistics database in ArcGIS. The road network was exported from ArcGIS into Google Earth, and within Google Earth the road segments were superimposed onto the street view images. Road segments that did not have a sidewalk were deleted from the road network within Google Earth. After deletions, the revised road network was imported back into ArcGIS so that the sidewalk distances could be calculated.

Road measures: Four neighbourhood road measures (percentage of roads with speed limits less than or equal to 60 km/h, total length of roads, street connectivity, and speed limit of the school's road) were obtained from CanMap Route Logistics in ArcGIS software. The speed limit of each school's road was categorized as ≤40 km/h, 50 km/h, or ≥60 km/h. The remaining three variables were obtained for the 1 km radial buffer surrounding the school. Street connectivity was calculated as a composite measure of intersection density, average block length, and connected node ratio, similar to measures identified by Dill[30] and Tresidder.[36] Intersection density was calculated as the number of intersections divided by the total land area in each buffer. Average block length was calculated as the total length of roads divided by the number of intersections.[36] The connected node ratio was calculated by dividing the number of true intersections by the number of all intersections including cul-de-sacs and dead ends.[36] Based upon prior work,[37] a principal component factor analysis showed that each street connectivity variable was related; factor loadings were: 0.93, 0.66, 0.89 for intersection density, average block length, and connected node ratio variables respectively (Cronbach's alpha standardized=0.78). These variables were combined with equal weight, then ranked as a composite variable.

SES: Neighbourhood SES was measured in the 1 km buffer surrounding each school, based upon the 2006 Canadian Census, using PCensus for MapPoint software. The overall median household income was calculated by weighting each census block by the total population. This variable was categorized into quartiles.

Climate*:* Annual climate variables (calculated from at least 15 years of data between 1971 and 2000) were obtained for each school using the Environment Canada National Climate Data and Information Archive[38] as inferred from the most proximal weather station to each school. These measures included average temperature (°C), average annual rainfall (mm), average annual snowfall (cm), average annual number of extreme hot days (maximum temperature >30°C), and average number of extreme cold days (minimum temperature <-20°C). Each climate variable was categorized into quartiles.

Statistical Analysis

Statistical analyses were performed with SAS version 9.2 (SAS Inc., Carry, NC). Potential correlates of active transportation were initially described for the sample using conventional descriptive statistics. They were further described by the percentage of individuals in each category that engaged in active transportation to school.

Prior to performing multi-level analyses, an empty model was run to calculate the intra-class correlation (ICC), which reflects the proportion of the total variance in the active transportation outcome explained by the area-level. An ICC value of 18% was obtained, suggesting that a large amount of variation was accounted for by school and neighbourhood characteristics.[39] This justified the use of multi-level analytical techniques in subsequent analyses.

Our approach to statistical modeling was governed by the following strategy. Due to the exploratory nature of our investigation, a backwards selection approach was employed. Studies of the built environment and walking and bicycling have found more variation at the individual- vs. area-levels.[40,41] Therefore, we performed multi-level modeling in steps, beginning with building a model at the individual-level (individual and family), followed by the introduction of variables at the area-level (school and neighbourhood). Our goal was to create a parsimonious list of potential correlates of active transportation to school while controlling for all of the selected variables at multiple levels.

Our multi-level models were then built using the following hierarchal approach: 1) all individual-level variables were considered in bivariate models with active transportation to school as the outcome (Multivariate Model 1); 2) backwards selection methods were performed next, with a cut-off value of $p<0.05$ for retention of individual-level variables; 3) area-level variables were then added to the significant individual-level effects (Multivariate Model 2); 4) backwards selection was again performed for the final model for retention of area-level variables, this time with a cut-off value of $p<0.20$, as power was less for the area-level variables. If any variable or dummy variable had significance at $p<0.05$ ($p<0.20$ for the area level variables), or the test for linear trend across categories was significant ($p<0.05$), they were retained in the final model (Multivariate Model 3). Area-level variables that were maintained in the final model were also tested as random effects; inclusions of these effects did not significantly improve the model.

All models were fit as generalized linear models and were built with the SAS GLIMMMIX procedure with a binomial distribution and a logit link to account for the clustered nature of the data. We assumed random intercepts but fixed effects. A Newton-Raphson with ridging technique was applied to all multilevel logistic models to optimize convergence.[42] Odds ratios were converted to relative risks (RR), as per existing precedents,[43] $RR = OR / [(1 – Po) + (OR \times Po)]$, where Po is the prevalence of active transportation in the referent group for each variable.

Additionally, we calculated the population attributable risk (PAR) to estimate the proportion of active transportation to school attributed to the correlates at the different levels. PAR was calculated based upon the RR estimates generated in Multivariate Model 3 with the following equation: $(Pe(RR-1)) / (1+Pe(RR-1))$ where Pe is the proportion of individuals exposed in similar populations.[44] For variables with more than two categories, PAR was calculated for each of the non-referent categories and then summed to obtain an overall PAR estimate. For variables with an RR less than 1, the effect was inverted to obtain an RR>1 prior to calculation of the PAR.

Results

Individual and family characteristics (individual-level) of the urban sample of students who lived in close proximity of their school are profiled in **Table 3-1**. A total of 3 997 students were available for analysis, with approximately equal numbers of boys and girls. The majority of the students were in grades 6 to 8, and there was considerable variation in social factors relevant to Canadian families and students’ possible choices to engage in active transportation to school. With respect to the study outcome, 62.6% engaged in regular active transportation to school.

Table 3-2 further describes the distribution of the student sample by school and neighbourhood characteristics (area-level) that could potentially impact active transportation choices.

Table 3-3 summarizes bivariate, then adjusted (Model 1), associations between each individual-level variable and engagement in active transportation to school. While the bivariate analyses indicated that a number of individual-level factors are potential correlates of active transportation, Model 1 (individually adjusted) results suggested a more modest list of correlates. **Table 3-4** extends these results through the examination of area-level correlates of the school and neighbourhood; few of these factors achieved statistical significance. The final multi-level model is presented in **Table 3-5**.

The final model indicates that factors at both individual and area-levels were associated with active transportation. *Individual and family characteristics (individual-level)* included gender (female: RR=0.86, 95% CI: 0.80-0.91); living with one parent and one step-parent (RR=1.10, 95% CI: 1.00-1.19); "average" (RR=1.16, 95% CI: 1.08-1.24) to "not very well off" (RR=1.14, 95% CI: 1.01-1.26) perceived family affluence; two or more cars in the household (RR=0.87, 95% CI: 0.74-0.97); and "disagree" that the residential neighbourhood is safe for children (RR=0.83, 95% CI: 0.70-0.95). *School characteristics (area-level)* included presence of a walk/bike to school day program or a walking school bus program (RR= 0.89, 95% CI: 0.74-1.03). *Neighbourhood characteristics (area-level)* included a higher percentage of roads with sidewalks (quartile 3: RR=1.17, 95% CI: 0.96-1.34); a higher speed limit of the school's road (50 km/h: RR=1.22, 95% CI: 0.92-1.43; ≥60 km/h: RR=1.26, 95% CI: 0.96-1.47); increased total length of roads (quartile 4: RR=1.23, 95% CI: 1.00-1.42,); litter in neighbourhoods perceived as a major problem (RR=1.47, 95% CI: 1.16-1.57); presence of vacant or shabby housing (p_{trend}=0.19); a lower average daily temperature (quartile 2: RR=0.77, 95% CI: 0.54-1.00; quartile 3: RR=0.76, 95% CI: 0.46-1.08); higher amounts of rain (quartile 4: RR=1.25, 95% CI: 0.91-1.45); and more extreme hot days in a year (quartile 4: RR=1.33, 95% CI: 1.05-1.53).

Table 3-6 displays the PAR estimates for the correlates of active transportation to school that were present in the final model (Multivariate Model 3). We did not calculate the PAR for three variables, including the lack of walk/bike to school days, the presence of litter in the neighbourhood, and the speed limit of the school's street due to the confusing RRs. These variables were ignored, as it does not make sense to reduce active transportation programs in schools, or to increase litter in neighbourhoods, or to increase the speed limit of the school's road in order to increase active transportation to school. PAR estimates ranged from 2.3% to 10.8% (10.8% being the number of cars in the household) for the individual-level variables and from 6.9% to 16.6% (16.6% being average temperature) for the area-level variables.

Discussion

We identified the most important hypothesized correlates of active transportation to school in Canadian youth in our study using indicators of: 1) the strength of associations identified via regression analyses; 2) population attributable risk; and 3) the potential for intervention. The most important finding of this national study was that the choice to engage in active transportation to school was governed by multiple factors at the individual- and area-levels, as opposed to one or more very specific factors.

There are major differences between our study design and methods from those used in previous studies in this field. Our study involved a geographically diverse sample from across the country, but at the same time was limited to urban youth who lived in close proximity to their school (≤1.6 km) and would therefore likely not be eligible for school bussing. We measured multiple active transportation correlates at multiple levels, and because of this, employed multi-level analytical approaches.

Despite differences in study design and methods, many of the individual and family correlates that were identified in our study have been identified in previous studies that examined determinants of active transportation, such as gender,[7,8,19,20] family structure,[22] and the number of cars in the household.[6] However, unlike previous American studies which found that Hispanic and Black students were more likely to engage in active transportation to school,[16,19,21] we did not find any associations for race. This may be related to the differing racial minority compositions in the United States and Canada.[45,46] We also did not find an association between the number of siblings and active transportation, while several others have identified such an association.[10,22,47] Finally, most other studies have found that youth with a lower family SES were more likely to engage in active transportation to school.[10,12,22] Our results showed more of a U-shape pattern with SES, wherein students in the middle SES categories were the most likely to engage in active transportation to school.

There are two main reasons why our findings differ from existing literature that report higher rates of active transportation is associated with a lower family SES.[10,12,22] First, our sampling strategy included only urban youth living within close proximity to school. It is possible that there is a difference between students that live far from school and those that live close; those that live far from school and still engage in active transportation to school may do so out of necessity (e.g. low SES, fewer means of getting to school). Thus, the findings from this study are likely only generalizable to similar groups of students living near urban schools. Second, relatively few students reported a lower than average SES. The small sample size in this group created a wider confidence interval, and therefore, it was possible that this association was underpowered.

School correlates of active transportation are not well understood as few studies have investigated these associations. Our main finding for schools was that, of the three potential school correlates examined, only one was associated with active transportation. Specifically, and to our surprise, the presence of active transportation programs (walk/bike to school days and walking school bus programs) was negatively associated with active transportation to school. This may be an artifact of the lack of temporality in our cross-sectional study design. That is, it is possible that schools with lower active transportation rates implemented walk/bike to school days and walking school bus programs in an attempt to address this public health issue.

Several neighbourhood factors were also correlated with active transportation to school. Consistent with findings from a recent systematic review, we found no association with street connectivity (a measure of the directness of travel routes), but a positive association with the percentage of streets with sidewalks and the total length of streets.[25] Our finding that climate measures were associated with active transportation to school differs from other studies that were not as geographically diverse.[18,20] We also investigated several neighbourhood variables that, to date, have been unstudied. Of these, our findings suggest that there is a relationship between aspects of the environment that are related to safety and aesthetics (e.g., presence of sidewalks, presence of shabby housing, presence of litter).

As discussed above, several individual and area-level variables were correlated with active transportation in our study. In order to supply information for the development of informed policy, we identified the most important correlates based upon the strength of the identified association, its population attributable risk, and the potential for intervention (see **Table 3-6**). Using these criteria, the most important correlates of active transportation to school were gender, the perception of residential neighbourhood safety, the percentage of roads with sidewalks, and the total length of streets. In order to increase female engagement in active transportation to school, interventions could follow similar existing programs, such as the LEAP program implemented in South Carolina.[48] Additionally, other programs, such as ENACT suggest that resident-led neighbourhood programs are effective at increasing active transportation to school by improving perception of neighbourhood safety, with safety in numbers.[49]

At the area-level, we propose that the type of intervention would vary depending on whether it is an existing school or a newly constructed school. For existing schools, improvements to the existing active transportation infrastructure (e.g., traffic calming strategies, cross-walks, bicycle paths, new sidewalks and traffic diversion efforts), such as done by the Safe

Routes to School intervention in California, may improve rates of active transportation to school.[50] School siting policies could be reviewed along with those of the municipality to consider active transportation when constructing new schools, such as criteria for choosing school location (cost versus convenient location), sidewalk infrastructure, and car-free zones.[51]

The main limitations of our study include the following methodological issues. First, this study may have been affected by selection bias, as after excluding multiple schools and students, our final sample was reduced from 26 078 to 3 997 (many students were removed because they did not reside in an urban core, and because they did not live within ~1.6 km of their school). Second, due to the cross-sectional nature of the data, temporality between the variables cannot be assured. Third, there may be measurement error with the distance from school inclusion, as the geographical centre of the postal code area was considered as a proxy for the students' home location. Due to the fact that these analyses were limited to urban areas, the estimated locations should be relatively precise.[28] Fourth, we only have information on the trip from home to school; differences in mode of transportation may exist between journeys going to and leaving from school.[5,8,52] Finally, although there was sufficient power to study the individual and family variables and active transportation to school, power was more limited for the school and neighbourhood variables.

Conclusion

Potential correlates of active transportation (at the individual- and area-levels) among urban youth were examined using multi-level analytical methods. We found that the decision to engage in active transportation to school was affected by multiple factors at multiple levels. We identified gender, perception of residential neighbourhood safety, the percentage of streets with sidewalks, and the total length of roads as the most important correlates of active transportation to school. Recommendations for interventions (e.g., safe-walking programs directed towards girls, and improvements to active transportation infrastructure) were made with the purpose of increasing engagement in active transportation to school in youth.

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Table 3-1 Individual-level (individual and family) characteristics of urban youth (N = 3 997) sampled for study of active transportation to school in Canada

Characteristic	N (%)
Gender	
Male	1 930 (48.3)
Female	2 067 (51.7)
Grade	
6-8	2 759 (69.0)
9-10	1 238 (31.0)
Race	
Caucasian only	2 443 (61.1)
Caucasian and other	201 (5.0)
Aboriginal	396 (9.9)
Other	957 (23.9)
Number of siblings	
0	608 (15.2)
1	1 729 (43.3)
2+	1 660 (41.5)
Adults at home	
Both mother and father	2 655 (66.4)
One parent and one step-parent	418 (10.5)
Single parent	775 (19.4)
Other	149 (3.7)
Family SES	
Very well off	904 (22.6)
Well off	1 317 (32.9)
Average	1 405 (35.2)
Not very well off	266 (6.7)
Not at all well off	105 (2.6)
Number of cars in household	
0	176 (4.4)
1	1 186 (29.7)
2+	2 635 (65.9)
Residential neighbourhood is safe for children	
Strongly agree	1 109 (27.7)
Agree	1 792 (44.8)
Neither agree nor disagree	750 (18.8)
Disagree	242 (6.1)
Strongly disagree	104 (2.6)

Table 3-2 Area-level characteristics of the school and neighbourhood of urban Canadian youth (N = 3 997)

	N (%)	Median (IQR)
School Characteristics		
Bicycle storage available in a safe location		
No	835 (20.9)	
Yes	3 162 (79.1)	
Has walk/bike to school days and/or walking school bus programs		
No	2 751 (68.8)	
Yes	1 246 (31.2)	
Identification of safe walking/biking routes to school		
No	2 347 (58.7)	
Yes	1 650 (41.3)	
Neighbourhood Characteristics		
Sidewalk leading to school		
No	161 (4.0)	
Yes	3 836 (96.0)	
% of roads with sidewalks		64.6 (47.4 - 83.0)
Speed limit of school's road (km/h)		
≤40	311 (7.8)	
50	3 390 (84.8)	
≥60	296 (7.4)	
% of roads with speed limit ≤60 km/h		
<90	493 (12.3)	
90 – 93.99	851 (21.3)	
94 – 99.99	1 196 (29.9)	
100	1 457 (36.5)	
Total length of roads (km)		36.7 (29.5 – 40.9)
Street connectivity		
1 (lowest connectivity)	1 176 (29.4)	
2	1 034 (25.9)	
3	951 (23.8)	
4 (highest connectivity)	836 (20.9)	
Litter in neighbourhood		
No problem	1 285 (32.1)	
Minor problem	2 216 (55.4)	
Moderate problem	399 (10.0)	
Major problem	97 (2.4)	
Vacant or shabby housing		
No problem	2 999 (75.0)	
Minor problem	750 (18.8)	
Moderate problem	192 (4.8)	
Major problem	56 (1.4)	
Neighbourhood SES (median family income, $CAD)		70 432 (58 129 – 84 063)
Average temperature (°C)		4.7 (2.5 - 7.6)
Average annual rain (mm)		1 369 (609 – 1 747)
Average annual snow (cm)		231 (195 - 304)
Average number of hot days		4.5 (0.5 - 11.4)
Average number of cold days		26.0 (0.6 - 47.7)

IQR = interquartile range

Table 3-3 Bivariate and multivariate (Model 1) relationships of individual-level characteristics and active transportation to school (N = 3 997)

Individual-level characteristics	% Engaged in Active Transportation	Bivariate Model RR (95% CI)	Multivariate Model 1 RR (95% CI)
Gender			
Male	67.6	1.00	1.00
Female	57.9	0.86 (0.81 - 0.91)	0.85 (0.80 - 0.90)
Grade			
6-8	61.7	1.00	1.00
9-10	64.7	1.07 (0.98 - 1.15)	1.05 (0.96 - 1.13)
Race			
Caucasian only	60.3	1.00	1.00
Caucasian and other	70.2	1.09 (0.95 - 1.21)	1.10 (0.97 - 1.22)
Aboriginal	69.2	1.08 (0.98 - 1.18)	1.04 (0.92 - 1.14)
Other	64.1	0.92 (0.84 - 1.00)	0.92 (0.84 - 1.00)
Number of siblings			
0	65.5	1.00	1.00
1	60.1	0.92 (0.84 - 1.00)	0.96 (0.88 - 1.03)
2+	64.2	0.97 (0.90 - 1.05)	1.01 (0.93 - 1.08)
P trend		0.88	0.40
Adults at home			
Both mother and father	59.6	1.00	1.00
One parent and one step-parent	67.5	1.11 (1.02 - 1.20)	1.08 (0.98 - 1.17)
Single parent	69.0	1.13 (1.06 - 1.19)	1.06 (0.98 - 1.14)
Other	69.1	1.13 (0.97 - 1.26)	1.08 (0.92 - 1.23)
Family SES			
Very well off	57.1	1.00	1.00
Well off	62.3	1.09 (1.00 - 1.21)	1.07 (0.99 - 1.15)
Average	66.1	1.17 (1.10 - 1.25)	1.15 (1.07 - 1.23)
Not very well off	66.2	1.16 (1.04 - 1.28)	1.14 (1.00 - 1.26)
Not at all well off	59.1	1.02 (0.82 - 1.20)	0.97 (0.77 - 1.16)
P trend		0.0005	0.0091
Number of cars in household			
0	76.7	1.00	1.00
1	68.6	0.94 (0.82 - 1.04)	0.93 (0.82 - 1.04)
2+	59.0	0.85 (0.72 - 0.95)	0.86 (0.72 - 0.97)
P trend		<.0001	0.0001
Residential neighbourhood is safe for children			
Strongly agree	63.5	1.00	1.00
Agree	57.9	1.02 (0.96 - 1.08)	1.01 (0.94 - 1.07)
Neither agree nor disagree	63.6	0.99 (0.91 - 1.06)	0.96 (0.88 - 1.04)
Disagree	63.0	0.87 (0.75 - 0.99)	0.84 (0.72 - 0.97)
Strongly disagree	62.2	0.98 (0.81 - 1.14)	0.95 (0.77 - 1.12)
P trend		0.14	0.038

RR (95% CI) = relative risk (95% confidence interval)

Table 3-4 Bivariate and multivariate (Model 2) relationships of area-level characteristics and active transportation to school (N = 3 997)

Area-Level Characteristic	% Engaged in Active Transportation	Bivariate Model RR (95% CI)	Multivariate Model 2 RR (95% CI)
School Characteristics			
Bicycle storage available in a safe location			
No	68.3	1.00	1.00
Yes	61.1	0.89 (0.74 - 1.01)	0.94 (0.77 - 1.09)
Has walk/bike to school days and/or walking school bus programs			
No	64.3	1.00	1.00
Yes	58.8	0.90 (0.77 - 1.02)	0.91 (0.74 - 1.06)
Identification of safe walking/biking routes to school			
No	64.4	1.00	1.00
Yes	60.1	0.93 (0.80 - 1.05)	0.95 (0.79 - 1.09)
Neighbourhood Characteristics			
Sidewalk leading to school			
No	57.1	1.00	1.00
Yes	62.8	1.11 (0.79 - 1.37)	1.10 (0.74 - 1.39)
% of roads with sidewalks			
1 (1.45 - 47.20)	58.1	1.00	1.00
2 (47.21 - 64.30)	58.3	1.06 (0.87 - 1.23)	1.11 (0.87 - 1.32)
3 (64.31 - 84.49)	64.2	1.12 (0.93 - 1.27)	1.14 (0.88 - 1.35)
4 (84.50 – 100)	70.4	1.16 (0.97 - 1.32)	1.03 (0.76 - 1.27)
P trend		0.071	0.86
Speed limit of school's road (km/h)			
≤40	59.5	1.00	1.00
50	62.3	1.15 (0.92 - 1.34)	1.27 (0.90 - 1.50)
≥60	69.6	1.23 (0.94 - 1.43)	1.32 (0.96 - 1.53)
P trend		0.12	0.13
% of roads with speed limit ≤60 km/h			
1 (<90)	60.9	1.00	1.00
2 (90 – 93.99)	65.1	1.10 (0.89 - 1.27)	1.06 (0.82 - 1.27)
3 (94 – 99.99)	60.1	1.06 (0.85 - 1.24)	1.08 (0.84 - 1.29)
4 (100)	63.8	1.03 (0.83 - 1.21)	1.05 (0.81 - 1.25)
P trend		0.94	0.78
Total length of roads (km)			
1 (10.7 – 29.2)	55.6	1.00	1.00
2 (29.3 – 37.0)	60.8	1.10 (0.92 - 1.27)	0.99 (0.72 - 1.25)
3 (37.1 – 41.7)	60.8	1.16 (0.97 - 1.33)	1.10 (0.79 - 1.37)
4 (41.71 – 73.7)	73.7	1.32 (1.15 - 1.46)	1.27 (0.94 - 1.52)
P trend		0.0005	0.070
Street connectivity			
1 (lowest connectivity)	55.8	1.00	1.00
2	66.0	1.20 (1.02 - 1.36)	1.07 (0.81 - 1.30)
3	60.7	1.16 (0.97 - 1.32)	0.96 (0.65 - 1.25)
4 (highest connectivity)	70.2	1.24 (1.06 - 1.39)	0.91 (0.56 - 1.25)
P trend		0.020	0.45
Litter in neighbourhood			
No problem	62.1	1.00	1.00
Minor problem	61.6	1.03 (0.89 - 1.15)	1.05 (0.88 - 1.19)
Moderate problem	62.9	0.99 (0.77 - 1.18)	1.11 (0.82 - 1.33)
Major problem	91.8	1.48 (1.24 - 1.57)	1.48 (1.17 - 1.58)
P trend		0.13	0.055
Vacant or shabby housing			
No problem	62.7	1.00	1.00
Minor problem	59.7	0.98 (0.81 - 1.13)	0.91 (0.71 - 1.10)
Moderate problem	72.4	1.07 (0.81 - 1.28)	0.76 (0.44 - 1.09)

Major problem	60.7	1.07 (0.59 - 1.40)	0.73 (0.23 - 1.29)
P trend		0.70	0.11
Neighbourhood SES (median family income, $CAD)			
1 (32 984 – 56 979)	66.5	1.00	1.00
2 (56 980 – 67 400)	66.1	1.01 (0.85 - 1.15)	0.97 (0.75 - 1.16)
3 (67 400 – 80 300)	60.7	0.94 (0.77 - 1.10)	1.02 (0.80 - 1.19)
4 (80 301 – 108 010)	58.9	0.88 (0.72 - 1.04)	0.95 (0.69 - 1.16)
P trend		0.086	0.77
Average temperature (°C)			
1 (-4.45 – 2.75)	62.4	1.00	1.00
2 (2.76 – 4.40)	58.9	1.00 (0.82 - 1.16)	0.71 (0.34 - 1.13)
3 (4.41 – 7.40)	59.5	1.00 (0.83 - 1.16)	0.79 (0.30 - 1.30)
4 (7.41 – 10.60)	68.3	1.04 (0.87 - 1.19)	0.88 (0.27 - 1.42)
P trend		0.64	0.95
Average annual rain (mm)			
1 (326 – 615)	61.7	1.00	1.00
2 (616 – 1335)	62.1	1.02 (0.84 - 1.18)	0.93 (0.59 - 1.23)
3 (1336 – 1700)	66.3	1.01 (0.84 - 1.16)	1.25 (0.79 - 1.50)
4 (1701 – 3360)	60.6	1.02 (0.85 - 1.18)	1.27 (0.82 - 1.50)
P trend		0.82	0.33
Average annual snow (cm)			
1 (87 – 200)	68.2	1.00	1.00
2 (201 – 240)	70.0	1.04 (0.89 - 1.16)	1.10 (0.87 - 1.26)
3 (241 – 310)	51.7	0.85 (0.69 - 0.99)	0.88 (0.59 - 1.13)
4 (311 – 690)	61.8	0.94 (0.79 - 1.07)	0.84 (0.46 - 1.17)
P trend		0.11	0.19
Average annual number of hot days			
1 (0 – 0.63)	56.4	1.00	1.00
2 (0.64 – 4.65)	63.5	1.13 (0.94 - 1.30)	1.19 (0.84 - 1.46)
3 (4.66 – 10.50)	67.8	1.12 (0.92 - 1.28)	1.07 (0.70 - 1.39)
4 (10.51 – 26.00)	65.4	1.14 (0.95 - 1.31)	1.15 (0.74 - 1.46)
P trend		0.16	0.69
Average annual number of cold days			
1 (0 – 4.5)	63.3	1.00	1.00
2 (4.6 – 26.0)	60.9	0.99 (0.82 - 1.14)	1.17 (0.75 - 1.42)
3 (26.1 – 50)	64.9	1.03 (0.86 - 1.18)	1.17 (0.62 - 1.46)
4 (50.1 – 110.5)	61.5	0.96 (0.78 - 1.13)	1.14 (0.45 - 1.49)
P trend		0.87	0.69

Model 2 controls for the significant variables by backwards selection from the first model (gender, family structure, family SES, number of cars in household, and perceived residential neighbourhood safety).
RR (95% CI) = relative risk (95% confidence interval)

Table 3-5. Final multivariate model of the relationships of characteristics of the individual and family, school, and neighbourhood with active transportation to school (N = 3 997)

Characteristic	Multivariate Model 3 RR (95% CI)
Individual and Family Characteristics (Individual-level)	
Gender	
Male	1.00
Female	0.86 (0.80 - 0.91)
Family structure, living with:	
Both mother and father	1.00
One parent and one step-parent	1.10 (1.00 - 1.19)
Single parent	1.07 (0.99 - 1.14)
Other	1.10 (0.94 - 1.24)
Family SES	
Very well off	1.00
Well off	1.08 (1.00 - 1.16)
Average	1.16 (1.08 - 1.24)
Not very well off	1.14 (1.01 - 1.26)
Not at all well off	1.00 (0.80 - 1.19)
P trend	0.0041
Number of cars in household	
0	1.00
1	0.94 (0.82 - 1.04)
2+	0.87 (0.74 - 0.97)
P trend	0.0003
Residential neighbourhood is safe for children	
Strongly agree	1.00
Agree	1.00 (0.94 - 1.07)
Neither agree nor disagree	0.95 (0.86 - 1.03)
Disagree	0.83 (0.70 - 0.95)
Strongly disagree	0.95 (0.76 - 1.11)
P trend	0.019
School Characteristics (Area-Level)	
Has walk/bike to school days and/or walking school bus programs	
No	1.00
Yes	0.89 (0.74 - 1.03)
Neighbourhood Characteristics (Area-Level)	
% of roads with sidewalks	
1 (1.45 - 47.20)	1.00
2 (47.21 - 64.30)	1.11 (0.90 - 1.30)
3 (64.31 - 84.49)	1.17 (0.96 - 1.34)
4 (84.50 – 100)	1.09 (0.87 - 1.28)
P trend	0.35
Speed limit of school’s road (km/h)	
≤40	1.00
50	1.22 (0.92 - 1.43)
≥60	1.26 (0.96 - 1.47)
P trend	0.13
Total length of roads (km)	
1 (10.7 – 29.2)	1.00
2 (29.3 – 37.0)	1.00 (0.76 - 1.22)
3 (37.1 – 41.7)	1.08 (0.85 - 1.29)
4 (41.71 – 73.7)	1.23 (1.00 - 1.42)
P trend	0.031
Litter in neighbourhood	
No problem	1.00
Minor problem	1.05 (0.89 - 1.18)

Moderate problem	1.09 (0.83 - 1.29)
Major problem	1.47 (1.16 - 1.57)
P trend	0.061
Vacant or shabby housing	
No problem	1.00
Minor problem	0.95 (0.77 - 1.11)
Moderate problem	0.83 (0.52 - 1.13)
Major problem	0.76 (0.29 - 1.26)
P trend	0.19
Average temperature (°C)	
1 (-4.45 – 2.75)	1.00
2 (2.76 – 4.40)	0.77 (0.54 - 1.00)
3 (4.41 – 7.40)	0.76 (0.46 - 1.08)
4 (7.41 – 10.60)	0.87 (0.53 - 1.19)
P trend	0.71
Average annual rain (mm)	
1 (326 – 615)	1.00
2 (616 – 1335)	0.94 (0.68 - 1.18)
3 (1336 – 1700)	1.16 (0.76 - 1.42)
4 (1701 – 3360)	1.25 (0.91 - 1.45)
P trend	0.20
Average number of hot days	
1 (0 – 0.63)	1.00
2 (0.64 – 4.65)	1.24 (0.95 - 1.46)
3 (4.66 – 10.50)	1.18 (0.90 - 1.41)
4 (10.51 – 26.00)	1.33 (1.05 - 1.53)
P trend	0.057

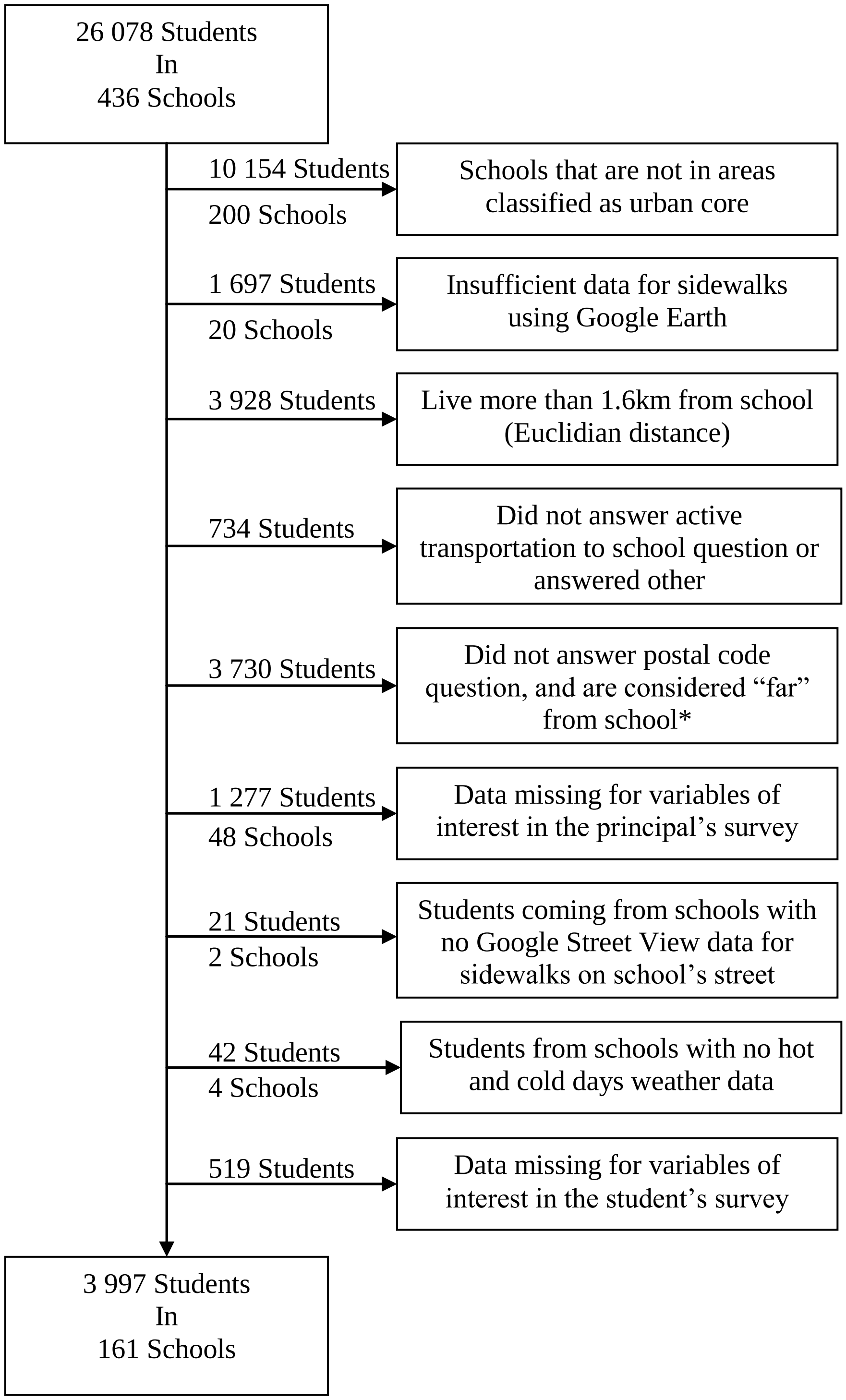
RR (95% CI) = relative risk (95% confidence interval)

Table 3-6 Population attributable risk and the potential for intervention of the correlates of active transportation to school

Characteristic	PAR	Potential to Intervene	Possible Interventions based on literature and interventions for similar issues
Individual Characteristics			
Female gender	7.1%	High	Safe walking programs directed towards females
Not living with both parents	2.8%	Low	
Low family SES (< very well off)	8.8%	Low	
Cars in household (1 or more)	10.8%	Low	
Low perceived neighbourhood safety	2.3%	High	Determine what makes a neighbourhood feel safe and direct intervention towards these factors
Neighbourhood Characteristics			
% of roads with sidewalks (> quartile 1)	9.5%	High	Construction of sidewalks on roads that have none
Total length of roads (> quartile 1)	6.9%	High	Building new schools in areas with more streets; or increasing multi-use trails
No problem with vacant or shabby housing	10.4%	Low	Improve the aesthetics of neighbourhoods where children live
Low average temperature (quartile 1)	16.6%	Low	
High total rain (quartiles 3 and 4)	9.8%	Low	
High number of hot days (> quartile 1)	16.1%	Low	

RR= Relative Risk, PAR = Population Attributable Risk

Figure 3-1 Exclusion flow chart



*Far from school: More than 15 minutes walking, or more than 5 minutes by bike, bus, train, subway, streetcar, ferry/boat, car, motorcycle, moped.

Chapter 4

Active Transportation to School in Canadian Youth: Should Injury be a Concern?

Abstract

Introduction: Active transportation to school provides a means for many youth to incorporate physical activity into their daily routines, and this has obvious benefits for child health. Studies of active transportation have rarely focused on negative health effects in terms of unintentional injury.

Methods: This cross-sectional study is based on the 2010 Canadian Health Behaviour in School-Aged Children survey. A large sample of children aged 11-15 years (n=20 076) was studied. Multi-level logistic regression was used to examine associations between walking or bicycling to school and related injury while accounting for the clustered nature of the data and covariates at both individual and area-levels.

Results: Regular active transportation to school at larger distances (approximately >1.6 km; 1.0 miles) was associated with higher relative odds of active transportation injury (OR: 1.52; 95% CI: 1.08-2.15), with suggestion of a dose-response relationship between longer travel distances and injury (p=0.02).

Conclusion: Physical activity interventions for youth should encourage participation in active transportation to school, while also recognizing the potential for unintentional injury.

Introduction

Active transportation is the engagement in physical activity specifically for travel and includes activities such as walking and bicycling.[1] This mode of transportation provides one means by which children and youth can incorporate physical activity into their daily routines. Indeed, children and youth who walk or bicycle to school have higher overall levels of physical activity, better cardiorespiratory fitness levels, and a healthier body composition.[2-3]

Studies of active transportation in youth have focused on its positive contributions to the maintenance of a healthy body weight and overall physical activity (for a recent synopsis, see Lee *et al.*);[4] however, negative effects of active transportation are also possible. One concern is the occurrence of unintentional injury. Injury is the leading cause of death in Canadian children, accounting for more deaths than all other causes combined.[5] Such possible negative side effects of active transportation to school have not been thoroughly examined in populations of young people.

The objective of this brief report was therefore to evaluate regular active transportation to school and its effects on injury in a large and contemporary national sample of Canadian youth. The study base was the 2009/10 Health Behaviour in School-Aged Children (HBSC) study.

Methods

Overview of Study Design and Measures

HBSC is a general health survey of preadolescent and adolescent children conducted in affiliation with the World Health Organization.[6] In Canada, Cycle 6 of this survey (2009/10) involved administration of both student (n=26 078) and school-level administrator (n=436) questionnaires. We combined these data with environmental measures describing school neighbourhoods that were obtained using geographic information systems (GIS).

Participants

The survey involved a systematic multi-stage cluster sample design that involved students and schools from 11 of 13 Canadian territories and provinces.[6] The sample available for the current analysis was 19 576 students (weighted sample 20 076) from 419 schools. Implicit or explicit consent to participate was obtained from school boards, individual schools, parents/guardians, and students, as per local jurisdictional requirements. The study protocol was reviewed and approved by the General Research Ethics Board of Queen's University (study approval number: GEDUC-430-09).

Key Measures

Based upon a standard self-report module, reports of active transportation injuries were identified for all participants for a 12 month period prior to survey administration.[6] Injuries that required medical attention and occurred (1) in the 'street/road/parking lot' or while (2) 'biking/cycling' or 'walking/running (not for a sports team or exercise)' were operationally defined as active transportation injuries.

Three levels of active transportation to school were identified: (1) youth who did not regularly engage in active transportation; (2) youth who regularly engaged in active transportation to school but lived near their school; and (3) youth who regularly engaged but lived far from school. Participants who reported that their usual mode of transportation to school was "bus, train, streetcar, subway, or boat/ferry" or "car, motorcycle, or moped" were placed in the first category. Students who reported regular active transportation (by walking or bicycling) with travel times either less than 5 minutes for cycling, or less than 15 minutes for walking, were placed in category 2. Those reporting greater lengths of time for walking or bicycling were placed in category 3. Participants who answered ‘other’ were excluded.

Both individual- and area-level variables were considered as potential confounders. Potential individual-level confounders were gender, age, race, perceived family socio-economic status (SES), perceived residential neighbourhood safety, and participation in organized sports. Potential area-level confounders describing the school neighbourhood were urban/rural geographic status, average precipitation levels as reported by Environment Canada, summary measures of total road lengths, street or road connectivity,[7] and speed limits in the 1km buffer surrounding each school, and Canada Census of Population estimates of median household incomes for 2006 (PCensus for MapPoint; Tetrad Computer Applications Inc., Vancouver, BC).

Analysis

Statistical analyses were performed using SAS version 9.2 (SAS Inc., Carry, NC). An initial descriptive analysis was used to characterize the study sample using proportions and measures of central tendency. Modeling was then performed. Examination of the clustered and nested structure of the data revealed an intra-class correlation of 2.6% (0.026) at the school level.[8] We therefore modeled effects at individual and school levels, while accounting for this clustering. Multi-level logistic regression modeling was used with random intercepts permitted for each school. Standardized weights (mean=1.00) were calculated and applied to account for the fact that children from different provinces and territories, school board types, languages of instruction, and urban/rural geographic status had different probabilities of entering the sample.

Following bivariate analyses, multi-level models were built as follows: 1) the active transportation variable and all individual-level factors were entered as risk factors into a model with the injury outcome (Multivariate Model 1); 2) backwards selection methods were performed using a change in estimate of >10% as a selection criterion;[9] then area-level variables were then added to the retained individual-level factors (Multivariate Model 2); 3) backwards selection was re-performed for the final model, using the same change-in-estimate approach (Multivariate Model 3). Conservatively, any covariate whose removal from the model caused a change in estimate greater than 10% or was statistically significant ($p<0.05$) was maintained. In the final model, the inclusion of interaction terms or random betas did not significantly improve the model. Finally, the modeling process was repeated for two specific active transportation injury outcomes, (1) walking or running injuries; (2) cycling injuries.

Results

A weighted sample of 20 076 students from 419 schools was available. About one-third (33.6%) of the sample engaged in active transportation to school and 357 (1.8% of the sample) incurred an active transportation injury (**Table 4-1**). Of these injuries, 68.9% occurred while cycling, 31.1% occurred while walking or running, 45.1% required medical treatment (e.g., placement of a cast or stitches), and 40.6% caused the participant to miss at least one day of activity (including school and/or extracurricular activities). Approximately one injury was reported for every 2 900 hours of exposure to active transportation.

Table 4-2 summarizes bivariate then adjusted models that describe the association between engagement in active transportation and the occurrence of related injury. Odds ratios can be interpreted as relative risks.[10] Model 3 provides final estimates for this relationship while controlling for potential confounders. A statistically significant positive association that followed a graded trend ($p_{trend}=0.02$) was observed, with an adjusted 1.52-fold increase (95% CI: 1.08-2.15) in the relative odds of active transportation injury for youth who regularly engage in active transportation over longer distances. These effects were observed consistently for the two specific active transportation injury outcomes. Two covariates were retained in the final model: age group (OR: 0.75; 95% CI: 0.57-0.97 for ages 14-15 *vs.* 11-13); and urban/rural status (OR: 1.64; 95% CI: 1.14-2.36 for urban *vs.* rural communities; p_{trend}=0.008)

Discussion

The most important finding from this study was that as young people engage in active transportation for longer distances, their risks for active transportation injury increase irrespective of their mode of active transportation.

Many health promotion interventions aim to increase participation in active transportation to school due to its inherent benefits to health.[11] However, these same interventions do not necessarily consider the negative outcomes of active transportation to school such as injury. Our findings therefore contribute to a more comprehensive understanding of this public health issue and associated health promotion messages.

This analysis has limitations. It is difficult to establish temporality in our observed effects due to the cross-sectional design. Our use of self-reported measures of injury and active transportation may have contributed to non-differential misclassification leading to bias of the odds ratios towards no effect. For example, it is quite possible that some of the events that were classified as active transportation injuries were actually recreational. Our lack of detailed information about some relevant contextual factors (e.g., bicycle helmet laws, cycling infrastructure, pedestrian guards and crossings) are a further limitation, and the analysis also does not account for the timing of injuries and whether they were experienced outside of school commuting times. Finally, there is the possibility of selection bias, such that youth not attending school on the day of survey administration may have been more likely to have active transportation injuries which in turn are differentially related to more active transportation to school. If this bias existed, it would again bias our odds ratio estimates towards no effect.

The two main strengths of this research were our use of a large nationally representative sample of students, as well as our focus on the negative side effects of an important public health topic with obvious benefits to health. Such negative health outcomes remain under-studied in the adolescent health promotion literature, and there is a need for future studies to investigate the relative benefits (e.g., reduced obesity) and potential harms (e.g., increased injury, bullying, abduction risks) within the same population.

Public health interventions targeted at increasing active transportation to school in Canadian youth should consider possible unintentional injury outcomes of active transportation. Interventions aimed at increasing physical activity should not lose sight of possible injury-related outcomes. Example interventions include the walking school bus where children travel together in large groups[12] and environmental solutions that foster improvements to walking and cycling infrastructure.[13] If well designed, these population health interventions could have a very positive impact on the physical health of Canadian youth overall, while limiting the potential for associated injuries.

Conclusion

The relationship between active transportation to school and active transportation injury was examined in a nationally representative sample of Canadian youth using multi-level analytical methods. We found a dose-response relationship between active transportation to school and active transportation injury across increasing travel distances. We suggest that new and existing interventions promoting active transportation to school should further incorporate injury control strategies in order to continue to encourage physical activity in the safest possible manner.

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Table 4-1 Description of sample demographics, engagement in active transportation to school, and the occurrence of active transportation injuries (N = 20 076)

	Weighted N	% engage in active transportation	p value
Demographic Characteristics			
Gender			<0.0001
Male	9 531	36.4	
Female	10 545	31.0	
Age			<0.0001
11-13	11 671	39.1	
14-15	8 405	27.2	
Race			
White only	14 315	31.1	
White and other	974	36.6	0.95
Aboriginal	1 120	38.5	0.22
Other	3 667	40.8	0.004
Family SES			<0.0001
Well off	11 490	32.5	
Average	6 771	34.1	
Not well off	1 815	38.0	

	Weighted N	% of population	% of active transportation injuries
Active Transportation Injuries			
Total Injuries	357	1.8	
Gender			
Male	183	1.9	
Female	174	1.7	
Age group			
11-12	234	2.0	
13-15	123	1.5	
Activity at time of injury			
Walking/running	111		31.1
Cycling	246		68.9
Required Medical Treatment	161		45.1
Loss of 1+ Days of Activity	145		40.6

Table 4-2 Results of multi-level logistic regression analyses examining potential risks for active transportation injury associated with engagement in active transportation to school (N = 20 076)

Injury Type: Active Transportation Level	**N**	**% injured**	**Bivariate Model OR (95% CI)**	**Model 1[1] OR (95% CI)**	**Model 2[2] OR (95% CI)**	**Model 3[3] OR (95% CI)**
Active Transportation Injuries						
No	13 488	1.5	1.00	1.00	1.00	1.00
Yes – short distance	5 049	2.1	1.17 (0.92-1.50)	1.13 (0.88-1.45)	1.12 (0.87-1.44)	1.13 (0.88-1.44)
Yes – long distance	1 539	2.7	1.56 (1.10-2.21)	1.53 (1.08-2.17)	1.55 (1.09-2.20)	1.52 (1.08-2.15)
P trend			0.01	0.02	0.02	0.02
Walking/Running Injuries						
No	13 488	0.4	1.00	1.00	1.00	1.00
Yes – short distance	5 049	0.8	1.54 (1.01-2.35)	1.59 (1.04-2.44)	1.52 (0.99-2.34)	1.49 (0.98-2.29)
Yes – long distance	1 539	0.8	1.47 (0.78-2.79)	1.52 (0.80-2.88)	1.44 (0.76-2.73)	1.43 (0.76-2.70)
P trend			0.06	0.05	0.08	0.08
Bicyling Injuries						
No	13 488	1.1	1.00	1.00	1.00	1.00
Yes – short distance	5 049	1.3	1.02 (0.76-1.39)	0.95 (0.70-1.29)	0.95 (0.70-1.31)	0.98 (0.72-1.33)
Yes – long distance	1 539	1.9	1.59 (1.05-2.40)	1.49 (0.98-2.25)	1.59 (1.05-2.41)	1.55 (1.03-2.35)
P trend			0.08	0.20	0.13	0.13

1 adjusted for individual-level variables (gender, age, race, family SES, perceived neighbourhood safety, participation in organized sports)
2 adjusted for significant individual level variables (age) and area-level variables (urban/rural geographic status, street connectivity, speed limit surrounding school, % roads with speed limit ≤60 km/h, total length of roads, school neighbourhood median family income, total rain, and total snow)
3 adjusted for age and urban/rural geographic status

Chapter 5

General Discussion

5.1 Summary of Key Findings

The purpose of this thesis was to investigate issues surrounding active transportation to school, with a focus upon the health of youth. The specific objectives were twofold: (1) to investigate the importance of a large number of potential correlates of active transportation to school, at multiple levels (individual and area), and (2) to study the potential association between regular active transportation to school and active transportation injury in a national sample of Canadian youth.

The first manuscript focused upon correlates of active transportation. Study findings suggested that a variety of factors at the individual- and area-levels were associated with engagement in active transportation to school. Population attributable risk (PAR) estimates and the possibility for public health intervention (modification) were both considered in the identification of correlates that held the most importance as potential determinants. Male gender, increased perceived levels of neighbourhood safety, higher sidewalk coverage on streets, and increased lengths of streets were deemed to be the most important correlates of active transportation to school. Identification of these variables provides a directional focus for school and neighbourhood-based interventions.

The second manuscript focused on injury as an outcome of active transportation in order to determine whether there were negative consequences of what is generally viewed as a positive health behaviour, and if so, the extent and severity of such negative consequences. Study findings identified a positive association between regular active transportation to school and the occurrence of active transportation injury. As the distance traveled by foot or bicycle increased, risks for injury also increased. However, the prevalence of active transportation injuries was small, and most injuries were not severe. The findings suggest that interventions that aim to increase active transportation to school should not be discouraged because of possible negative outcomes, but should instead emphasize the need to take precautions in order to minimize the risk for such negative outcomes.

The samples from manuscript 1 and 2 were different, based on inclusion and exclusion criteria. Manuscript 1 only included students living within close proximity to urban schools for the following reasons: 1) our need to use postal codes as a proxy for student home address; and 2) our hope to examine this association among students who are unlikely to receive bussing to school. Manuscript 2 had no such geographical limitations. These inclusions were different to manuscript 1, in order to have a larger sample size to improve power due to the small number of active transportation injuries, to examine these injuries across urban and rural locations, and to examine the effect of distance to school on active transportation injury. Due to these differing criteria, the prevalence of regular active transportation to school differed in the two samples. Approximately 63% of the sample used for the first manuscript walked and bicycled to school, while approximately 34% of the sample used for the second manuscript walked and bicycled to school.

5.2 Internal Validity

There are several common threats to the internal validity of any epidemiological study, including selection bias, information bias, and confounding. Selection bias is a distortion in the risk estimate for the primary exposure variable when there is a systematic difference between those included in the study and those that are not included. Information bias, or measurement error, is the misclassification of participants based on their exposure or outcome (or both) and that leads to bias in risk estimation due to these errors. Confounding occurs when the lack of control for certain variables masks the true effect of the focal relationship. The different aspects of internal validity will be discussed for manuscript one, followed by manuscript two.

It is possible that selection bias may be present in manuscript one. If there was a systematic difference between students selected for the survey compared to those that were not selected (e.g., absent from school the day of the survey, or parental consent was declined) while being related to both the outcome (active transportation to school) and one or more of the exposures, the risk estimates may be distorted when compared to their true effects. Volunteer bias results due to differences between the sample and the sampling population (e.g., more females volunteering than males). This is unlikely to have affected the associations in each manuscript due to their biological and social relationships, and is more likely to have affected the prevalence of exposures or outcomes (e.g. for example, if females were more likely to volunteer than males). In terms of measurement error, calculated distances to school may have been misclassified due to two sources of error. First, the geographic centre of the postal code was used as a proxy for student residential addresses. Although this was found to be a relatively accurate way of using a proxy for home location in past (particularly urban) studies,[1] it is possible that this level of accuracy would differ across Canada. Second, student reports of travel mode and travel time to school were also likely subject to error in recall and estimation. And finally, although many possible covariates were included in the analysis, there is still the possibility of uncontrolled or residual confounding. In particular, while measures of adult transportation habits[2] and parental perceptions of safety[3] are possible correlates of active transportation to school, they were not available for inclusion in the analysis.

Manuscript two also has the potential for selection bias. Students that did not participate in the HBSC survey may have differed based upon their experiences with the injury outcome measure. For example, those who experienced a severe injury may have been less likely to attend school due to their circumstances, thus leading to over-representation of the proportion of minor injuries. If there was also a true association between active transportation to school and active transportation injury, and selection occurred in association with both the exposure and the outcome, the resulting risk estimate would be distorted, most likely towards no effect. Similar to the first manuscript, volunteer bias may have been present, but is unlikely to have affected the association between active transportation to school and active transportation injury, and instead was more likely to have affected prevalence and power. Information bias may have existed as the estimation of distances to school was based solely on student reports of travel mode and travel time; hence misclassification was likely non-differential by injury outcome. Due to the operational definition of an active transportation injury, some injuries may also be misclassified as active transportation injuries, thus there may be outcome misclassification by exposure status, also biasing risk estimates towards the null. There is also the possibility that active transportation injuries may be underreported or even “overshadowed” by other injuries that occurred in the past twelve months, further biasing the odds ratio towards the null. Finally, I identified one other opportunity for differential misclassification; students reporting active transportation injuries may have changed their method of transportation to school, yet again biasing the odds ratio towards the null.

Finally, although numerous possible covariates of active transportation to school were included in manuscript 2, there is the possibility of residual confounding. For example, the presence of sidewalks was not included in the analysis; some studies suggest that the presence of sidewalks is associated with the exposure, active transportation to school,[4-6] and that it may be related to active transportation injury.[7] Residual confounding can also be caused by poorly measured confounders; it is possible that confounders, such as family SES, may have been poorly or incompletely measured.

In summary, there is the possibility of selection bias, information error, and residual confounding in both of these manuscripts. Due to the comparable design of each study, biases are similar between the two analyses.

5.3 External Validity

Both manuscripts examined aspects of active transportation to school in a large, nationally representative sample of Canadian youth. If one overlooks the threats to internal validity, the results of each study may be generalizable to populations that extend beyond the sample of young people that were studied.

Results from manuscript one suggested that there were a variety of factors from the individual/family, school, and neighbourhood environments that potentially affected decisions to engage in active transportation to school in urban youth living in close proximity to school. One threat to the external validity is the possibility of variations between school policies surrounding transportation to school (e.g., bussing policies and not allowing active transportation in certain areas). It is therefore reasonable to apply these findings to youth from across Canada who also live in urban environments near their schools and share similar policies as the sampled population. In addition, specific relationships between some of the correlates and active transportation to school (such as gender and distance to school) can likely be generalized across Canada as well, due to the strength and consistency of findings from this thesis as well as other studies performed around the world, for example, studies from Canada,[8-10] the United States,[3, 11] Australia,[2] the United Kingdom,[12] and Switzerland.[13] I would argue that the findings from this study may be even more generalizable that other published studies, as many different factors that could influence active transportation were included (individual/family, school, and neighbourhood characteristics), the sample came from a wide geographic area, and appropriate multi-level modeling methods were used. In comparison, of all the studies investigating the correlates of active transportation to school, only three include adjusted modeling for all three aspects (individual/family, school, and neighbourhood),[10-12] only two of these utilize multi-level modeling,[10,12] and all were performed in relatively small geographic areas, or not an entire country: Ontario,[10] California,[11] and Norfolk county, UK.[12]

Findings from manuscript two suggested that there was a direct relationship between active transportation to school and active transportation injury among the sample of HBSC youth under study. Although there was oversampling of the northern territories, this was accounted for with the weights applied throughout the analysis. On balance, it is reasonable to generalize that there is a positive association between active transportation to school and active transportation injury in Canadian youth. However, it is less reasonable to generalize the severity of the injuries resulting from school travel, due to the likely underestimation of minor active transportation injuries. Similarly, the proportion of injuries incurred from walking or bicycling may differ across many communities based on policy and infrastructure.

In addition to generalizing these ideas and relationships to populations of youth in Canada, it may be reasonable to extend these results to youth in industrialized countries, for example, the United States,[3, 11] Western Europe,[12, 13] and Australia,[2] due to similar findings for the correlates of active transportation to school. Items that may prevent generalizing such relationships mostly surround the specific qualities of school policies.

5.4 Causation

Most epidemiological research aims to determine whether relationships of interest are causal. Several of Hill's criteria of causation (temporality, consistency, biological plausibility, dose-response relationship, strength of association, and statistical significance) will be discussed with reference to each manuscript separately.[14]

Manuscript 1

Temporality. The temporality of an association is weighted heavily when determining whether a relationship is causal. The HBSC data that were used in this thesis are cross-sectional in nature, creating difficulties when causality is considered. However, many of the variables under study were more likely to have been in place before decisions were made to engage in active transportation to school. For example, gender, age, family socio-economic status, the number of siblings, and aspects of the built environment (e.g., sidewalks, street lengths, street connectivity), are all more likely to be established before active transportation to school is considered. Thus, temporality of such associations may exist.

Consistency. Consistent relationships are evident for many of the different correlates of active transportation to school within the literature and the current manuscript. Correlates that have been consistently identified in past studies include gender, race, distance to school, urban/rural setting (see **Tables 2-1** and 2-**3** in the literature review). Due to the lack of consensus across many of the other possible correlates, consistency is difficult to establish.

Plausibility. The relationships investigated in manuscript one are based upon a social-ecological framework for health behaviours suggesting that there are different spheres of influence on an individual's behaviour.[15] In addition, this study fits into a larger body of literature suggesting that there are multiple correlates of active transportation to school at different conceptual levels. Hence, our findings are plausible when considered in light of existing theory.

Dose-Response. A dose-response relationship was observed for several of the correlates of active transportation to school: as the number of cars in a household increase (over multiple categories), engagement in active transportation to school decreased (RR point estimates for 0, 1, and 2 cars per family were 1.00, 0.94, and 0.87) while as the total length of roads surrounding a school increased, so did active transportation to school (RR of 1.00, 1.00, 1.08, and 1.23 for quartiles 1 through 4, respectively). Similar relationships were observed for the perception of neighbourhood safety, the presence of vacant or shabby houses in the neighbourhood, and the average annual rainfall, however these associations were less clear-cut, or were not statistically significant.

Strength and Statistical Significance of Associations. The strengths of the associations were measured using multi-level logistic modeling and were described as relative risks (RR). The results displaying the associations between the correlates and active transportation to school only depict weak associations, however, this is common for the relationships between environmental level effects and behaviours.[16] Although the risk estimates are weak, there are many people that are affected by the aspects of the environment. Several correlates reached statistical significance with $p<0.05$ (for example: gender and the number of cars in the household), although a more liberal level of statistical significance ($p<0.2$) was applied to the area-level measurements, due to issues of power. Statistically significant trends were noted for family SES (not very well off *vs.* very well off: RR=1.14; p=0.0041), number of cars in the household (2 or more cars *vs.* 0 cars: RR=0.87; p=0.0003), perceived neighbourhood safety (disagree *vs.* strongly agree: RR=0.83; p=0.019), and the total length of roads in the neighbourhood (quartile 4 *vs.* quartile 1: RR=1.23; p=0.031).

Manuscript 2

Temporality. For manuscript two, the temporality of the focal relationship cannot be confirmed, thus it is not possible to conclude that regular active transportation to school leads to higher rates of active transportation injury. Due to the small number of active transportation injuries, minimal severity, and the likelihood that time has passed since the last injury, it is more likely that active transportation to school leads to active transportation injury, rather than the inverse.

Consistency. Consistency of this relationship between active transportation to school and active transportation injury is difficult to determine due to the small body of literature in this subject area. However, consistency was demonstrated through further analyses; the associations between active transportation to school and walking or bicycling active transportation injuries showed similar results to general active transportation injury, as seen in Chapter 4, **Table 4-3**.

Plausibility. In terms of biological plausibility, the relationship between active transportation to school and active transportation injury follow the general and well characterized relationship between physical activity and injury.[17-19]

Dose-Response. There is evidence of a dose-response relationship for the relationship between active transportation to school and active transportation injury: as distance to school increased, the risk for injury increased (short distance: OR=1.13, 95% CI: 0.88-1.44; long distance: OR=1.52, 95% CI: 1.08-2.15; p_{trend}=0.02). This further strengthens the argument for causality in this association.

Strength and Statistical Significance of Associations. The strength of the associations were measured using multi-level logistic modeling and were described as odds ratios. However, because of the rarity of the outcome, active transportation injury, the odds ratio provides a good approximation of the relative risk.[20] A moderate association between the exposure and outcome was noted and was also statistically significant (OR=1.52, 95% CI: 1.08-2.15). Despite the relatively large sample size, this manuscript also suffered from issues with statistical power, as there were very few active transportation injuries in the sample population (N=357, or 1.8% of sample).

In summary, several of Hill's criteria for causal inference were met in both manuscripts. Although causality cannot be confirmed in either of these studies, it is reasonable to suggest that the relationships may in fact be causal.

5.5 Strengths of the Thesis

This thesis contains two unique manuscripts utilizing a large, nationally representative sample of Canadian students. There are few studies that examine the correlates of active transportation to school in Canada and there is limited information surrounding the relationship between active transportation to school and active transportation injury.

Manuscript one is one of the few existing studies that examine correlates of active transportation to school that simultaneously considers factors from the individual and family, school, and neighbourhood, while using the appropriate multi-level modeling techniques. Very few studies have examined these correlates of active transportation to school as factors from the individual/family, school, and neighbourhood in an adjusted model[10-12] and only two of these studies have used multi-level modeling.[10,12] In addition, these studies have been performed in relatively small geographic areas, which does not permit the inclusion of certain variables such as climate or the urban/rural status of the school and neighbourhood.[10-12]

To my knowledge, manuscript two is the first study to investigate the focal relationship between active transportation to school and active transportation injury. A previous study only compared crude rates of injury across different methods of travel to school.[21]

Employing multi-level modeling was a methodological strength of this thesis. Multi-level modeling does not assume that the participants are independent. The HBSC uses stratified cluster sampling to obtain survey participants, and as students attending one school are likely more similar than students between two schools, this is an appropriate modeling technique. In addition, multi-level modeling allows for the simultaneous study and control of variables at multiple levels (e.g., level 1: individual/family; and level 2: school and neighbourhood).

Finally, the use of several modern data sources and software (e.g., ArcGIS, Google Street View, and Google Earth) was also a strength and novel aspect of this thesis. The use of

ArcGIS (with appropriate map data) allowed analyses over a wide geographic area. Similarly, the use of Google Street View (Google Inc., Mountain View, CA), allowed analysis from a centralized location as opposed to direct visual audits at hundreds of locations across Canada.

5.6 Future Research Directions

This thesis has identified areas of research that could benefit from further investigation. School programs aimed at increasing active transportation to school should be objectively evaluated. Although the results from the first manuscript provided non-statistically significant associations due to the low number of schools included in that analysis, it is possible that there may be positive effects between such programs and engagement in active transportation to school. More thorough observational or experimental studies that evaluate the effectiveness of programs such as a the walking school bus,[22] bicycle rack availability and safety, and the identification of safe routes to school across large number of schools would benefit the current body of literature surrounding correlates of active transportation to school. Once there is foundational observational research, further study via randomized controlled trials may be warranted.

Although the nature of the data available for this thesis did not include qualitative measures of the environment, it is likely that this information would also provide insight into the correlates and outcomes of active transportation to school. For example, the quality of the active transportation infrastructure (e.g., sidewalks) may have an effect on the decision on whether to walk to school, or the risk for injury. Historically, this would have required direct observational audits, but with the improving imaging software (e.g., Google Street View), this would be a realistic option for this field of research.

Manuscript two provides a foundation for further research surrounding active transportation injuries as an outcome of regular active transportation to school. However, a more complete understanding would prove valuable. Further observational studies comparing the risks for injury across the varying methods of transportation to school while simultaneously controlling for covariates (via multi-level modeling) are warranted. Randomized-controlled trials could simultaneously assess the effect of interventions (e.g., the walking school bus) on both rates of active transportation to school (walking or cycling to school as the usual mode of transportation) and active transportation injuries (injuries incurred while traveling to and from school). To my knowledge, interventions that have been implemented to increase active transportation to school have not reported on the rates of injury, or the severity of such injuries. In addition, a better understanding of the etiology of active transportation injuries in youth is needed to inform policy for prevention efforts.

5.7 Public Health and Policy Implications

Results from the first manuscript suggest that there are many factors that are associated with active transportation to school. Because I considered whether these factors are modifiable and estimated their potential impact through the calculation of a population attributable risk (PAR) estimates, I was able to compose a short list of what was determined to be the most important correlates of active transportation to school. These included gender, perception of neighbourhood safety, sidewalk coverage along streets in school neighbourhoods, and the total length of streets in school neighbourhoods. In order to create well-rounded interventions focused around active transportation to school, outcomes, such as injury, should also be considered.

Interventions can be targeted at the individual and family in order to increase active transportation to school and to improve safety while walking or cycling to school. The LEAP program aimed to help girls develop and maintain a healthy lifestyle through education, a healthy school environment, and through parent and teacher encouragement.[23] This program was assessed through a randomized controlled trial conducted within a population of 2 744 girls in 24 high schools in South Carolina.[24] Results suggested that more girls (44.5%) that attended intervention schools recalled one or more 30 minute blocks of physical activity in a three day recall period compared to those that attended the control schools (36.4%).[24] Similar programs could be used to increase female engagement in active transportation to school.

Other programs target different correlates of active transportation. For instance, one part of the ENACT program focuses on increasing active transportation to school through resident-led neighbourhood initiatives that aim to increase the perception of safety through safety in numbers.[25] ENACT provides tools for those looking to make their community a safe place for play and physical activity.[25] Many communities in the United States have utilized these tools and include projects such as parent-led walking groups and improvements to bicycle infrastructure.[25] It also contains a database for those interested in such policies that are implemented across different communities.[25] Programs such as this would likely increase the general safety of walking and cycling to school and may possibly reduce the risk for active transportation injury, although the effectiveness of these programs remains yet to be measured.

Although interventions such as the walking school bus were not found to be associated with a higher amount of active transportation to school in this thesis, other research suggests that there may be a positive association between such programs and active transportation to school.[26] These programs may promote safety through adult supervision. In addition, school siting and municipality policies could be reviewed to consider active transportation when building new schools[27] by further considering location (cost versus convenience while considering bussing costs), and infrastructure that may encourage safe active transportation to school (e.g. car-free zones and sidewalks).

Finally, interventions that target aspects of the neighbourhood are likely to have an effect on both participation in active transportation to school and active transportation injuries. For existing schools, improvements to the existing active transportation infrastructure, such as the construction of bicycle paths, improved sidewalks, addition of crosswalks, and traffic diversion techniques may affect both rates of walking and cycling to school, and risk for injury; results from the Safe Routes to School program in California found that adjustments such as these increased the percentage of students engaging in active transportation.[28] The effect of interventions, such as these on the rates of injury, have not been estimated. Studies of more general populations of cyclists have found that clearly marked bicycling infrastructure (such as bicycle lanes, paths, and routes) provide a safer means for transportation via bicycle than does on street or alongside pedestrian cycling.[29]

5.8 Conclusion

There are many aspects of the individual/family, school, and neighbourhood environments that are associated with decisions to engage or not in active transportation to school. Second, while active transportation is obviously associated with the potential for improved health, it also likely increases the risk for active transportation injuries. Interventions that focus on increasing rates of active transportation to school should also consider the outcomes of active transportation to school, particularly active transportation injury, in order to make a well-rounded improvement to youth health. Future studies in this research area could focus on qualitative measures of the environment and programs, in addition to the etiology of active transportation injuries obtained while walking or bicycling to school.

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Appendix A
HBSC Survey Methodology

Overview

This thesis used data from the 2009/2010 Health Behaviour in School-Aged Children (HBSC) survey. HBSC is a cross-sectional survey that collects information on a variety of health-related behaviours, determinants of health, and personal and demographic characteristics in children in grades 6-10 across Canada. HBSC is funded internationally by the World Health Organization, and in Canada, by the Public Health Agency of Canada and also Health Canada. A total of 43 countries in Europe and North America participated in the 2009/2010 survey cycle. In addition to the student information that is gathered from the HBSC, there is also a school-based administrator questionnaire that is completed by a principal or designate at each of the participating schools that inquires about school policy, programs, and information about the school's neighbourhood. In Canada, geographic and other contextual measures of the neighbourhood surrounding each school are also obtained using geographic information systems.

Sampling Strategy

In Canada, a single stage cluster sampling strategy was implemented to obtain survey participants, in accordance with the international protocol.[1] For the 2009/2010 cycle all provinces and territories participated, with the exception of New Brunswick and Prince Edward Island. Students from the territories and some of the provinces were over-sampled and a sample weight was calculated to produce nationally representative estimates. A total of 26 078 students participated from 436 schools, with an overall response rate of 75%.

The primary sampling unit of the HBSC is the school classroom. Each classroom with the requisite age/grade levels in the same school had the same probability of being selected for the survey administration. Classes were systematically selected from an ordered list based on school jurisdiction, province or region, language, public or Catholic designation, community size, and community location. Youth attending private schools (with the exception of those in the territories) or special needs school, and those who were home-schooled or institutionalized were excluded. Permission to participate in the survey was obtained from the school board, school, parents or guardians (via explicit or implicit consent determined by school board policy), and individual students. The students participated in the survey on a voluntary basis. Ethics approval for the Canadian HBSC survey was obtained from the Queen's University General Research Ethics Board, and approval for my specific analyses were obtained from the Queen's Health Research and Affiliated Teaching Hospitals Ethics Review Board.

Survey Administration

The HBSC is a classroom-based survey that is administered by teachers during the school day over approximately 45 minutes. In order to maintain anonymity, each student sealed their unsigned survey into an envelope before returning the booklet to their teachers. The administrator questionnaire was completed by a principal or designate and returned with the surveys from the students. Canadian data collection occurred from October 2009 until May 2010 for the 2009/2010 HBSC cycle.

1. Currie C, Griebler R, Inchley J, et al. *Health Behaviour in School-aged Children (HBSC) Study Protocol: Background, Methodology and Background Items for the 2009/10 Survey*. Edinburgh:CAHRU & Vienna: LBIHPR, 2010. http://www.hbsc.org (accessed 11 Apr 2012).

Appendix B

Key HBSC Questions

Active Transportation to School

25. How long does it usually take you to travel to school from your home?

1 ☐ Less than 5 minutes
2 ☐ 5-15 minutes
3 ☐ 16-30 minutes
4 ☐ 31 minutes to 1 hour
5 ☐ More than 1 hour

26. On a typical day, the MAIN part of your journey TO school is made by…

1 ☐ Walking
2 ☐ Bicycle
3 ☐ Bus, train, streetcar, subway or boat/ferry
4 ☐ Car, motorcycle or moped
5 ☐ Other

Active Transportation Injury

Many young people get hurt or injured from activities such as playing sports or fighting with others at different places such as the street or home. Injuries can include being poisoned or burned. Injuries do not include illnesses such as measles or the flu. The following questions are about injuries you may have had during the past 12 months.

43. During the past 12 months, how many times were you injured and had to be treated by a doctor or nurse?

- [1] ☐ I was not injured in the past 12 months
- [2] ☐ 1 time
- [3] ☐ 2 times
- [4] ☐ 3 times
- [5] ☐ 4 times or more

If you had more than one injury, think only about the one most serious injury that you had during the past 12 months that was treated by a doctor or nurse. The next questions are about your one most serious injury (the injury that took the most time to get better). If you were not injured, answer "I was not injured in the past 12 months" for each question.

44. Where were you when this one most serious injury happened? *(Check the one best answer to describe your most serious injury)*

- [1] ☐ I was not injured in the past 12 months
- [2] ☐ At home/in yard (yours or someone else's)
- [3] ☐ School, including school grounds, during school hours
- [4] ☐ School, including school grounds, after school hours
- [5] ☐ At a sports facility or field (not at school)
- [6] ☐ In the street/road/parking lot
- [7] ☐ Other location

45. What were you doing when this one most serious injury happened? *(Check the one best answer to describe your most serious injury)*

- [1] ☐ I was not injured in the past 12 months
- [2] ☐ Biking/cycling
- [3] ☐ Playing or training for sports/recreational activity
- [4] ☐ Skating (including inline skating, skateboards, ice skating)
- [5] ☐ Walking/running (not for a sports team or exercise)
- [6] ☐ Riding/driving in a car or other motor vehicle
- [7] ☐ Fighting
- [8] ☐ Paid or unpaid work
- [9] ☐ Other activity

46. **Did this <u>one most serious injury</u> need medical treatment such as the placement of a cast, stitches, surgery, or staying in a hospital overnight?**

- [1] ☐ I was not injured in the past 12 months
- [2] ☐ Yes
- [3] ☐ No

Appendix C

Summary of Key Study Variables

Table C-1 Summary of key study variables included in Manuscript 1 and 2

Study Construct	Variables Employed to Measure Construct	Data Source[A]	Level[B]
Key Exposure – Manuscript 1			
Individual and family factors	**Age/grade** **Gender** **Race** **Distance to school** -estimated by postal codes or time and travel method **Number of cars in the household** **Family structure** -parents' marital status, or legal guardians **Number of siblings** **Family SES** -how "well off" the child's family is **Perceived neighbourhood safety** -response to question: *generally speaking, I feel safe in the area where I live*	**HBSC** **HBSC** **HBSC** **HBSC** **HBSC** **HBSC** **HBSC** **HBSC** **HBSC**	**1** **1** **1** **1** **1** **1** **1** **1** **1**
School factors	**Bicycle racks** -available in safe locations **Walking School Bus and/or Walk/Bike to School Days** -program to promote active transportation **Identification of safe routes to school**	**Admin** **Admin** **Admin**	**2** **2** **2**
Neighbourhood factors	**Street connectivity*** -intersection density -average block length -connected node ratio **Speed limits** -of the road on which the school is located -the percentage of roads with a speed limit ≤60km/h* **Street lengths*** -total distance (km) of roads in the buffer **Sidewalks*** -percentage of roads with a sidewalk **School sidewalks** -the presence of a sidewalk on the street the school is located **Neighbourhood aesthetics** -presence of litter, or shabby buildings **Socioeconomic status**	**GIS** **GIS** **GIS** **GE and GIS** **Google Street View** **Admin** **Cens**	**2** **2** **2** **2** **2** **Admin** → **2** **2**

	-Neighbourhood-level median household income **Regional climate (by historical averages)** -number of “hot” days -number of “cold” days -total precipitation -average rainfall -average snowfall	 **Environ Canada**	 **2**
Key Outcomes – Manuscript 1			
Active Transportation	**Walking or Bicycling to school**	**HBSC**	**1**
Key Exposure – Manuscript 2			
Active Transportation	**Walking or bicycling to school** **-**short distance (approximately 1.6 km) -long distance (approximately 1.6 km)	**HBSC**	**1**
Key Outcomes – Manuscript 2			
Injury	**Physical activity injuries occurring in the street or while biking, walking, and/or running** -injuries obtained that are likely related to active transportation	**HBSC**	**1**
Covariates – Manuscript 2			
Individual factors	**Age/grade** **Gender** **Race** **Family SES** - how “well off” the child’s family is **Participation in organized sports** **Perceived neighbourhood safety** -response to question: *generally speaking, I feel safe in the area where I live*	**HBSC** **HBSC** **HBSC** **HBSC** **HBSC** **HBSC**	**1** **1** **1** **1** **1** **1**
Neighbourhood factors	**Urban/rural status** **Street connectivity*** -intersection density -average block length -connected node ratio **Street lengths*** -total distance (km) of roads in the buffer **Speed Limits** -of the road on which the school is located -the percentage of roads with a speed limit <60km/h* **Regional climate (by historical averages)** -average rainfall -average snowfall **Socioeconomic status**	**CHASS** **GIS** **GIS** **GIS** **Environ Canada** **Cens**	**2** **2** **2** **2** **2** **2**

	- Neighbourhood-level median household income		

* In the 1-km radius buffer that surrounds the school

Data Source[A]

Admin = HBSC Administrator’s survey
Cens = Census data via PCensus
CHASS = Canadian Census Analyzer: 2006 Census/Postal Code Conversion File
Environ Canada = Environment Canada
GE = Google Earth
GIS = GIS via ArcGIS
Google Street View = Google Street View
HBSC = Student HBSC survey

Level[B]

1 = Individual-level (individual and family characteristics)
2 = Area-level (school and neighbourhood characteristics)

Appendix D
Collection of Geographic Information Systems (GIS) Data

Many variables included in this thesis came from geographical sources. Several of these variables were obtained from a 1-km buffer surrounding each school, while others were measured at a specific point(s). The descriptions of the variables and their collection follow.

Measures from CanMap Route Logsitics (DMTI Spatial Inc., Markham, ON) and ArcGIS (ESRI, version 9.3)

Distance from school

Distances between particpants' homes and their school were estimated using direct distance from the geographical centre of their postal code to the school address. Postal code locations were geo-coded onto a layer in ArcGIS; the geographic centre of the postal code area was selected as the point location. The Euclidian distance was then calculated between each student's postal code and their school's address.

Street connectivity measures

Using the Network Analyst Extension, nodes were placed on every street intersection, or at each street's dead-end, within the 1 km buffer surrounding each school. Some nodes were erroneously placed (e.g., on a turn in a road) and required manual removal. Nodes that had 1 or 2 intersecting streets were categorized as dangle-nodes (dead-ends and cul-de-sacs), while nodes with more intersecting streets were categorized as real nodes (true intersections). ArcGIS provided a summed total of the number of each type of node. In order to calculate the connected-node ratio for each school's neighbourhood, the number of real nodes was divided by the total number of nodes. Intersection density was calculated by dividing the number of real nodes by the total land area. Average block length was calculated by dividing the length of streets by the number of real nodes. In order to calculate an overall street connectivity measure, a principal component factor analysis was performed for each manuscript with the connected-node ratio, intersection density, and average block length variables.

Speed limit of school's road

The speed limit of the school's road was obtained by selecting the road on which the school was located. This information was attached to each road segment. If the school was located on an intersection, the road of the school's address was selected.

Street lengths

The total length of streets in the each school's buffer was obtained from a summed total produced by the software.

Percentage of roads with speed limits <60km/h

The total length of streets in each school's 1 km buffer at each different speed limit was gathered from the software. This information was then summed to determine the percentage of roads with speed limits <60km/h.

Measures from Google Earth and Google Street View (Google Inc., Mount View, CA)

Percentage of streets with sidewalks

The road network for a school's 1 km buffer was extracted from ArcGIS and saved as a kml file. The kml file was opened in Google Earth where the road network overlayed onto the Google Earth satellite images. Sidewalks were detected along streets by zooming, panning, or using the Google Street View option that is embedded in Google Earth. Any street segment that did not possess a sidewalk on either side of the street was deleted from the road network. After deletions, the revised road network was imported back into ArcGIS allowing sidewalk distances to be calculated.

Sidewalk on school's street

Each school was located on Google Street View using the school's address. The location of each school was confirmed visually. If the Google Street View image confirmed that there was a sidewalk on either side of the street on which the school was located, this variable was categorized as "yes", otherwise it was categorized as "no". In cases where a school was located on an intersection, the street of the school's address was observed for the presence of a sidewalk.

Measures from PCensus for MapPoint (Tetrad Computer Applications Inc., Vancouver, BC)

Neighbourhood socioeconomic status

Neighbourhood SES (median household income) was measured in the 1 km buffer surrounding each school, based upon the 2006 Canadian Census, using PCensus for MapPoint software. Each school was located with the MapPoint Software. A 1 km buffer was constructed around each school's location and 2006 census information was obtained for the 1 km buffers. The overall median household income was calculated by weighting each census dissemination block by the total population for each dissemination block included in the buffer.

Measures from Environment Canada

Regional Climate

The X,Y coordinates were obtained from each school's location in ArcGIS. This information was then entered into Environment Canada's website to find the closest weather station to each school:

http://www.climate.weatheroffice.gc.ca/advanceSearch/searchHistoricData_e.html?Prov=ON&StationID=9999&Year=2012&Month=4&Day=10&timeframe=1.

This website provides summary information on various climate measures over time. The historical averages, over at least 15 years between 1971 and 2000, for each measure of interested were then calculated.

Appendix E

A priori Power Calculations

As there is no established method for calculating power (or sample size) in multi-level analyses, power was estimated using a classical power equation and the design effect for the HBSC survey. The design effect accounts for clustering and was estimated at 1.2, as suggested by existing precedents.[1]

Table E-1 Estimated power for detecting active transportation to school associations with selected exposures (Manuscript 1)

	N adjusted	% exposed	N exposed	r	RR	p**	p0	p1	d	za/2	Z(1-b)	Power
Street Connectivity*	2083	0.5	1041	1	1.2	0.3	0.27	0.33	0.05	1.96	0.76	77.5%
	2083	0.5	1041	1	1.5	0.3	0.24	0.36	0.12	1.96	4.01	100%
Street Lengths*	2083	0.5	1041	1	1.2	0.3	0.27	0.33	0.05	1.96	0.76	77.5%
	2083	0.5	1041	1	1.5	0.3	0.24	0.36	0.12	1.96	4.01	100%
School Sidewalks*	2083	0.5	1041	1	1.2	0.3	0.27	0.33	0.05	1.96	0.76	77.5%
	2083	0.5	1041	1	1.5	0.3	0.24	0.36	0.12	1.96	4.01	100%
Bicycle Racks Available	8333	0.7	5833	0.43	1.2	0.3	0.26	0.32	0.05	1.96	2.8	99.8%
	8333	0.7	5833	0.43	1.5	0.3	0.22	0.33	0.11	1.96	8.18	100%
Walking School Buses	8333	0.2	1666	4	1.2	0.3	0.29	0.35	0.06	1.96	2.64	99.6%
	8333	0.2	1666	4	1.5	0.3	0.27	0.41	0.14	1.96	8.90	100%
Distance from School*	2083	0.5	1041	1	1.2	0.3	0.27	0.33	0.05	1.96	0.76	77.5%
	2083	0.5	1041	1	1.5	0.3	0.24	0.36	0.12	1.96	4.01	100%
Cars per Capita*	2083	0.5	1041	1	1.2	0.3	0.27	0.33	0.05	1.96	0.76	77.5%
	2083	0.5	1041	1	1.5	0.3	0.24	0.36	0.12	1.96	4.01	100%
Number of Siblings*	2083	0.5	1041	1	1.2	0.3	0.27	0.33	0.05	1.96	0.76	77.5%
	2083	0.5	1041	1	1.5	0.3	0.24	0.36	0.12	1.96	4.01	100%
Climate variables *	2083	0.5	1041	1	1.2	0.3	0.27	0.33	0.05	1.96	0.76	77.5%
	2083	0.5	1041	1	1.5	0.3	0.24	0.36	0.12	1.96	4.01	100%

Table E-2 Estimated power for detecting active transportation injury associations (Manuscript 2)

	N adjusted	% exposed**	N exposed	r	RR	p	p0	p1	d	za/2	Z(1-b)	Power
Injury	11666	0.3	3500	2.33	1.2	0.1	0.09	0.11	0.02	1.96	1.15	87.6%
	11666	0.3	3500	2.33	1.5	0.1	0.09	0.13	0.04	1.96	5.21	100%
Severe Injury	11666	0.3	3500	2.33	1.2	0.03	0.02	0.03	0.005	1.96	-0.46	32.1%
	11666	0.3	3500	2.33	1.5	0.03	0.02	0.03	0.01	1.96	1.49	93.1%

* Comparing the highest and lowest quartile (except for walking school buses and bicycle rack availability)

** Estimated using data from the Greater Toronto Area[2]

$N_{adjusted}$ is the sample size adjusted for the design effect

$N_{exposed}$ is the number of students exposed

r is the ratio of unexposed to exposed

RR is the detectable relative risk

p is the proportion of students who have the outcome (i.e., actively commute to school, or have active transportation related injuries)

p_0 is the prevalence of active transportation/injury in the *unexposed*

p_1 is the prevalence of active transportation/injury in the *exposed*

d is the difference between p_1 and p_0

$z_{\alpha/2}$ is the level of significance

Design effect estimated at 1.2.

Manuscript 1: Total Adjusted N= 8,333. Quartile N= 2,083

Manuscript 2: Total Adjusted N=11,666.

Power = $\Phi\ Z_{(1-\beta)} = \Phi\ [d\ [(nr)/p(1-p)(1+r)]^{1/2} - Z_{\alpha}$

1. Janssen I, Katzmarzyk PT, Boyce WF, et al. Overweight and obesity in Canadian adolescents and their associations with dietary habits and physical activity patterns. *J Adolescent Health*. 2004;**35**:360-7.

2. Buliung RN, Mitra R, Faulkner G. Active school transportation in the Greater Toronto Area, Canada: An exploration of trends in space and time (1986–2006). *Prev Med* 2009;48:507-12.

Appendix F

Additional Tables – Manuscript 2

Table F-1 Bivariate and multivariate models including covariate data

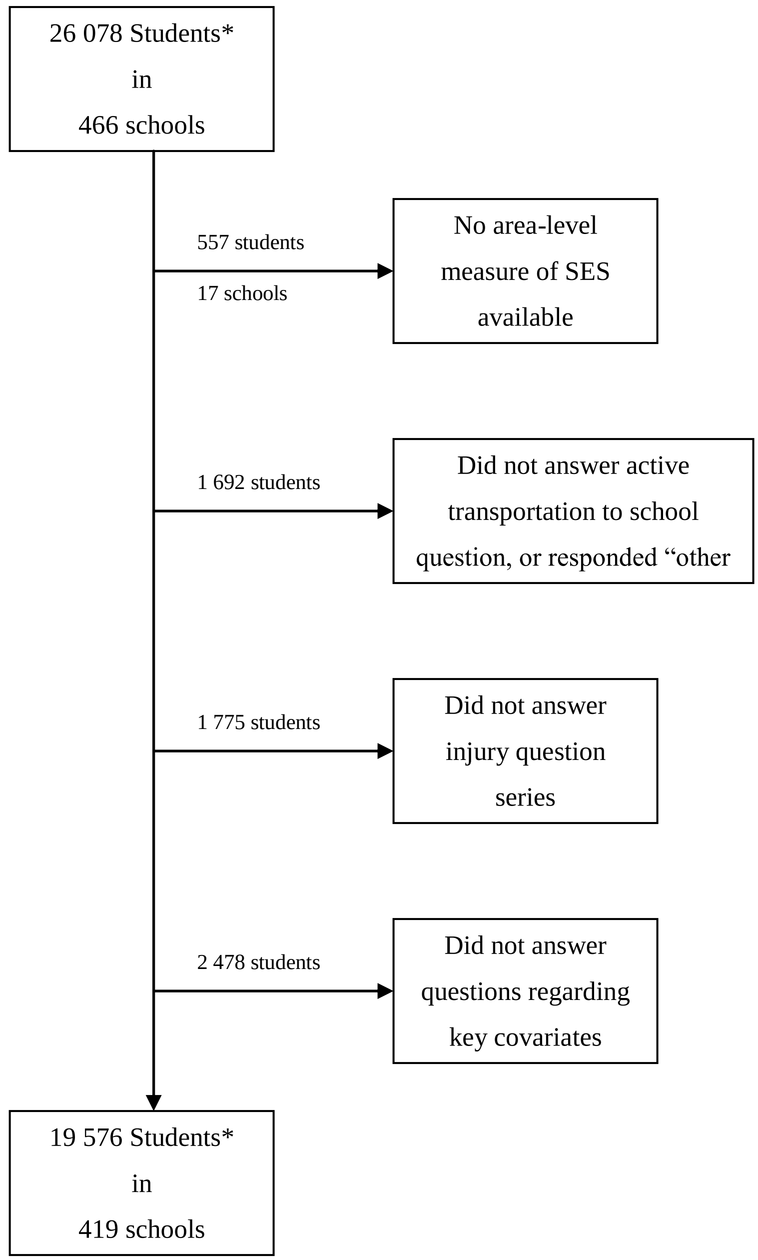
	N	% with AT injury	Bivariate Relationships - Injuries OR (95% CI)	Model 1 – All Individual Level Variables OR (95% CI)	Model 2 – Area-Level variables with significant individual-level variables OR (95% CI)	Model 3 – Final Model
Active Transportation to School						
No	13488	1.5	1.00	1.00	1.00	1.00
Yes – short distance	5049	2.1	1.17 (0.92-1.50)	1.13 (0.88-1.45)	1.12 (0.87-1.44)	1.13 (0.88-1.44)
Yes – long distance	1539	2.7	**1.56 (1.10-2.21)**	**1.53 (1.08-2.17)**	**1.55 (1.09-2.20)**	**1.52 (1.08-2.15)**
P trend			**0.01**	**0.02**	**0.02**	**0.02**
Individual-Level Covariates						
Gender						
Male	9531	1.9	1.00	1.00	-	-
Female	10545	1.7	0.83 (0.67-1.02)	0.84 (0.68-1.04)		
P value			0.08	0.10		
Grade						
6-8	11671	2.0	1.00	1.00	1.00	1.00
9-10	8405	1.5	**0.75 (0.57-0.97)**	**0.76 (0.59-0.99)**	0.76 (0.58-1.01)	0.75 (0.57-0.97)
P value			**0.03**	0.04	0.06	0.03
Race						
White only	14315	1.7	1.00	1.00	-	-
White other	974	2.5	1.41 (0.92-2.17)	1.37 (0.89-2.11)		
Aboriginal	1120	1.5	0.90 (0.54-1.51)	0.89 (0.53-1.49)		
Other	3667	2.0	1.24 (0.93-1.66)	1.18 (0.88-1.59)		
Family SES						
Well off	11490	1.5	1.00	1.00	-	-
Average	6771	1.7	0.90 (0.72-1.14)	0.89 (0.71-1.13)		
Not well off	1815	1.9	0.73 (0.49-1.10)	0.70 (0.46-1.05)		
P trend			0.12	0.07		
Neighbourhood is safe for children						
Strongly agree or agree	15247	1.7	1.00	1.00	-	-
Neither agree nor disagree	3328	1.9	1.16 (0.88-1.54)	1.15 (0.87-1.53)		
Strongly disagree or disagree	1501	2.3	1.36 (0.94-1.96)	1.34 (0.93-1.93)		
P trend			0.07	0.09		
Participation in organized sports						
Yes	10895	1.6	1.00	1.00	-	
No	9181	2.0	1.21 (0.98-1.50)	1.23 (0.99-1.53)		
P value			0.08	0.06		
Area-Level Covariates						
Urban/Rural Status of School Location						
Rural	5041	1.3	1.00	-	1.00	1.00
Small Urban Centre	1540	1.5	1.32 (0.70-2.48)		1.20 (0.59-2.45)	1.39 (0.75-2.60)
Urban	13495	2.0	**1.65 (1.14-2.38)**		1.92 (1.05-3.51)	**1.64 (1.14-2.36)**
P trend			0.007		**0.04**	**0.008**
Street connectivity						
1 (lowest)	4644	1.4	1.00	-	1.00	-
2	4557	1.8	1.41 (0.90-2.20)		1.36 (0.76-2.42)	
3	5928	2.0	**1.53 (1.00-2.34)**		1.52 (0.83-2.77)	
4 (highest)	4947	1.8	1.48 (0.96-2.28)		1.50 (0.74-3.02)	
P trend			0.08		0.31	
Speed limit of school's road (km/h)						
≤40	3611	2.3	1.00		1.00	-
50	7907	1.8	0.95 (0.63-1.44)		0.87 (0.54-1.39)	
≥60	8558	1.5	0.74 (0.48-1.12)		0.79 (0.45-1.38)	
P trend			0.09		0.39	

% of roads with speed limit ≤60 km/h						
0	3533	1.6	1.00	-	1.00	-
1-84.9	5000	1.9	1.27 (0.79-2.06)		1.07 (0.62-1.85)	
85-94.1	4667	1.5	1.18 (0.73-1.90)		0.64 (0.29-1.40)	
>95	7076	2.0	1.46 (0.94-2.26)		0.75 (0.36-1.59)	
P trend			0.12		0.68	
Total length of roads (km)						
1 (3.7-18.3)	3640	1.4	1.00	-	1.00	-
2 (18.4-27.8)	5127	2.0	1.37 (0.85-2.20)		0.90 (0.48-1.70)	
3 (27.9-38.2)	4773	2.0	1.58 (0.99-2.52)		0.92 (0.44-1.92)	
4 (38.3-74.1)	6536	1.7	1.37 (0.87-2.15)		0.78 (0.35-1.73)	
P trend			0.23		0.49	
Neighbourhood Median Family Income (CAD $)						
1 (32,500-53,200)	4567	1.8	1.00	-	1.00	-
2 (53,201-62,870)	5139	1.8	0.91 (0.60-1.36)		0.91 (0.59-1.41)	
3 (62,871-77,100)	5432	1.8	0.91 (0.61-1.37)		0.88 (0.56-1.38)	
4 (77,101-113,160)	4938	1.8	0.90 (0.59-1.37)		0.85 (0.53-1.36)	
P trend			0.64		0.50	
Total rain (mm)						
1 (123-610)	1030	2.2	1.00	-	1.00	-
2 (611-900)	3272	1.8	0.84 (0.48-1.48)		0.78 (0.42-1.46)	
3 (901-1630)	8881	1.8	0.73 (0.43-1.23)		0.60 (0.32-1.14)	
4 (1631-3617)	6893	1.7	0.66 (0.38-1.14)		0.60 (0.33-1.09)	
P trend			0.09		0.10	
Total snow (cm)						
1 (88-211)	3357	1.7	1.00	-	1.00	-
2 (212-267)	4974	2.1	1.10 (0.73-1.68)		1.11 (0.68-1.82)	
3 (268-416)	4061	1.9	1.14 (0.73-1.77)		1.33 (0.80-2.24)	
4 (417-854)	7684	1.5	0.84 (0.55-1.26)		1.09 (0.65-1.84)	
P trend			0.31		0.68	

Appendix G

Exclusion Flow Chart for Manuscript 2

Figure G-1 Exclusion flow chart for Manuscript 2



*=unweighted

Appendix H

Ethics Approval

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

Queen's University

March 21, 2011

This Ethics Application was subject to:

☐ Full Board Review
Meeting Date:
☒ Expedited Review

Ms. Kathleen Gropp
Department of Community Health and Epidemiology
c/o Emergency Medicine Research
Angada 5-315
Kingston General Hospital

Dear Ms. Gropp,

Study Title: Determinants and Outcomes of Active Transportation Among Canadian Youth

Co-Investigators: Dr. William Pickett, 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 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

March 24, 2011
Date

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

Study Code: EPID-341-11

- **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**