Pedestrian Traffic Safety and Outdoor Active Play Among 10 – 13 Year Olds in a Mid-Sized Canadian City

By

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Abstract

Objectives: This study examined the associations between objective and perceived measures of pedestrian traffic safety in the home neighbourhood with outdoor active play among 10- to 13-year-olds. It also determined if the association between objectively measured pedestrian safety and outdoor active play is moderated by parents' perceptions of pedestrian safety.

Methods: This was a cross-sectional study of 10- to 13-year-olds (N = 458) from Kingston, ON, Canada (population 123,798). Outdoor active play was measured over 7 consecutive days using a combination of data from activity logs, accelerometers, Global Positioning System loggers, and Geographic Information System. 1 km road network buffers were used to define participants' home neighbourhoods. Within these buffers Geographic Information System software and data were used to create traffic volume, traffic calming, traffic speed, pedestrian infrastructure, and overall pedestrian safety indexes. Parents' perceptions of these pedestrian safety domains were obtained by questionnaire. General linear models were used to examine the relationships of interest. Several covariates were adjusted for in these models.

Results: The average outdoor active play was 38.3 min/day (27.6 SD). The overall perceived and objective pedestrian safety indexes were not associated with outdoor active play ($p > 0.1$); however, significant associations were observed for some of the specific domains of pedestrian safety. Children whose parents perceived moderate or high traffic speeds in their neighbourhood had outdoor active play values that were 0.35 (SE=0.10, p=0.021) and 0.20 (SE=0.15, p=0.048) SD units higher, respectively, than children whose parents perceived low traffic speed. By comparison to children from neighbourhoods in the lowest tertile, children from the highest traffic volume tertile had higher outdoor active play levels (0.26, SE=0.12, p=0.029), while children from neighbourhoods in the moderate traffic calming tertile (-0.28, SE=0.11, p=0.008) and the moderate pedestrian infrastructure tertile (-0.25, SE=0.11, p=0.023) had lower outdoor active play levels. There were no interactions between the objective and perceived measures (p>0.05).

Conclusions: In this study of 10- to 13-year-olds from a mid-sized city there was some albeit inconsistent evidence that outdoor active play was lower in children residing in the most pedestrian safe neighbourhoods.

Co-Authorship

This thesis, titled *Pedestrian Traffic Safety and Outdoor Active Play Among 10 – 13 Year Olds in a Mid-Sized Canadian City*, is the work of Andrew Linh Nguyen under the supervision of Dr. Ian Janssen. The data used in this thesis are from the Active Play Study, for which Chao Xue was the lab coordinator and Dr. Janssen was the primary investigator. The idea to study pedestrian safety as a predictor of outdoor active play was a collaborative effort between Andrew Linh Nguyen and Dr. Ian Janssen.

Andrew Linh Nguyen conducted the literature review, SPSS dataset management, statistical analyses, interpretation of results, and writing of the thesis chapters. Dr. Ian Janssen provided technical and general guidance and edited the thesis. In addition, Chao Xue helped with the data collection and cleaning, and study recruitment.

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List of Acronyms

CI	confidence interval
OR	odds ratio
RR	relative risk
MVPA	moderate-to-vigorous physical activity
GIS	geographic information system
GPS	global positioning system

Chapter 1

General Introduction

1.1 Overview

Over the past few decades physical activity levels among children and adolescents have declined drastically worldwide.[1] Only 19% to 23% of 11- to 13-year-olds from 39 different countries met the recommended 60 minutes of moderate-to-vigorous physical activity (MVPA) on a daily basis based on self-reported data.[2] Even more troubling, objectively measured data on a representative sample of 5- to 17-year-old Canadians suggests that only 9% accumulate the recommended 60 minutes of MVPA on a daily basis.[3] The low proportion of children and adolescent not meeting the physical activity guidelines reflects that they are not doing well in at least one type of physical activity, which include organized sports and programs, physical activity performed as part of the school curriculum (e.g., physical education), active transportation, and active play.[4-5] ParticipACTION's most recent report card on physical activity in Canadian children and adolescents assigned a D+ grade for active play,[3] which suggests that active play is a type of physical activity that needs to be addressed among young Canadians.

While there is no consensus on the definition of active play, it has often been described as a spontaneous, self-motivated, fun, and unstructured form of physical activity.[1,5,6] The benefits of outdoor active play extend beyond increased energy expenditure and the physical health benefits of physical activity. Active play also facilitates improved social bonding (e.g. ability to co-operate with peers) and an increased ability to cope with emotions (e.g., decrease anxiety, aggression).[7] Similarly, it has been suggested that the decline of outdoor active play in recent decades is associated with decreases in a children's sense of personal control, increases in the inability to manage emotions, and increases in social isolation.[8]

To develop effective interventions that address the decline of outdoor active play, researchers need to understand the determinants of this behaviour. One potential determinant is pedestrian traffic safety, which is a reflection of traffic speed, traffic calming, traffic volume and pedestrian traffic infrastructure.[9] Several previous studies have shown that parents who are worried about pedestrian traffic safety restrict their children's independent mobility and outdoor play.[10-15] A consistent limitation of these studies is the use of subjective measures of the exposure variables (e.g., perceived traffic speeds) and outcome variables (e.g., questionnaire measures of active play and physical activity). It has been documented that there is a poor agreement between objective and subjective measures of traffic safety[16] and between objective and subjective measures of physical activity.[17,18] Therefore, the use of self-reported measures in previous studies examining the association between traffic safety and physical activity likely led to considerable misclassification of these variables, which would have led to underestimated or overestimated associations between traffic safety and active play. It is also important to note that all of the previous studies on this topic have been conducted in large metropolitan centres such as Toronto, Canada and Melbourne, Australia. These findings may not be generalizable to areas with less people and less traffic.

1.2 Scientific and Public Health Significance

Despite the fact that public health programs have given great attention to increasing child physical activity levels in recent years, the physical activity levels of Canadian children remain low.[1] The lack of effectiveness of these programs may reflect their emphasis on organized, adult led and supervised activities – such as organized sport and physical education at school - rather than unorganized child led activities such as outdoor active play.[5] Pedestrian traffic safety and parental concerns of the lack of safety may be important determinants of outdoor active play.

Knowledge about the associations and interrelations among pedestrian traffic safety and active play could potentially be used to help develop interventions that aim to address the decline in active play an overall physical activity levels among young people.

1.3 Thesis Objectives and Hypotheses

Objective 1: To investigate the independent associations between objective and perceived measures of pedestrian traffic safety in the home neighbourhood with objectively measured outdoor active play among 10- to 13-year-old children. I hypothesize that both objective and perceived pedestrian traffic safety will be positively associated with active play. That is, young people will play more if they live in a neighbourhood with more traffic safety features (e.g., less traffic volume, slower traffic speeds, more pedestrian infrastructure) and in a neighbourhood that is perceived as being more safe.

Objective 2: To investigate whether the association between objectively measured traffic safety and outdoor active play is moderated by parents' perceptions of traffic safety. I hypothesize that the strength of the relationship between objectively measured traffic safety and children's active play will be stronger when parental concerns of traffic safety are high.

1.4 Research Approach and Study Sample

This thesis project is based on data from a cross-sectional study that was designed to investigate outdoor active play levels and the determinants and health outcomes of outdoor active play amongst 10- to 13-year-olds from Kingston, ON. Outdoor active play was objectively measured over one week. Pedestrian traffic safety of the home neighbourhood of each participant was measured objectively using Geographic Information System software and subjectively using a questionnaire.

1.5 Thesis Organization

This is a manuscript-based thesis that includes four chapters. Chapter 1 provides a general summary of the topic area and explains the objectives of the thesis. Chapter 2 critically appraises the literature examining the association between measures of pedestrian traffic safety (e.g., traffic speed, traffic calming, traffic volume) with physical activity and outdoor active play levels. Chapter 3 is the manuscript. Chapter 4, the general discussion, summarizes the main results, strengths and limitation of the study, future research directions, and my contribution to the research. Lastly, the appendices provide additional details on some of the study methods that could not be included in the manuscript.

1.6 References

1. Tremblay MS, Gray CE, Akinroye K, Harrington DM, Katzmarzyk PT, Lambert EV, et al. Physical activity of children: a global matrix of grades comparing 15 countries. Journal of Physical Activity and Health. 2014;11(Suppl 1):S113-25.
2. Currie C, Zanotti, C, Morgan, A, et al. Social determinants of health and well-being among young people. Health Policy for Children and Adolescents. 2012;6(6):272.
3. Tremblay MS, Barnes, J, LeBlanc, A, & Janson, K. Are Canadian kids too tired to move? WellSpring. 2016;27 p. 1-4.
4. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Medicine & Science in Sports & Exercise. 2000;32(5):963-975
5. Janssen I. Active play: an important physical activity strategy in the fight against childhood obesity. Canadian Journal of Public Health. 2014;105(1):e22-7.
6. Faulkner G, Mitra R, Buliung R, Fusco C, Stone M. Children's outdoor playtime, physical activity, and parental perceptions of the neighbourhood environment. International Journal of Play 2015;4(1):84-97.
7. Burdette HL, Whitaker RC. Resurrecting free play in young children: looking beyond fitness and fatness to attention, affiliation, and affect. Archives of Pediatrics & Adolescent Medicine. 2005;159(1):46-50.
8. Gray P. The decline of play and the rise of psychopathology in children and adolescents. American Journal of Play. 2011;3(4):463.
9. Carver A, Timperio A, Hesketh K, Crawford D. Are safety-related features of the road environment associated with smaller declines in physical activity among youth? Journal of Urban Health. 2010;87(1):29-43.

10. Cecil-Karb R, Grogan-Kaylor A. Childhood body mass index in community context: neighborhood safety, television viewing, and growth trajectories of BMI. Health & Social Work. 2009;34(3):169-77.

11. Kalish M, Banco L, Burke G, Lapidus G. Outdoor play: A survey of parent's perceptions of their child's safety. Journal of Trauma. 2010;69(4 Suppl):S218-22.

12. Weir LA, Etelson D, Brand DA. Parents' perceptions of neighborhood safety and children's physical activity. Preventive Medicine. 2006;43(3):212-7.

13. Esteban-Cornejo I, Carlson JA, Conway TL, Cain KL, Saelens BE, Frank LD, et al. Parental and adolescent perceptions of neighborhood safety related to adolescents' physical activity in their neighborhood. Research Quarterly for Exercise and Sport. 2016;87(2):191-9.

14. Davison KK, Lawson CT. Do attributes in the physical environment influence children's physical activity? A review of the literature. International Journal of Behavioral Nutrition and Physical Activity. 2006;3:19.

15. Valentine G, McKendrick J. Children's outdoor play: Exploring parental concerns about children's safety and the changing nature of childhood. Geoforum. 1997;28(2):219-35.

16. McGinn AP, Evenson KR, Herring AH, Huston SL, Rodriguez DA. Exploring associations between physical activity and perceived and objective measures of the built environment. Journal of Urban Health. 2007;84(2):162-84.

17. LeBlanc AGW, Janssen I. Difference between self-reported and accelerometer measured moderate-to-vigorous physical activity in youth. Pediatric Exercise Science. 2010;22(4):523-34.

18. Lin L, Moudon AV. Objective versus subjective measures of the built environment, which are most effective in capturing associations with walking? Health Place. 2010;16(2):339-48.

19. Gray CE, Barnes JD, Cowie Bonne J, Cameron C, Chaput JP, Faulkner G, et al. Results from Canada's 2014 report card on physical activity for children and youth. Journal of Physical Activity and Health. 2014;11 Suppl 1:S26-32.

Chapter 2

Literature Review

2.1 Outline

The literature review begins by describing key terms and concepts used through the thesis. The second section reviews the health benefits of outdoor active play. Next, the different types of pedestrian traffic safety are described. The literature review then examines the association between pedestrian traffic safety and outdoor active play. Key strengths, gaps, and limitations of this literature are discussed. Other correlates of outdoor active play are also discussed.

2.2 Key Terms and Definitions

2.2.1 Children and Adolescents

A child is defined as someone that is less than 12 years old. The period of adolescence occurs after childhood and before adulthood, from ages 12 to 19. This thesis project focuses on 10- to 13-year-olds, who are considered pre- and early adolescents. This age group was target for three reasons. First, older adolescents are likely to engage in little outdoor active play. Second, compliance issues with the outdoor active play measures would be far more significant in younger children (e.g., recording on the logs). Finally, indoor active play will likely be minimal at this age group compare to younger children. The studies discussed in the literature review include samples of school-aged children and adolescents.

2.2.2 Physical Activity

Physical activity is any sort of bodily movement generated by skeletal muscles that results in energy levels above resting.[1] Physical activity can be categorized into different intensities such as light, moderate, or vigorous. Light-intensity physical activity is defined as any activity generating less than 3 metabolic equivalent (METS). Moderate-intensity activity and vigorous-intensity activity are defined as any activity generating 3 to 5.9 METS and 6 METS or greater, respectively.[2] Children and adolescents accumulate their physical activity through different domains including organized sports and programs, curriculum-based activities at school, active travel, and active play. Organized sports are characterized as structured forms of physical activity (e.g., soccer, dance, and martial arts class) that typically have regulations and rules and are supervised by adults such as a coaches and referees.[3] Curriculum-based activities (e.g., physical education classes in schools) are defined as structured physical activities that occur within an educational environment that promote motor skill development and movement in children. Active travel is a form of transportation that relies upon physical activity, such as walking or biking, to get to the destination (e.g., school, stores).[4] Active play has often been described as a spontaneous, self-motivated, fun, and unstructured form of physical activity.[5-7] The focus of this thesis is on the active play domain of physical activity, with an emphasis on active play performed outdoors.

2.2.3 Geographic Information System and Global Positioning System

Geographic information system (GIS) is a computer system that has the capacity to store, capture, examine and illustrate geospatial data.[8] GIS can be used to objectively measure the traffic safety features described in the next paragraph. Global positioning system (GPS) is a navigation system that can record time stamped latitude and longitude locations as well as direction and speed of movement.[9]

2.2.4 Pedestrian Traffic Safety

Pedestrian traffic safety refers to the extent to which pedestrians are protected from motorized vehicles while on or in proximity to roads. It is a function of the volume and speed of vehicle traffic, traffic calming features that are put in place to reduce the volume and/or speed of vehicle traffic, and pedestrian infrastructure which serves to separate pedestrians from motorized vehicles. Traffic calming consists of physical measures that aim to reduce vehicle speeds and includes crosswalks, speed humps, chicanes (i.e., bend in the road), sidewalk/curb extension (which reduces the road crossing distance for pedestrians), and mini-roundabouts.[10] In this literature review, pedestrian infrastructure refers to physical infrastructure that is designated specifically for use by non-motorists and includes sidewalks, bicycle lanes, and walking paths.

2.3 Active Play Levels of Children

For the third consecutive year, the 2016 ParticipACTION Report Card on children and youth physical activity in Canada had a D- grade for overall physical activity levels.[11] This means that the majority of Canadian children and adolescents do not meet the recommended physical activity levels. The low overall physical activity levels in young Canadian reflects that they are not doing very well in one or more of the specific domains of physical activity such as active play, organized sports, physical education, and active transport. The 2016 ParticipACTION Report Card grades for organized sport and school physical activity domains were in the B range while the grades for the active play and active transportation domains were in the D range.[11] This suggests that efforts aimed at increasing the overall physical activity levels in children and adolescents should focus on these latter two domains.

2.4 Health Benefits of Active Play

Children who are involved in active play are more likely to meet physical activity guidelines and have better cardiovascular fitness, lower blood pressure, and less chance of having overweight or obesity in comparison to children who engage in little or no active play.[12-13] In addition, play provides opportunities for children to interact with others, and through these interactions gain important social skills such as compromise and cooperation.[14] In terms of mental health, active play influences critical thinking and cognitive and language development.[14-17] In addition, participation in active play can decrease children's anxiety, depression, and aggression and bring forth happiness.[14] A recent systematic review of 21 studies suggests that risky outdoor play offers greater health benefits in comparison to activities which avoid risky outdoor play.[18]

2.5 Traffic Safety Concerns

Tremblay et al. (2014) suggested that parent's concerns about the dangers posed by automobile traffic is one of the reasons why children in developed countries have lower outdoor active play levels than children in developing countries.[6] According to Brussoni et al. (2012), 43% of parents in the U.K. are concerned about a lack of traffic safety.[19] Another study from the U.K. concluded that 40% of parents of 7- to 11-year-olds do not allow their children to travel to or from school alone because of concerns about traffic danger.[20]

The increased concerns that parents have about a lack of traffic safety and how this might impact their child is contrary to temporal trends in injuries, which suggest that the road environment is safer than it was in past decades. For example, from 2003 to 2012 the rate of pedestrian injuries and fatalities in Toronto decreased from 20 per 1 million walking trips to 16 per 1 million walking trips.[21] This also highlights that pedestrian injuries and fatalities are rare events. Of the approximately 7 million Canadian children aged 14 of under, 2,414 injured on an annual basis as pedestrians.[22] By comparison, more than 5,957 are injured as passengers in a motorized vehicle.[23] Thus, one could argue that being a passenger in a vehicle is a greater health hazard than being a pedestrian.

2.6 Pedestrian Traffic Risk and Active Play

2.6.1 Traffic Volume

One aspect of pedestrian traffic safety that could impact outdoor active play in children and adolescents is traffic volume. Aarts et al. (2012) found that parents' perceptions of traffic volume in home neighbourhoods, which was calculated based on a 6-item questionnaire derived scale, was not significantly related to active play among 4- to 12-year-old Dutch children.[24] Conversely, Carver et al. (2008) found that 13- to 15-year-old girls' concerns about a high traffic volume (e.g., I think there is heavy traffic in the streets where I live) was negatively associated with their objectively measured MVPA outside of school hours such that each one-unit increase (on a 5-point scale) in concern about heavy traffic was associated with 1.5 minute/day decrease in MVPA.[25] Page et al. (2010) also found a positive relationship between perceptions of high traffic volume and self-reported frequency of active play within girls aged 10 - 11 years.[26] The results of that study indicated that girls who had positive perception of traffic safety of their neighbourhood had a 1.63 (95% CI: 1.14, 2.34) higher odds of engaging in active play in comparison to girls who did not perceive traffic safety in a positive light.[26]

Studies that used GIS to objectively measure features of traffic volume have also reported that traffic volume is associated with physical activity behaviours. All of these studies used cross-sectional designs. Carver et al. (2008) found that the absence of traffic lights in a child's home neighbourhood, which is indicative of low traffic volume, was negatively associated with 8 to 9-year-old girls' physical activity within Melbourne, Australia.[27] Specifically, it was reported that girls were 2.7 (95% CI: 1.2, 2.6) times more likely to participate in 7 or more walking/cycling trips in their neighbourhood if their neighbourhood had 2 or 3 traffic lights by comparison to girls who lived in a neighbourhood with 1 or no traffic lights.[27] However, Carson et al. (2014) found no association between traffic volume and physical activity in pre-school aged children in Kingston, Ontario.[28] In that study, high traffic volume was categorized by roads that have speed limits in excess of 60 km/hr. The limitation of that study was that physical activity in children were parental-reported, meaning that the levels of physical activity could have been over or underestimated.[28] An Australian study also found that having a school route along a busy road was negatively associated with 10 to 12-year-old children's active travel (OR = 0.3; $p \leq 0.05$).[29]

2.6.2 Traffic Speed

The literature examining the relationship between traffic speeds and outdoor active play and other measures of physical activity suggests that both perceived measures of traffic speed and objective measures of traffic speed are important. Faulkner et al. (2015) found that Torontonian parents' concerns about fast drivers in their neighbourhood were inversely related to the duration of their child's active play on weekdays ($p = 0.03$).[7] Their findings suggested that each one-unit increase (on a 5-point scale) in parental concerns about fast drivers in their neighbourhood was associated with a 15 minute/day decrease in active play duration on weekdays. Another study reported that adults who perceived slower traffic speeds on the route to their nearest parks were more likely to have gone to these parks in the past month.[30] This study is important because adults' perception of road traffic speed is a barrier to park access; therefore, it may hamper their children's park-based physical activity such as outdoor play.

A literature review examining the relationship between objectively measured built environment features and physical activity among children found that one of the most consistent relationships observed in the literature was for traffic speed.[31] This relationship was recently confirmed by Oliver et al.'s (2015) cross-sectional study, which found that GIS-measured road speed limits around the school were inversely related to the proportion of after-school time spent in moderate-to-vigorous physical activity (MVPA), as measured with accelerometers, among children and adolescents aged 8 to 13 years.[32] The results of that study suggested that each one percentage increase in the proportion of high to low speed roads in school neighbourhoods was associated with a 2.5% reduction in the proportion of after-school time spent in MVPA.[32]

2.6.3 Traffic Calming

To my knowledge, only two studies, both of which employed a cross-sectional design, have examined the relationship between traffic calming and physical activity measures among children and adolescents. Relative risk (RR) was used in one of the two studies and it is defined as a ratio of the probability of an outcome happening in the exposed group in comparison to the probability of the outcome happening in the unexposed group. A study conducted in the Netherlands found that several different perceived traffic calming measures in the home neighbourhood were positively associated with outdoor active play.[24] These included the positive correlations between the presence of pedestrian crossings without traffic lights among girls aged 4–6 years (RR = 1.14) and boys aged 7–9 years (RR = 1.20), the presence of pedestrian crossings with traffic lights among boys aged 4–6 years (RR = 1.13), the presence of speed humps among boys aged 7– 9 years (RR = 1.25), and the presence of roundabouts among boys age 4- to-6-years (RR = 1.14).[24] In another study of 8 – 9 year olds conducted in Melbourne, Australia, the authors found that the presence of speed humps in the home neighbourhood, which they defined as an 800 m radius around the child's home, was related to accelerometer measured MVPA during afterschool hours among boys ($\beta = 0.23$, $p = 0.015$) and MVPA during non-school hours among girls ($\beta = 0.33$, $p = 0.020$).[33] These regression coefficients suggested that each additional speed hump in the home neighbourhood was associated with 0.23 and 0.33 minute/day increase in MVPA for boys and girls, respectively. An observational study conducted in Toronto, Canada found that the density of traffic lights and pedestrian crossovers were associated with children's participation in active travel to school.[34] It is possible that these associations would be similar for active play since streets are a common location for children to play.[35]

2.6.4 Pedestrian Infrastructure

Only a few studies have examined the association between pedestrian infrastructure, active play, and other physical activity measures within children. Aarts et al. (2012) found that girls aged 10-12 years old who lived near sidewalks were a 1.45 times more likely to engage in outdoor play by comparison to girls who did not have sidewalks in their home neighbourhood.[24] Similarly, a systematic review found that sidewalk and bike lane accessibility in neighbourhoods were positively associated with physical activity in Dutch, Canadian and American children.[36] This may be the case because sidewalks and bike lanes can be an informal play setting and because they can be used by children travel to other outdoor play spaces such as parks or a friend's yard.

2.6.5 Gaps and Limitations of Research Examining the Link Between Pedestrian Traffic Safety and Outdoor Active Play

Most studies examining the association between pedestrian traffic safety and children's physical activity measured overall physical activity (or a specific physical activity intensity), rather than specific physical activity domains such as outdoor active play. This lack of specificity is an important limitation since different physical activity domains are likely influenced by different built environmental attributes. To illustrate this point, it is reasonable to believe that outdoor active play is related to traffic safety in the home neighbourhood, because that is where children play. Conversely, because participation in organized sport typically occurs on designated sports fields and in facilities (e.g., arena, dance studio), it is unlikely to be directly influenced by traffic safety. Ultimately, the lack of specificity of physical activity measures in previous studies may mean that the observed associations are weaker than they would have been had the appropriate domain specific measures of physical activity been examined.

The use of subjective measures of physical activity behaviours and traffic safety measures likely lead to misclassification of these variables, and this misclassification would have led to underestimated or overestimated associations between physical activity and traffic safety. It has been well documented that subjective physical activity measures are poorly correlated with objective measures.[37-38] While several studies examined total physical activity or MVPA using objective measures, [32-33,39] all of the studies looking at active play and pedestrian traffic risk measured active play by questionnaire. [24,26] In a similar vein, objective and subjective measures of built environmental features are also poorly correlated.[40] Despite the fact that several studies examined objective environmental attributes,[27,40-41] most of the studies looking at traffic safety and physical activity were based on self-reported measures of traffic safety. [24,31,42-43]

Most studies examining the association between pedestrian traffic safety and physical activity considered a single measure of traffic safety and did not account for other traffic safety measures. For instance, Carver et al.'s (2008) study of children's physical activity and road features in neighbourhoods did not look at or control for other traffic safety measures such as location-specific speed limits (e.g., residential streets, one – way street) and density of intersections with traffic signs (e.g. 4-way stop).[27] This is problematic for two reasons. First, since traffic safety is a function of several variables, looking at a single variable on its own would not fully capture traffic risk. Second, the relationship between neighbourhood environment (e.g., traffic lights and crosswalks) and physical activity in these studies could have been confounded by these other traffic safety measures. With that said, adjusting for other traffic safety measures in a multivariate model might lead to multicollinearity issues since these safety measures may be highly correlated to each other.

An alternative approach to including all of the individual traffic safety measures in the same regression model would be to create a pedestrian traffic safety index that is based upon multiple measures. For example, an overall scale could be developed based upon measures of traffic speed, traffic calming and traffic volume. Not only would this solve the multicollinearity issue, it would also solve the problem of having a measure of traffic safety that is not comprehensive enough. To my knowledge, this approach has not been used in pedestrian traffic safety and physical activity literature.

Furthermore, previous studies were conducted in larger cities, such as Toronto, Boston, and Melbourne, with populations ranging from 600,000 to over 5 million. Traffic patterns and pedestrian safety are likely very different in less densely populated areas. In addition, larger and mid-size cities have different proportions of suburb types (i.e., transit suburb, auto suburb, and exurban),[71] which may change the domains of pedestrian safety and physical activity levels.[72] For instance, in 2011 46% of the population of Kingston lived in automobile-oriented suburbs, while large cities like Toronto, Vancouver and Montreal have over 80% of the population living in automobile-oriented suburbs.[71] In addition, mid-sized cities have lower proportion of residents living in transit-oriented suburbs in comparison to larger cities (8% vs., 12%).[71]

Lastly, the literature in this area is comprised almost exclusively of cross-sectional studies. Although this limitation is not addressed in my thesis research, it is important to recognize in this critical literature review that the results of cross-sectional studies on their own do not provide evidence of a causal relationship.

2.7 Other Correlates of Active Play

When studying the influence of pedestrian traffic safety on active play within an observational study, it is important to consider the role of confounding variables. Four conditions must be met for a variable to be a confounder.[44] First, it must be an independent cause of the outcome (i.e., outdoor active play). Secondly, it must be correlated with the exposure (i.e., traffic safety). Thirdly, it should not be in the causal pathway between the exposure and outcome. These conditions for confounding were considered when determining the relevant confounders for my research. My decisions were also guided by social ecological models, which posit that physical activity behaviours, such as active play, are influenced by a variety of factors occurring at the intrapersonal, interpersonal, and environmental levels.[45]

At the intrapersonal level, sex, age, ethnicity and socioeconomic status are associated with physical activity, and by extension, active play. Boys are more involved in physical activity and have a greater degree of independent mobility than girls.[46] British children aged 10- to 11-years-old who attended high to middle socioeconomic status schools were involved more in organized sports than children who attended low socioeconomic status schools; however, the children in the less advantaged schools reported that they participated in active play with friends more often.[47] An American study of 4- to 11-year-olds found that older age, female, and a non-Hispanic black race were characteristics relating to a high probability of low active play.[48]

There are several interpersonal correlates of active play. Studies have found that parents can impact their child's physical activity through role modelling, [47] co-participation, facilitation, and encouragement.[49] Positive parental role modelling occurs when parents display the importance of and the passion for physical activity by being physically active themselves. [49-50] Parental co-participation is a type of parental influence where parents engage in physical activities with their children.[49,51] These parental influences are significant and conducive to active travel and organized sports. However, there is no evidence that role modelling and co-participation influence active play, and such influences might not exist because active play is an unstructured and unsupervised activity that does not mirror the types of structured activities parents would role model and which typically do not include parents' involvement.

Although parental role modelling and co-participation may not be relevant for the active play domain of physical activity, there is evidence that facilitation and encouragement are important. One study found that 8- to 9-year-old children whose parents took them to a park at least once per week were seven times more likely to play in a park or playground than children whose parents did not take them.[52] This suggests that participation in active play relies on whether or not parents' restrict their child's independent mobility. An Italian study found that children who had more freedom to roam around their neighbourhood were more likely to play with their peers.[53] In terms of encouragement, Ferrao and Janssen (2015) found that parents' use of verbal cues to encourage their 7- to 12-year-old children to play outside was independently associated with outdoor active play.[54]

A young person's peers can also shape their physical activity behaviour through social support and encouragement.[55-56] Ommundsen et al. (2006) found that peer support positively predicted informal games play in school settings ($\beta = 0.32$, $p < 0.001$) among Norwegian children and adolescents aged 9-15 years.[55] In terms of peer encouragement, perceived peer encouragement was associated with physical activity during the school lunchtime period in New Zealand adolescents.[56] These studies show that peer-focused social groups can increase motivation, persistence for physical activity and ultimately, active play. In terms of sibling support, it was found to be a significant correlate of after-school physical activity among 12-14 year olds ($p = 0.0001$) and of recess physical activity among 12-18 year olds.[56]

At the environmental level, greenspace and physical environments such as street connectivity, and cul-de-sacs could impact a child's active play. Greenspace is defined as the areas devoted for trees, grass, and other plants that are separate from recreational or aesthetic purposes in an urban setting. Janssen and Rosu's (2015) reported that each additional 5% of neighbourhood land area devoted to treed areas was associated with a corresponding 5% increase in the likelihood that children would engage in free-time physical activity outside of school hours.[57] In another large cross-sectional study (n= 6626) of 11- to 15-year-old Canadians, the proportion of neighbourhood land dedicated to park space was not associated with physical inactivity.[58] However, a 10% difference in green space was related to an average increase of 2 minutes/day of physical activity on weekdays in 4-5-year-old Australian boys.[59] Although neighbourhood parks and public greenspaces are easily accessible for youth, these spaces were found to impact physical activity in younger children more so than in older children and adolescents. This may be due to the fact that park amenities, such as monkey bars, slides and swings, may not be engaging for older children and adolescents.

Studies have shown that some built environmental attributes of the streets and roads that do not relate to safety can also have an impact on active play. One attribute is street connectivity, which can be defined as "the directedness or ease of travel between two points which is directly related to characteristics of street design".[60] High street connectivity and walkable environments encourage active travel.[60-61] Conversely, the density of cul-de-sacs, a marker of poor street connectivity, is positively associated with free-time physical activity, perhaps because they provide easily accessible and open areas for youth to engage in unorganized sports and play (e.g., street hockey) near their homes.[58]

Environmental factors could also include variables such as the weather and season. One qualitative study identified the weather and seasons as concerns that deterred 10- to 11-year-olds from participating in active play. According to one participant, "Um sometimes the weather because when it's snowing it's quite alright cos you can go up the slopes and that but when it's raining, you like can't go out you just have to stay in and, like wait for the rain to go off or, just do nothing".[62] Studies that examined adolescents and children's physical activity levels using accelerometers or pedometers also found that seasonality substantially affect their physical activity levels.[63-68] Furthermore, precipitation and wind speed can affect children's physical activity as well. Duncan et al. (2008) found that ambient temperature and rainfall can considerably decrease 5- to 12-year-old children's daily step counts in New Zealand.[69] Another study found that precipitation (inches), wind speed (mph), heating (65°F < mean temperature) and cooling degrees (65°F ≥ mean temperature) were negatively associated with total physical and MVPA in American children.[70]

2.8 Summary

The overall physical activity levels and active play levels of Canadian children and adolescents are alarmingly low.[6] A potential determinant of active play is pedestrian traffic safety. Although several studies have found that traffic safety concerns are negatively associated with children's physical activity levels, there are some consistent limitations and gaps in this literature. For example, these studies have not examined specific domains of physical activity, include mostly self-reported measures of traffic safety and physical activity behaviours, and explore only a single measure of traffic safety. The proposed thesis aims to address these gaps and limitations by specifically examining whether outdoor active play is associated with a comprehensive and objective measure of traffic safety.

2.9 References

1. World Health Organization. Physical activity. [homepage on the Internet]. 2016. [cited 2017 March 19] Available from: http://www.who.int/topics/physical_activity/en/
2. Colley RC, Tremblay MS. Moderate and vigorous physical activity intensity cut-points for the Actical accelerometer. Journal of Sports Sciences. 2011;29(8):783-9.
3. Lipnowski S, Leblanc CM. Healthy active living: Physical activity guidelines for children and adolescents. Paediatrics Child Health. 2012;17(4):209-12.
4. Public Health Agency of Canada. What is active transportation?. [homepage on the Internet]. 2014. [cited 2017 March 19] Available from http://www.phac-aspc.gc.ca/hp-ps/hl-mvs/pa-ap/at-ta-eng.php
5. Janssen I. Active play: an important physical activity strategy in the fight against childhood obesity. Canadian Journal of Public Health. 2014;105(1):e22-7.
6. Tremblay MS, Gray CE, Akinroye K, Harrington DM, Katzmarzyk PT, Lambert EV, et al. Physical activity of children: a global matrix of grades comparing 15 countries. Journal of Physical Activity and Health. 2014;11 Suppl 1:S113-25.
7. Faulkner G, Mitra R, Buliung R, Fusco C, Stone M. Children's outdoor playtime, physical activity, and parental perceptions of the neighbourhood environment. International Journal of Play. 2015;4(1):84-97.
8. Chang KT. Geographic Information System. International Encyclopedia of Geography: People, the Earth, Environment and Technology: John Wiley & Sons, Ltd; 2016.
9. Jones AP, Coombes EG, Griffin SJ, van Sluijs EM. Environmental supportiveness for physical activity in English schoolchildren: a study using Global Positioning Systems. International Journal of Behavioral Nutrition and Physical Activity. 2009;6(1):42.

10. Transportation Association of Canada. Traffic calming in Canadian urban areas. [homepage on the Internet]. 2010. [cited 2017 March 19] Available from: http://data.tc.gc.ca/archive/eng/programs/environment-utsp-trafficcalming-1172.htm#definition_and_purpose_of_traffic_calming
11. Tremblay, M. S., Barnes, J., LeBlanc, A., & Janson, K. Are Canadian kids too tired to move? WellSpring. 2016;27:1-4.
12. Hay J, Maximova K, Durksen A, et al. Physical activity intensity and cardiometabolic risk in youth. Archives of Pediatrics & Adolescent Medicine. 2012;166(11):1022-9.
13. Schaefer L, Plotnikoff RC, Majumdar SR, Mollard R, Woo M, Sadman R, et al. Outdoor time is associated with physical activity, sedentary time, and cardiorespiratory fitness in youth. The Journal of Pediatrics. 2014;165(3):516-21.
14. Burdette HL, Whitaker RC. Resurrecting free play in young children: Looking beyond fitness and fatness to attention, affiliation, and affect. Archives of Pediatrics & Adolescent Medicine. 2005;159(1):46-50.
15. Rodger S, Ziviani J. Play-based occupational therapy. International Journal of Disability, Development and Education. 1999;46(3):337-65.
16. Sturgess J. A model describing play as a child-chosen activity — is this still valid in contemporary Australia? Australian Occupational Therapy Journal. 2003;50(2):104-8.
17. Stagnitti K. Understanding play: The Implications for play assessment. Australian Occupational Therapy Journal. 2004;51(1):3-12.
18. Brussoni M, Gibbons R, Gray C, Ishikawa T, Sandseter E, Bienenstock A, et al. What is the relationship between risky outdoor play and health in children? A systematic review. International Journal of Environmental Research and Public Health. 2015;12(6):6423.

19. Brussoni M, Olsen LL, Pike I, Sleet DA. Risky play and children's safety: balancing priorities for optimal child development. International Journal of Environmental Research and Public Health. 2012;9(9):3134.

20. Hillman, M., Adams, J., & Whitelegg, J. One false move: a study of children's independent mobility. London: Policy Studies Unit Publisher. 1990.

21. Bassil, K., Rilkoff, H., Belmont, M., Banaszewska, A., & Campbell, M. Pedestrian and cycle safety in Toronto. Toronto Public Health. [cited 2017 April 11] Available from: http://www.toronto.ca/legdocs/mmis/2015/hl/bgrd/backgroundfile-81601.pdf

22. Arason N, Boase, P., Belluz, L., Desapriya, E., Dewar, R., Eisan, C., Gane, K., Miller, C., Peddie, S., Todd, V., Wilson, J., Zayoun, M. Countermeasures to improve pedestrian safety in Canada. 2013;1-103.

23. Transport Canada. Canadian motor vehicle traffic collision statistics 2014. [homepage in Internet]. 2016. [cited 2017 May 7] Available from: https://www.tc.gc.ca/media/documents/roadsafety/cmvtcs2014_eng.pdf

24. Aarts MJ, de Vries SI, van Oers HA, Schuit AJ. Outdoor play among children in relation to neighborhood characteristics: a cross-sectional neighborhood observation study. International Journal of Behavioral Nutrition and Physical Activity. 2012;9(1):98.

25. Carver A, Timperio A, Crawford D. Perceptions of neighborhood safety and physical activity among youth: The CLAN study. Journal of Physical Activity and Health. 2008;5(3):430-44.

26. Page AS, Cooper AR, Griew P, Jago R. Independent mobility, perceptions of the built environment and children's participation in play, active travel and structured exercise and

sport: the PEACH Project. International Journal of Behavioral Nutrition and Physical Activity. 2010;7(1):17.

27. Carver A, Timperio AF, Crawford DA. Neighborhood road environments and physical activity among youth: The CLAN study. Journal of Urban Health. 2008;85(4):532.
28. Carson V, Rosu A, Janssen I. A cross-sectional study of the environment, physical activity, and screen time among young children and their parents. BMC Public Health. 2014;14(1):61.
29. Timperio A, Ball K, Salmon J, Roberts R, Giles-Corti B, Simmons D, et al. Personal, family, social, and environmental correlates of active commuting to school. American Journal of Preventive Medicine. 2006;30(1):45-51.
30. Kaczynski AT, Koohsari MJ, Stanis SAW, Bergstrom R, Sugiyama T. Association of street connectivity and road traffic speed with park usage and park-based physical activity. American Journal of Health Promotion. 2014;28(3):197-203.
31. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth. American Journal of Preventive Medicine. 2011;41(4):442-55.
32. Oliver M, Mavoa S, Badland H, Parker K, Donovan P, Kearns RA, et al. Associations between the neighbourhood built environment and out of school physical activity and active travel: An examination from the Kids in the City study. Health & Place. 2015;36:57-64.
33. Carver A, Timperio A, Hesketh K, Crawford D. Are safety-related features of the road environment associated with smaller declines in physical activity among youth? Journal of Urban Health. 2010;87(1):29-43.

34. Rothman L, To T, Buliung R, Macarthur C, Howard A. Influence of social and built environment features on children walking to school: An observational study. Preventive Medicine. 2014;60:10-5.
35. Wheway R, Millward, A. Child's play: Facilitating play on housing estates. Westwood way. 1997. pp.1-74.
36. Oliveira AF, Moreira C, Abreu S, Mota J, Santos R. Environmental determinants of physical activity in children: a systematic review. Archives of Exercise in Health and Disease. 2014;4(2):254-61.
37. LeBlanc AGW, Janssen I. Difference between self-reported and accelerometer measured moderate-to-vigorous physical activity in youth. Pediatric Exercise Science. 2010;22(4):523-34.
38. Lin L, Moudon AV. Objective versus subjective measures of the built environment, which are most effective in capturing associations with walking? Health & Place. 2010;16(2):339-48.
39. Crawford D, Cleland V, Timperio A, Salmon J, Andrianopoulos N, Roberts R, et al. The longitudinal influence of home and neighbourhood environments on children's body mass index and physical activity over 5 years: the CLAN study. International Journal of Obesity. 2010;34(7):1177-87.
40. McGinn AP, Evenson KR, Herring AH, Huston SL, Rodriguez DA. Exploring associations between physical activity and perceived and objective measures of the built environment. Journal of Urban Health. 2007;84(2):162-84.

41. Vries SId, Bakker I, Mechelen WV, Hopman-Rock M. Determinants of activity-friendly neighborhoods for children: Results from the SPACE study. American Journal of Health Promotion. 2007;21(4 suppl):312-6.

42. Rosenberg D, Ding D, Sallis JF, Kerr J, Norman GJ, Durant N, et al. Neighborhood environment walkability scale for youth (NEWS-Y): Reliability and relationship with physical activity. Preventive Medicine. 2009;49(2):213-8.

43. Kerr J, Norman GJ, Sallis JF, Patrick K. Exercise aids, neighborhood safety, and physical activity in adolescents and parents. Medicine and Science in Sports and Exercise. 2008;40(7):1244-8.

44. McNamee R. Confounding and confounders. Occupational and Environmental Medicine. 2003;60(3):227.

45. Sallis JF, Owen N, Fisher E. Ecological models of health behavior. Health behavior: theory, research, and practice 5th ed San Francisco: Jossey-Bass. 2015:43-64.

46. Mitchell C, Clark A, Gilliland J. Built environment influences of children’s physical activity: Examining differences by neighbourhood size and sex. International Journal of Environmental Research and Public Health. 2016;13(1):130.

47. Brockman R, Jago R, Fox KR, Thompson JL, Cartwright K, Page AS. "Get off the sofa and go and play": Family and socioeconomic influences on the physical activity of 10–11 year old children. BMC Public Health. 2009;9(1):253.

48. Anderson SE, Economos CD, Must A. Active play and screen time in US children aged 4 to 11 years in relation to sociodemographic and weight status characteristics: a nationally representative cross-sectional analysis. BMC Public Health. 2008;8(1):366.

49. Gustafson SL, Rhodes RE. Parental correlates of physical activity in children and early adolescents. Sports medicine. 2006;36(1):79-97.
50. Fuemmeler BF, Anderson CB, Mâsse LC. Parent-child relationship of directly measured physical activity. International Journal of Behavioral Nutrition and Physical Activity. 2011;8(1):17.
51. Welk GJ, Wood K, Morss G. Parental influences on physical activity in children: An exploration of potential mechanisms. Pediatric Exercise Science. 2003;15(1):19-33.
52. Veitch J, Salmon J, Ball K. Individual, social and physical environmental correlates of children's active free-play: a cross-sectional study. International Journal of Behavioral Nutrition and Physical Activity. 2010;7(1):11.
53. Prezza M, Pilloni S, Morabito C, Sersante C, Alparone FR, Giuliani MV. The influence of psychosocial and environmental factors on children's independent mobility and relationship to peer frequentation. Journal of Community & Applied Social Psychology. 2001;11(6):435-50.
54. Ferrao T, Janssen I. Parental encouragement is positively associated with outdoor active play outside of school hours among 7–12 year olds. PeerJ. 2015;3:e1463
55. Ommundsen Y, Klasson-Heggebø L, Anderssen SA. Psycho-social and environmental correlates of location-specific physical activity among 9- and 15- year-old Norwegian boys and girls: The European youth heart study. International Journal of Behavioral Nutrition and Physical Activity. 2006;3(1):32.
56. Hohepa M, Scragg R, Schofield G, Kolt GS, Schaaf D. Social support for youth physical activity: Importance of siblings, parents, friends and school support across a segmented

school day. The International Journal of Behavioral Nutrition and Physical Activity. 2007;4:54

57. Janssen I, Rosu A. Undeveloped green space and free-time physical activity in 11 to 13-year-old children. International Journal of Behavioral Nutrition and Physical Activity. 2015;12(1):26.
58. Laxer RE, Janssen I. The proportion of youths' physical inactivity attributable to neighbourhood built environment features. International Journal of Health Geographics. 2013;12(1):31.
59. Sanders T, Feng X, Fahey PP, Lonsdale C, Astell-Burt T. The influence of neighbourhood green space on children's physical activity and screen time: findings from the longitudinal study of Australian children. International Journal of Behavioral Nutrition and Physical Activity. 2015;12(1):126.
60. Saelens BE, Sallis JF, Frank LD. Environmental correlates of walking and cycling: Findings from the transportation, urban design, and planning literatures. Annals of Behavioral Medicine. 2003;25(2):80-91.
61. van Loon J, Frank LD, Nettlefold L, Naylor P-J. Youth physical activity and the neighbourhood environment: Examining correlates and the role of neighbourhood definition. Social Science & Medicine. 2014;104:107-15.
62. Brockman R, Jago R, Fox KR. Children's active play: self-reported motivators, barriers and facilitators. BMC Public Health. 2011;11(1):461.
63. Loucaides CA, Chedzoy SM, Bennett N. Differences in physical activity levels between urban and rural school children in Cyprus. Health Education Research. 2004;19(2):138-47.

64. Fisher A, Reilly JJ, Montgomery C, Kelly LA, Williamson A, Jackson DM, et al. Seasonality in Physical Activity and Sedentary Behavior in Young Children. Pediatric Exercise Science. 2005;17(1):31-40.
65. Beighle A, Alderman B, Morgan CF, Masurier GL. Seasonality in children's pedometer-measured physical activity levels. Research quarterly for exercise and sport. 2008;79(2):256-60.
66. Vadiveloo M, Zhu L, Quatromoni PA. Diet and physical activity patterns of school-aged children. Journal of the American Dietetic Association. 2009;109(1):145-51.
67. Cleland V, Crawford D, Baur LA, Hume C, Timperio A, Salmon J. A prospective examination of children's time spent outdoors, objectively measured physical activity and overweight. International Journal of Obesity. 2008;32(11):1685.
68. Riddoch CJ, Mattocks C, Deere K, Saunders J, Kirkby J, Tilling K, et al. Objective measurement of levels and patterns of physical activity. Archives of Disease in Childhood. 2007;92(11):963.
69. Duncan JS, Hopkins WG, Schofield G, Duncan EK. Effects of weather on pedometer-determined physical activity in children. Medicine and Science in Sports and Exercise. 2008;40(8):1432-8.
70. Edwards NM, Myer GD, Kalkwarf HJ, Woo JG, Khoury PR, Hewett TE, et al. Outdoor temperature, precipitation, and wind speed affect physical activity levels in children: A longitudinal cohort study. Journal of Physical Activity and Health. 2015;12(8):1074-81.
71. Gordon, DLA, Janzen, M. Suburban nation? estimating the size of Canada's suburban population. Journal of Architectural and Planning Research. 2013;*30*(3):197–220.

72. Lachapelle U, Frank L, Saelens BE, Sallis JF, Conway TL. Commuting by public transit and physical activity: where you live, where you work, and how you get there. Journal of Physical Activity and Health. 2011;8(s1):S72-S82.

Chapter 3: Manuscript

Pedestrian Traffic Safety and Outdoor Active Play Among 10 – 13 Year Olds in a Mid-Sized Canadian City

3.1 Abstract

Objectives: This study examined the associations between objective and perceived measures of pedestrian traffic safety in the home neighbourhood with outdoor active play among 10- to 13-year-olds. It also determined if the association between objectively measured pedestrian safety and outdoor active play is moderated by parents' perceptions of pedestrian safety.

Methods: This was a cross-sectional study of 10- to 13-year-olds (N = 458) from Kingston, ON, Canada (population 123,798). Outdoor active play was measured over 7 consecutive days using a combination of data from activity logs, accelerometers, Global Positioning System loggers, and Geographic Information System. 1 km road network buffers were used to define participants' home neighbourhoods. Within these buffers Geographic Information System software and data were used to create traffic volume, traffic calming, traffic speed, pedestrian infrastructure, and overall pedestrian safety indexes. Parents' perceptions of these pedestrian safety domains were obtained by questionnaire. General linear models were used to examine the relationships of interest. Several covariates were adjusted for in these models.

Results: The average outdoor active play was 38.3 min/day (27.6 SD). The overall perceived and objective pedestrian safety indexes were not associated with outdoor active play ($p > 0.1$); however, significant associations were observed for some of the specific domains of pedestrian safety. Children whose parents perceived moderate or high traffic speeds in their neighbourhood had outdoor active play values that were 0.35 (SE=0.10, p=0.021) and 0.20 (SE=0.15, p=0.048) SD units higher, respectively, than children whose parents perceived low traffic speed. By comparison to children from neighbourhoods in the lowest tertile, children from the highest traffic volume tertile had higher outdoor active play levels (0.26, SE=0.12, p=0.029), while children from neighbourhoods in the moderate traffic calming tertile (-0.28, SE=0.11, p=0.008) and the moderate pedestrian infrastructure tertile (-0.25, SE=0.11, $p=0.023$) had lower outdoor active play levels. There were no interactions between the objective and perceived measures ($p>0.05$).

Conclusions: In this study of 10- to 13-year-olds from a mid-sized city there was some albeit inconsistent evidence that outdoor active play was lower in children residing in the most pedestrian safe neighbourhoods.

3.2 Introduction

Active play is a spontaneous, self-motivated, fun, and unstructured form of physical activity that provides children with physical, mental, and social health benefits.[1,2] In the 2016 ParticipACTION report card on physical activity in Canadian children and youth, active play received a D+ grade.[3] Therefore, active play is a type of physical activity that needs to be addressed among young Canadians. Understanding the correlates of active play is an important step in developing effective interventions for this behaviour.

One potential determinant of active play is the extent to which children are safe and protected from motorized vehicle traffic when they are playing outdoors.[4] Pedestrian safety is a reflection of the speed and volume of motorized vehicle traffic and the presence of physical infrastructure, such as sidewalks and walking paths, that separate pedestrians from this traffic. Previous studies have consistently reported that parents who are concerned about the lack of pedestrian safety in their neighbourhood are more likely to restrict their children's outdoor active play.[5-8] However, no studies have examined the association between objectively measured pedestrian safety features and outdoor active play. This is an important gap that needs to be addressed because parents' perceptions of pedestrian safety may not reflect the actual degree of traffic safety.[31-34] Thus, it is unclear if outdoor active play interventions and policies should be designed to address pedestrian safety itself, or the apparent disconnect between perceptions of pedestrian safety and the real degree of pedestrian safety.

Therefore, the primary purpose of this study was to investigate the independent and interactive associations between perceived and objective measures of pedestrian safety in the home neighbourhood and outdoor active play in children. This study is based on a sample of 10- to 13-year-olds from a mid-sized city who had their outdoor active play measured over 7 days. It was hoped that the results of this study could help inform the development of interventions aimed at improving outdoor active play.

3.3 Methods

3.3.1 Study Design and Participants

A total of 458 children (230 boys and 228 girls) aged 10 to 13 years who lived and attended school in Kingston, Ontario were recruited to participate in this cross-sectional study. Kingston is a city on Canada's southern border with a population of 123,798 and a population of density of 274 people per km^2.[39] Data were collected between January 2015 and December 2016. A systematic recruitment strategy was used to ensure proportional representation across the 4 seasons, sex, age, and Kingston's 12 electoral districts. Recruitment strategies consisted of distribution and posting of advertisements (e.g., posters, brochures), social media, and word of mouth (see Appendix A on page 85 for an example advertisement). Informed consent was provided by the child participants and a parent/guardian. The study was approved by the General Research Ethics Board at Queen's University (Appendix C, page 93). Participants were given $40 for completing the study.

3.3.2 Data Collection Overview

Participation in the study consisted of two visits to the Physical Activity Epidemiology laboratory at Queen's University that were separated by a 7-day physical activity measurement period. During the first visit to the laboratory, participants were given an Actical accelerometer (Philips Respironics, Murrysville, Pennsylvania, USA) and a Garmin Forerunner 220 Global Positioning System (GPS) watch (Garmin Ltd., *Schaffhausen, Switzerland*), which they were asked to wear continuously for the following 7 days (Appendix D, page 95). During the 7-day physical activity measurement period, participants also completed a log to document their waking and sleep times, times they participated in organized sports and chores/work, as well as the times they removed the accelerometer and/or GPS watch (Appendix E, page 100). After the 7-day physical activity measurement period concluded, participants returned to the laboratory and during this visit they and a parent/guardian each completed a ~20 minute long questionnaire on a tablet computer (Appendix G, page 105). These questionnaires assessed the demographic characteristics of the child and their family and child and parent beliefs, perceptions and barriers to outdoor active play.

3.3.2.1 Pedestrian Safety in the Home Neighbourhood

Four domains of pedestrian safety were considered in this study: traffic volume, traffic speed, traffic calming, and pedestrian infrastructure. Perceived and objective measures of each of these pedestrian safety domains were obtained. As explained below, participants were placed into 'low', 'moderate', or 'high' groups for each domain separately for the perceived and objective measures. Summary pedestrian safety indexes that were based on all 4 domains were also created.

3.3.2.2 Perceived Measures of Pedestrian Safety

Parental perceptions of traffic safety in their home neighbourhood were assessed using the following 4 items: 1) "There is heavy traffic on our local streets", 2) "The speed of traffic on our local streets is usually slow (50 km per hour or less)", 3) "There are traffic slowing devices (e.g., speed humps) on our local streets", and 4) "There are sidewalks on most streets in our neighbourhood". [11] For items 1 (traffic volume), 3 (traffic calming), and 4 (pedestrian infrastructure), responses of "Strongly Disagree" and "Disagree" were merged to create the "low" group, "Neutral" responses created the "moderate" group, and "Agree" and "Strongly Agree" responses were merged to create the "high" group. For item 2 (traffic speed), wherein less agreement equated to higher traffic speeds, responses of "Strongly Disagree" and "Disagree" were merged to create the "high" group, the "Neutral" response created the "moderate" group, and the "Agree" and "Strongly Agree" responses were merged to create the "low" group.

The test-retest reliability of the perceived traffic safety items was determined in a sample of 51 parents who completed the questionnaire twice separated by 8-10 days. The intraclass correlation between repeated responses indicated strong agreement with values of 0.84 for the traffic volume item, 0.91 for the traffic speed item, 0.92 for the traffic calming item, and 0.70 for the pedestrian infrastructure item.

3.3.2.3 Objective Measures of Pedestrian Safety

A 1 km road network buffer surrounding each participant's home was created to define their home neighbourhood. The objective measures of pedestrian safety were obtained inside these buffers. The decision around the type and size of buffer was based on research which found that a 1 km road network buffer provides the best exposure measurement for young Canadians.[12,13] Pedestrian safety measures were obtained using ArcGIS software version 10.4 (ESRI, Redlands, California, USA) and several geographic information system (GIS) databases that were developed and maintained by the GIS and engineering departments for the City of Kingston.

A traffic volume index was created. This index reflected the number of motorized vehicles per day per km of road that travelled on the roads in each neighbourhood buffer. It was based on the distances of arterial, collector, and local roads within each buffer and the average number of motorized vehicles that travel on these types of roads in Kingston. As part of their traffic flow and planning studies, the City of Kingston periodically collects traffic volume data on road segments throughout the city. These data were collected at different time points for different road segments. Data were not available for all road segments, particularly for local roads and roads in newly developed areas. We used all available traffic volume data to estimate the average number of motorized vehicles per day that travel on arterial (n=11,054), collector (n=4,041), and local (n=400) road segments within Kingston. The traffic volume index was then calculated as follows: ((km of arterial roads in buffer * 11,054) + (km of collector roads in buffer * 4,041) + (km of local roads in buffer * 400)) / (total road distance in buffer in km). Participants were placed into tertiles to define “low”, “moderate”, and “high” groups, with the “high” group representing neighbourhoods with the most traffic volume. Note that there is only one expressway in Kingston (i.e., the 401). This expressway was not included in the traffic volume index because pedestrians are not permitted on this road.

A traffic speed index was created based on the proportion of the total road distance within each neighbourhood buffer that was made up of local roads. This is a proxy measure for traffic speed that reflects that vehicle speeds are typically lower on local roads than they are on collector and arterial roads. The traffic speed index was calculated as: ((distance of local roads in buffer) / (total road distance in buffer) * (-1)). Participants were placed into tertiles to define “low”, “moderate”, and “high” groups, with the “high” group representing neighbourhoods with the fastest traffic speeds.

A traffic calming index was created in each neighbourhood buffer to reflect the number of traffic calming factors per km of road. It was calculated as: (((# 4-way-stop intersection signs) + (# speed hump signs) + (# school zone signs) + (# crosswalk signs) + (# park/children playing signs) + (# pedestrian walking signs) + (# 40 km/h speed zone signs)) / (total road distance in km). Participants were placed into tertiles to define “low”, “moderate”, and “high” groups, with the “high” group representing neighbourhoods with the most traffic calming features. Note that other traffic calming features such as traffic chokers, chicanes, and traffic circles were not included because GIS data for these features were not available. Our experiences suggest that these unmeasured traffic calming features are rare in Kingston.

The pedestrian infrastructure variable reflected the total length of sidewalks within the neighbourhood buffers. Participants were placed into tertiles to define “low”, “moderate”, and “high” groups, with the “high” group representing neighbourhoods with the most pedestrian infrastructure. We limited the objective pedestrian infrastructure variable to sidewalks because it best matched the questionnaire item used to assess parents’ perceptions of pedestrian infrastructure. Furthermore, dedicated walking paths are not commonplace in Kingston. In addition, the bicycle lanes in Kingston are almost exclusively located on the shoulder of arterial roads and they only separate bicycle and vehicle traffic with a painted line rather than space, height, or a physical barrier. These bicycle lanes were designed to increase active travel in adults over longer distances and not to help children travel within their neighbourhood.

3.3.2.4 Summary Pedestrian Safety Indexes

To create the summary indexes, participants were initially given scores of 1, 2, or 3 for each pedestrian safety domain based on whether they were in the most, moderate, or least safe group. These scores were then summed, and “low”, “moderate”, and “high” pedestrian safety index groups were created based on tertiles of the summed score. The “low” group represents the safest neighbourhoods.

3.3.4 Outdoor Active Play

The method for assessing outdoor active play over 7 consecutive days was developed by our laboratory and was one of the main objectives for the Active Play Study. This method uses data from several sources and includes a combination of manual checks and corrections and computer automated steps.

First, all of the times participants recorded in the log (start and end times for sleep, organized sports, outdoor chores, and accelerometer non-wear periods) were checked by using Actical 3.10 software (Philips Respironics, Murrysville, Pennsylvania, USA) to visually examine the accelerometer data around the recorded times. If necessary, corrections were made to the recorded times.

Second, Personal Activity and Location Measurement (PALMS) software (Center for Wellness & Population Health Systems, University of California San Diego, San Diego, California, USA) was used to merge the accelerometer and GPS data based on each 15-second accelerometer epoch. Shorter epoch lengths (i.e., 15 seconds instead of 60 seconds) is preferred in children since their movement, including movement during outdoor active play, is very sporadic and includes many short bursts of activity. PALMS identified periods of time with missing GPS latitude and longitude coordinates, which occurred if the satellite signal was lost (e.g., when a participant entered a large building). When possible, missing geospatial coordinates were imputed by the research team by using satellite and street view images in Google Maps software (Google, Mount View, California, USA) to determine where the participant was immediately before the signal was lost and immediately after the signal returned. For instance, if the signal was lost for 30 minutes when a participant was in a building, the latitude and longitude coordinates for the centre of that building were imputed for all 15-second epochs that occurred during that 30 minutes.

Third, PALMS software detected all vehicle and non-vehicle (e.g., walking, bicycling) trips using a validated algorithm,[14] and all 15-second epochs that occurred during trips were flagged. Trip detection was based on distance traveled over time (i.e., travel ≥100 meters over≥ 180 seconds at a speed of ≥ 1 km/hr). Trip modality was determined by the 90th percentile of travel speed (walking, 1-9.99 km/hr; cycling, 10-24.99 km/hr; vehicle, ≥25 km/hr). Each of the trips identified by PALMS were checked by visually inspecting all of the GPS coordinates for that trip in Google Maps. During these visual inspections we identified and then deleted a number of false positive trips. An example of a false positive trip is a trip identified by PALMS that, upon visual inspection, was found to occur on school groups during the recess period. This false positive trip reflected the participant running around the playground at their school and not active transportation.

The data from each participant was then exported from PALMS into a CSV file that was subsequently opened in ArcMap version 10.4 software (Esri, Redlands, California, USA). The latitude and longitude coordinates for each 15-second epoch were geocoded into a map layer. A second map layer that contained the footprints for all buildings within the city of Kingston was opened. The two map layers were spatially joined, the latitude and longitude coordinates of each 15-second epoch where identified as being in a building (indoors) or not in a building (outdoors), and the joined data was exported as an Excel file (Microsoft Corporation, Redlands, Washington, USA). The Excel files were merged together using SAS statistical software version 9.4 (SAS Inc., Carry, North Carolina, USA), wherein falsely identified indoor times were corrected by an algorithm that had a specificity of 95%.

The merged file contained over 18 million rows, with 40,320 rows per participant (i.e., one row of data for each 15-second long epoch that occurred over the 7-day measurement period).[15] Additional "time" variables were merged into the master file, including 1) the sleep, organized sport, and chore/work times that were recorded in the logs; 2) the start and end times of the school day and school recess times; and 3) whether each day represented a school day or non-school day (i.e., weekend or holiday).[15]

A SAS program was then developed to determine the minutes/day spent in OAP from these merged data. The SAS program started by identifying and deleting all 15-second epochs for the days in which there was insufficient (< 10 hours) accelerometer and/or GPS watch wear time.[26] We then flagged all 15-second epochs that could not have occurred during OAP because one or more of the following conditions were met: 1) it occurred during time in bed, 2) it occurred indoors, 3) it occurred during school curriculum time (but not recess time) on a school day, 4) it occurred during a vehicle trip or non-vehicle trip, 6) it occurred while participating in an organized sport or program, or 7) it occurred while performing work or chores. All of the 15-second epochs that were not flagged in the proceeding step were then classified as either occurring during outdoor active play or as sedentary time spent outdoors using a specifically designed algorithm that has a specificity of 85%, sensitivity of 85%, and positive predictive value of 99%. These epochs for outdoor active play were summed to create a total for each day, and then a daily average was determined.

3.3.5 Confounding Variables

Confounding variables considered in the analyses consisted of age (continuous),[32] sex,[32] race (white vs. non-white including mixed race), family structure (single or dual parent household, number of siblings in household), annual household income (≤ $50,000, $50,001-$100,000, or >$100,000), parent's education (high school, 2 years college, university, graduate degree), parents' values on outdoor play (a continuous score based on Carver et al.'s questionnaire items[11]), average daily temperature and precipitation during the 7 day outdoor active play collection period (continuous), season of participation (winter, spring, summer, or fall based on equinox and solstice dates), and other neighbourhood built environment features that may influence outdoor play. These built environment features consisted of the Walk Score® (continuous measure of walkability around a home address),[24-25] greenspace (% neighbourhood land area devoted to green space),[26-29] and number of cul-de-sacs in the neighbourhood. These confounders were chosen based on prior knowledge of their relationship with physical activity and outdoor active play.

3.3.7 Statistical Analysis

Statistical analyses were conducted using IBM SPSS Statistics version 24 software (International Business Machines Corp, New York, New York, USA). Because some of the participants had missing values for one or two of the confounding variables (i.e., 11.5% of participants had missing data on income and 0.7% had missing data on marital status) and outdoor active play (i.e., 18.0% had missing values due to insufficient accelerometer and/or GPS data), multiple imputation was performed. This simulation based technique was used to handle the missing data in a way that would result in valid statistical inference and allow complete data for all participants to be analyzed.[30] Five iterations of multiple imputation were used. The imputation model contained all exposure, outcomes, and confounders. Estimates obtained from the five imputations were pooled to create the final estimates. Note that the findings were similar irrespective of whether multiple imputation was or was not used.

Standard descriptive statistics such as means and proportions were used to describe the sample. Associations between perceived and objective measures of pedestrian safety were determined using Spearman’s rho correlation. Because the outdoor active play outcome variable was highly skewed, it was transformed using Templeton’s two-step approach and then converted to a z-score prior to regression analyses.[16] General linear models were used to determine whether the perceived and objective pedestrian safety measures were related to the outdoor active play outcome. In a first set of models (model 1), the perceived and objective measures were examined in separate models. In a second set of models (model 2), the perceived and objective measures were both included in the same model. In a third set of models (model 3), a perceived X objective interaction term was added to the model. For all models a backwards stepwise selection approach was used to remove confounding variables from the models that were not related to the outcome based on a conservative p value of 0.20.

3.4 Results

3.4.1 Descriptive characteristics of sample

A description of the 458 participants is provided in Table 3.1 (page 47). By design, approximately half were male. The majority were white, belonged to a dual parent household, and lived with at least one other sibling. The average age was 12.0 years (SD = 1.15). On average, participants accumulated 38.3 min/day (SD = 27.6) of outdoor active play.

Table 3.1 Sociodemographic characteristics of participants (n = 458).

Characteristic	**N**	**% of Total**
Sex		
Male	230	50.2
Female	228	49.8
Age (years)		
10	116	25.3
11	115	25.1
12	118	25.8
13	109	23.8
Race		
White	393	85.8
Non-white	65	14.2
Number of Parents in Household		
Single parent	66	14.4
Dual parent	339	85.6
Number of Siblings in Household		
0	50	10.9
1	230	50.2
2	123	26.9
3+	55	12.0
Family Income ($ CDN per year)		
≤ 50,000	84	18.2
50,001 – 100,000	145	31.6
> 100,000	230	50.2

Table 3.2 (page 49) shows the distribution of responses to the pedestrian safety questionnaire items. When asked about their local streets, 33% of parents agreed that there was heavy traffic, 60% disagreed that there were traffic slowing devices, 23% disagreed that traffic was usually slow, and 18% disagreed that most streets had sidewalks. Descriptive information on the GIS measures used to create the objective traffic safety measures are provided in Table 3.3 (page 50). The correlations between the perceived and objective pedestrian safety measures were as follows: $r = 0.18$ for traffic volume, $r = 0.20$ for traffic speed, $r = 0.43$ for traffic calming, and $r = 0.37$ for pedestrian infrastructure (all p values <0.001).

Table 3.2 Descriptive information on perceived pedestrian safety measures

Pedestrian Safety Questionnaire Item and Response Option	**N**	**%**
There is heavy traffic on our local streets		
Disagree or Strongly Disagree (low traffic volume)	246	53.7
Neutral (moderate traffic volume)	63	13.8
Agree or Strongly Agree (high traffic volume)	149	32.5
There are traffic slowing devices (e.g., speed humps) on our local streets		
Disagree or Strongly Disagree (low traffic calming)	275	60.0
Neutral (moderate traffic calming)	28	6.1
Agree or Strongly Agree (high traffic calming)	155	33.9
The speed of traffic on our local streets is usually slow (50 km per hour or less)		
Disagree or Strongly Disagree (high traffic speed)	107	23.4
Neutral (moderate traffic speed)	40	8.7
Agree or Strongly Agree (low traffic speed)	311	67.9
There are sidewalks on most streets in our neighbourhood		
Disagree or Strongly Disagree (low pedestrian infrastructure)	82	17.9
Neutral (moderate pedestrian infrastructure)	10	2.2
Agree or Strongly Agree (high pedestrian infrastructure)	366	79.9

Table 3.3 Description of neighbourhood GIS measures used to derive the objective pedestrian safety measures.

GIS Measure	**Average (SD)**
Traffic Volume and Traffic Speed	
Arterial road distance, km	1.9 (1.6)
Collector road distance, km	1.0 (1.4)
Local road distance, km	8.3 (4.5)
Total road distance, km	11.4 (6.5)
Traffic Calming	
School zone signs, n	2.8 (3.4)
Crosswalk signs, n	0.4 (0.9)
Speed hump signs, n	4.6 (5.6)
40 km/hr speed zone signs, n	2.6 (4.1)
Playground (children playing) signs, n	3.0 (3.3)
Pedestrian signs, n	0.8 (1.3)
4-way-stop signs, n	2.7 (3.4)
Pedestrian Infrastructure	
Sidewalk distance, km	13.3 (12.3)

Table 3.4 (page 53) summarizes the association between the pedestrian safety measures and outdoor active play. After controlling for covariates (Model 1), the perceived measures of neighbourhood traffic volume, traffic calming, pedestrian infrastructure, and the pedestrian safety index were not significantly associated with outdoor active play ($p>0.1$). However, parents' perceptions of traffic speed were associated with outdoor active play such that children whose parents perceived moderate or high neighbourhood traffic speed had outdoor active play values that were 0.35 (SE=0.10, p=0.021) and 0.20 (SE=0.15, p=0.048) standard deviation units higher, respectively, than children whose parents perceived low traffic speed. The relationship remained statistically significant for the moderate traffic speed group (p= 0.023) but not the high traffic speed group (p=0.10) after adjusting for the objective traffic speed measure (Model 2).

The objective measures of traffic volume, traffic calming, and pedestrian infrastructure but not traffic speed or the pedestrian safety index were associated with outdoor active play after adjusting for covariates (Table 3.4, page 53). By comparison to children in the lowest tertile, children in the highest traffic volume tertile had a higher outdoor active play (0.26, SE=0.12, p=0.029) while children in the moderate traffic calming tertile (-0.28, SE=0.11, p=0.008) and moderate pedestrian infrastructure tertile (-0.25, SE=0.11, p=0.023) had lower outdoor active play levels. After further adjusting for the perceived measures, the relationships for high traffic volume (p=0.025) and moderate traffic calming (p=0.008) remained statistically significant while the relationship for moderate pedestrian infrastructure (p=0.074) was of borderline significance.

Objective measure X perceived measure interaction terms were added to the models shown in Table 3.4 to determine if the relationships between objective safety and outdoor active play were moderated by perceptions of safety. None of these interaction terms were significant ($p>0.3$).

Table 3.4 Relationship between pedestrian safety measures and outdoor active play z-scores.

Type of Pedestrian Safety	**Perceived Measures**		**Objective Measures**	
	Model 1, β (SE)	***Model 2, β (SE)***	***Model 1, β (SE)***	***Model 2, β (SE)***
Traffic Volume				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	-0.01 (0.14)	0.01 (0.14)	0.06 (0.10)	0.06 (0.10)
High	-0.04 (0.10)	-0.07 (0.10)	0.26 (0.12)*	0.27 (0.12)*
Traffic Speed				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	0.35 (0.15)*	0.35 (0.15)*	-0.17 (0.11)	-0.15 (0.11)
High	0.20 (0.10)*	0.16 (0.10)	-0.19 (0.12)	-0.15 (0.12)
Traffic Calming				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	-0.17 (0.18)	-0.18 (0.18)	-0.28 (0.11)*	-0.29 (0.11)*
High	0.02 (0.09)	0.04 (0.10)	-0.06 (0.12)	-0.07 (0.13)
Pedestrian Infrastructure				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	-0.34 (0.31)	-0.29 (0.31)	-0.25 (0.11)*	-0.21 (0.12)
High	-0.24 (0.16)	-0.19 (0.17)	-0.16 (0.15)	-0.13 (0.15)
Pedestrian Safety Index				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	-0.14 (0.15)	-0.15 (0.15)	-0.04 (0.11)	-0.04 (0.12)
High	0.03 (0.09)	0.01 (0.10)	0.12 (0.11)	0.12 (0.12)

β = Beta coefficient, SE = Standard Error, * $P \leq 0.05$.

Model 1: Perceived and objective measures were included in separate regression models. Adjusted for sex, age, season, race, family income, neighbourhood Walk Score, temperature and precipitation during data collection

Model 2: Perceived and objective measures were included in the same regression models. Adjusted for sex, age, season, race, family income, neighbourhood Walk Score, temperature and precipitation during data collection

Figure 3.1 Differences in outdoor active play z-scores according to perceived pedestrian safety measures. The “Low” group served as the referent for comparisons and the bars for the “Moderate” and “High” groups represent the differences versus the “Low” group. Findings have been adjusted for the objective measures of pedestrian safety and confounders. * denotes statistically significant differences (P ≤ 0.05).

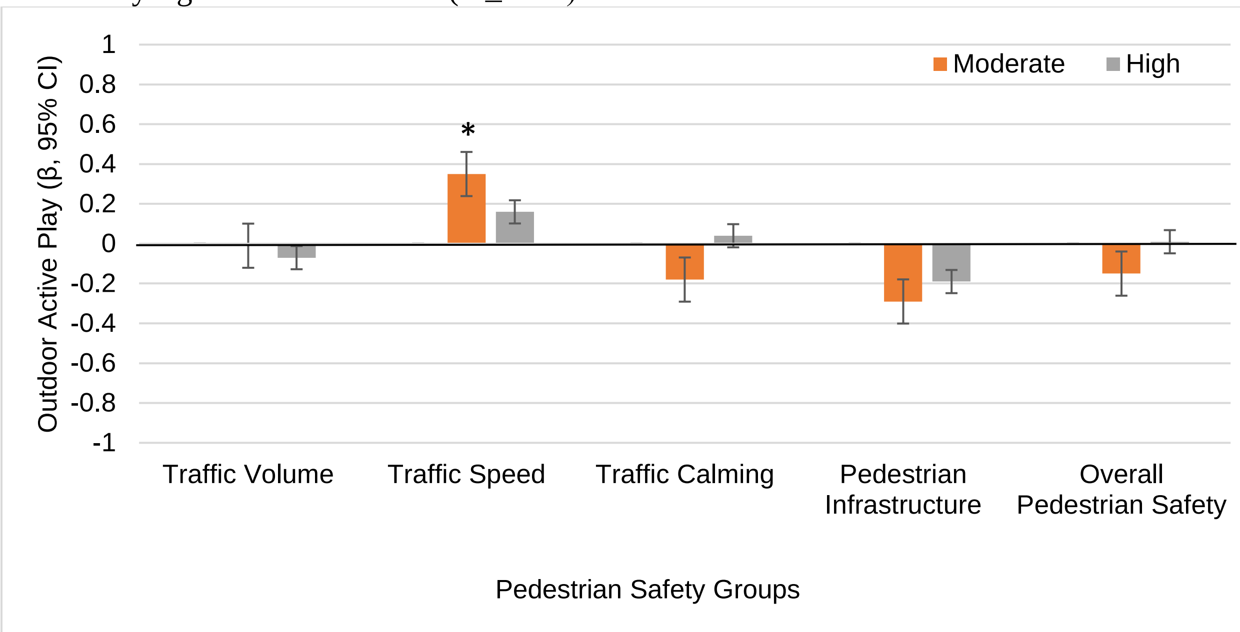
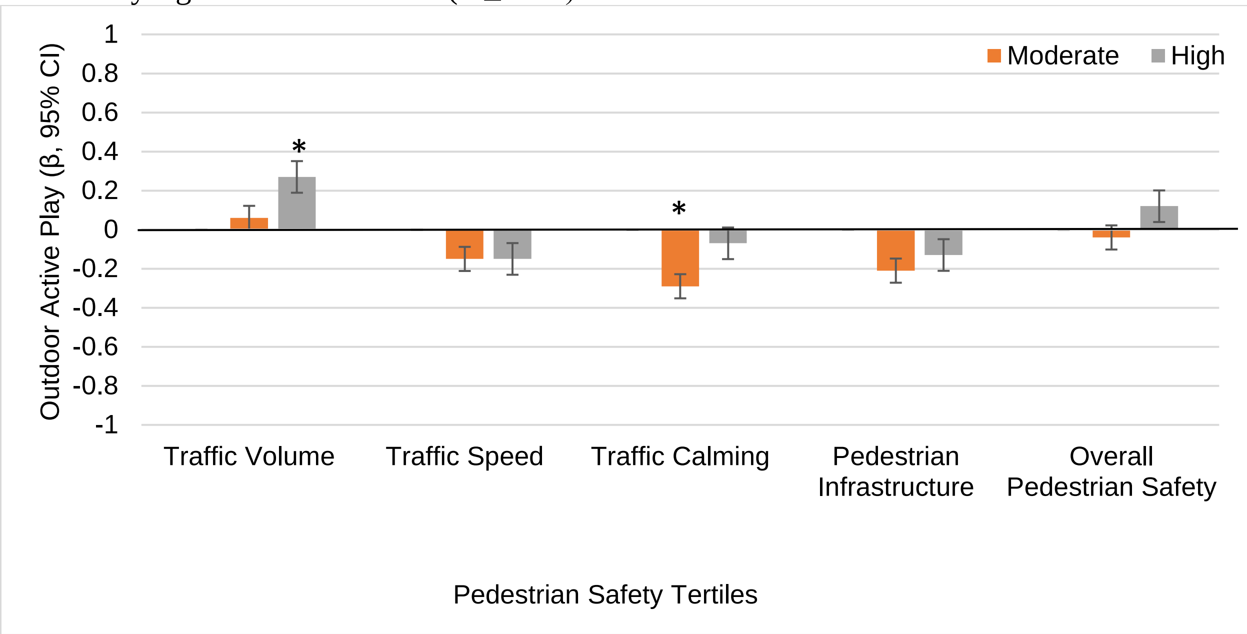


Figure 3.2 Differences in outdoor active play z-scores according to objective pedestrian safety measures. The "Low" group served as the referent for comparisons and the bars for the "Moderate" and "High" groups represent the differences versus the "Low" group. Findings have been adjusted for the perceived measures of pedestrian safety and confounders. * denotes statistically significant differences (P ≤ 0.05).



Given the surprising findings on the relationships between the pedestrian safety measures and outdoor active play, a decision was made *a posteriori* to repeat the regression analyses within the subsample of 407 (89% of total) participants who lived within the urban areas of the city (i.e., downtown core, subdivisions) that are illustrated in Figure 1. The rationale being that children who lived in the rural and semi-rural areas of the city, who tended to score poorly on the pedestrian safety measures, might have skewed the results. As shown in Table 3.5 (page 57), the pattern of results for the urban residing participants were extremely similar to the results within the entire sample that are shown in Table 3.4.

Table 3.5 Relationship between pedestrian safety measures and outdoor active play z-scores in urban residing participants (n = 407).

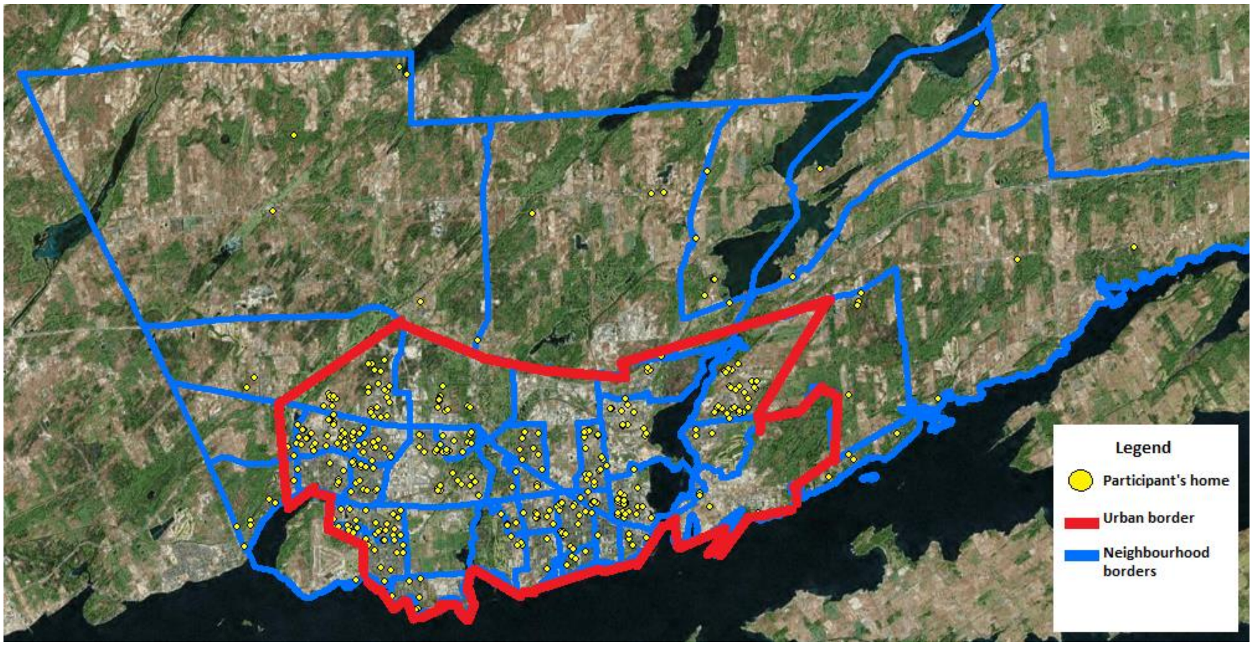
Type of Pedestrian Safety	**Perceived Measures**		**Objective Measures**	
	Model 1, β (SE)	***Model 2, β (SE)***	***Model 1, β (SE)***	***Model 2, β (SE)***
Traffic Volume				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	-0.04 (0.13)	-0.03 (0.13)	0.11 (0.10)	0.09 (0.10)
High	-0.08 (0.10)	-0.09 (0.10)	0.33 (0.12)*	0.27(0.13)*
Traffic Speed				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	0.34 (0.16)*	0.34 (0.16)*	-0.19 (0.12)	-0.17 (0.12)
High	0.22 (0.11)*	0.21 (0.11)	-0.26 (0.12)*	-0.22 (0.12)
Traffic Calming				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	-0.11 (0.18)	-0.12 (0.18)	-0.23(0.11)	-0.24 (0.12)*
High	0.08 (0.10)	0.06 (0.10)	0.01 (0.13)	-0.02 (0.13)
Pedestrian Infrastructure				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	-0.20 (0.34)	-0.18 (0.33)	-0.18 (0.12)	-0.17 (0.13)
High	-0.15 (0.17)	-0.13 (0.18)	-0.13 (0.15)	-0.11 (0.15)
Pedestrian Safety Index				
Low	0 (REF)	0 (REF)	0 (REF)	0 (REF)
Moderate	-0.13 (0.15)	-0.14 (0.15)	-0.03 (0.11)	-0.03 (0.11)
High	-0.04 (0.10)	-0.05 (0.10)	0.09 (0.11)	0.11 (0.12)

β = Beta coefficient, SE = Standard Error, * $P \leq 0.05$.

Model 1: Perceived and objective measures were included in separate regression models. Adjusted for sex, age, season, race, family income, neighbourhood Walk Score, temperature and precipitation during data collection

Model 2: Perceived and objective measures were included in the same regression models. Adjusted for sex, age, season, race, family income, neighbourhood Walk Score, temperature and precipitation during data collection

Figure 3.3 Illustration of the location of participants' homes within the City of Kingston (yellow dots). The blue lines represent the 43 neighbourhood borders the City of Kingston uses for planning and service delivery. The red line represents the border used in our study to define the urban areas of the city.



3.5 Discussion

This study examined the association between pedestrian safety and outdoor active play among 10- to 13-year olds from Kingston, Ontario. A key finding was that the overall perceived and objective pedestrian safety indexes were not associated with outdoor active play. Some of the specific pedestrian safety domains were significantly associated with outdoor active play. However, these associations were not consistent as they were only present for some of the moderate and high risk groups for some of the domains, they did not follow dose-response patterns (e.g., significant different for moderate group but not the high group), they were not consistent with underlying theory or findings in other studies, the effect sizes were small (e.g., Cohen's d was 0.26 for objective measures of traffic volume between high and low tertiles), and they were based on cross-sectional data. Thus, it is unlikely that the few significant associations that were observed were causal in nature.

The associations between perceived and objectively measured pedestrian safety and outdoor active play in our study were not what we were expecting and are inconsistent with those of similar studies of comparably aged children.[20, 23, 28] For instance, a study from Toronto, Canada found that parental concerns about fast drivers in their neighbourhood was inversely related to the duration that their 10-12 year old children played outdoors on weekdays ($\beta = -0.26$, $p = 0.03$).[23] Another study from Melbourne, Australia found that the number of traffic lights in a the home neighbourhood was negatively associated with physical activity among 8 to 9-year-old girls ($\beta = -0.88$, $p > 0.05$).[4] We do not feel that the methodological improvements in our study, which include a more comprehensive assessment of pedestrian safety and a specific measure of outdoor active play that was in large part based on data collected from objective instruments, would explain the lack of associations in our study. If anything, these improvements would have led to stronger associations, had such associations existed. We speculate that discrepancy in findings reflects that Kingston, Ontario, the city where our study was conducted, is very different from the cities where these other studies of this topic were conducted. Kingston is a mid-sized city with a population of 123,798 and a population density of 274 persons per km^2.[39] Previous studies have been conducted in large metropolitan areas such as Toronto,[24] Melbourne,[4,11,36] San Diego, Boston, and Cincinnati.[42] These metropolitan areas have populations ranging from 1 million to 6 million and population densities ranging from 400 to 4500 persons per km^2.[4,11,23,36,42] Traffic patterns and pedestrian safety are likely to be very different in Kingston in comparison to these considerably larger and more densely populated cities. We speculate that the least pedestrian safe neighbourhoods in Kingston would not be amongst the least pedestrian safe neighbourhoods in these larger cities. In support of this, more than 100,000 vehicles per day pass through some of Toronto's busiest intersections.[40] By comparison, 23,000 vehicles per day pass through Kingston's busiest intersection.[41]

In our study, the correlation coefficients between the objective and perceived measures of pedestrian traffic safety ranged from 0.18 to 0.43. This indicates that parents' perceptions were largely determined by factors other than the actual traffic features. The poor associations between the objective and perceived measures could also reflect that many of the parents had little or no experience of being in their neighbourhood as a pedestrian and therefore did not understand the pedestrian risks in their neighbourhood. Evidence suggests that there is a greater disconnect between perceived and objective measures in people who are not physically active in their neighbourhood[37] and people who have lived in their neighbourhood for a shorter period of time.[38]

There are several limitations of this study. First, this was a cross-sectional study which means that inferences about cause-and-effect cannot be made. Secondly, as the study was limited to 10- to 13-year-olds from Kingston, Ontario, the findings may not be generalizable to children of different ages, to children living in rural areas, or large metropolitan areas. However, there are other mid-size cities in Canada for which the results may be more generalizable such as Guelph, ON (population 151,984), St. John's, NF (population 205,955), and Barrie, ON (population 197,059).[40] There are 56 cities in Canada with a population 50% smaller than Kingston's to double that of Kingston's (ie, 75,000-250,000) and the combined population in these cities is over 7 million people.[39] Lastly, some of our objective measures of pedestrian safety were proxy measures. For example, our measurement of traffic speed was based on the proportion of roads in the neighbourhood buffers that was made up of local roads. The basic assumption of this measures is that traffic speeds are lower on local roads than they are on collector and arterial roads.

3.6 Conclusion

The results of this study suggest that perceived and objective measures of pedestrian safety were not associated with outdoor active play among 10-13 year olds from Kingston, Ontario. The relationship between pedestrian safety and outdoor active play in this mid-sized city was different from that previously observed in large, metropolitan centres.[4,11,23,36,42] Future studies should investigate whether the relationship between pedestrian safety and physical activity varies according to the municipality size.

3.7 References

1. Tremblay MS, Gray C, Babcock S, Barnes J, Costas Bradstreet C, Carr D, et al. Position statement on active outdoor play. International Journal of Environmental Research and Public Health. 2015;12(6):6475-505.
2. Burdette HL, Whitaker RC. Resurrecting free play in young children: Looking beyond fitness and fatness to attention, affiliation, and affect. Archives of Pediatrics & Adolescent Medicine. 2005;159(1):46-50.
3. Tremblay MS, Barnes, J, LeBlanc, A, & Janson, K. Are Canadian kids too tired to move? WellSpring. 2016;27 p. 1-4.
4. Carver A, Timperio A, Hesketh K, Crawford D. Are safety-related features of the road environment associated with smaller declines in physical activity among youth? Journal of Urban Health. 2010;87(1):29-43.
5. Cecil-Karb R, Grogan-Kaylor A. Childhood body mass index in community context: neighborhood safety, television viewing, and growth trajectories of BMI. Health & Social Work. 2009;34(3):169-77.
6. Kalish M, Banco L, Burke G, Lapidus G. Outdoor play: A survey of parent's perceptions of their child's safety. Journal of Trauma. 2010;69(4 Suppl):S218-22.
7. Valentine G, McKendrick J. Children's outdoor play: Exploring parental concerns about children's safety and the changing nature of childhood. Geoforum. 1997;28(2):219-35.
8. Weir LA, Etelson D, Brand DA. Parents' perceptions of neighborhood safety and children's physical activity. Preventive Medicine. 2006;43(3):212-7.
9. Oliver M, Mavoa S, Badland H, Parker K, Donovan P, Kearns RA, et al. Associations between the neighbourhood built environment and out of school physical activity and

active travel: An examination from the Kids in the City study. Health & Place. 2015;36:57-64.

10. Crawford D, Cleland V, Timperio A, Salmon J, Andrianopoulos N, Roberts R, et al. The longitudinal influence of home and neighbourhood environments on children's body mass index and physical activity over 5 years: the CLAN study. International Journal of Obesity. 2010;34(7):1177-87.
11. Carver A, Timperio A, Crawford D. Perceptions of neighborhood safety and physical activity among youth: The CLAN study. Journal of Physical Activity and Health. 2008;5(3):430-44.
12. Seliske L, Pickett W, Rosu A, Janssen I. Identification of the appropriate boundary size to use when measuring the food retail environment surrounding schools. International Journal of Environmental Research and Public Health. 2012;9(8):2715-27.
13. Seliske L, Pickett W, Rosu A, Janssen I. The number and type of food retailers surrounding schools and their association with lunchtime eating behaviours in students. International Journal of Behavioral Nutrition and Physical Activity. 2013;10(1):19.
14. Carlson JA, Jankowska MM, Meseck K, Godbole S, Natarajan L, Raab F, et al. Validity of PALMS GPS scoring of active and passive travel compared to SenseCam. Medicine and Science in Sports and Exercise. 2015;47(3):662-7.
15. Borghese MM, & Janssen, I. Measuring different types of physical activity in children using accelerometry, GPS, and activity logs. [In progress]..
16. Templeton GF. A two-step approach for transforming continuous variables to normal: Implications and recommendations for IS research. Communications of the Association for Information Systems. 2011;28:41-58.

17. Cohen J. A coefficient of agreement for nominal scales. Educational and Psychological Measurement. 1960;20(1):37-46.

18. Rutenfranz J, Andersen KL, Seliger V, Masironi R. Health standards in terms of exercise fitness of school children in urban and rural areas in various European countries. Annals of Clinical Research. 1982;14 Suppl 34:33-6.

19. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Medicine & Science in Sports & Exercise. 2000;32(5):963-75.

20. Aarts MJ, de Vries SI, van Oers HA, Schuit AJ. Outdoor play among children in relation to neighborhood characteristics: a cross-sectional neighborhood observation study. International Journal of Behavioral Nutrition and Physical Activity. 2012;9(1):98.

21. Carson V, Rosu A, Janssen I. A cross-sectional study of the environment, physical activity, and screen time among young children and their parents. BMC Public Health. 2014;14(1):61.

22. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth. American Journal of Preventive Medicine. 2011;41(4):442-55.

23. Faulkner G, Mitra R, Buliung R, Fusco C, Stone M. Children's outdoor playtime, physical activity, and parental perceptions of the neighbourhood environment. International Journal of Play. 2015;4(1):84-97.

24. Duncan DT, Aldstadt J, Whalen J, Melly SJ, Gortmaker SL. Validation of WalkScore(®) for estimating neighborhood walkability: An analysis of four US metropolitan areas. International Journal of Environmental Research and Public Health. 2011;8(11):4160-79.

25. Smith AL, Troped PJ, McDonough MH, DeFreese JD. Youth perceptions of how neighborhood physical environment and peers affect physical activity: a focus group study. International Journal of Behavioral Nutrition and Physical Activity. 2015;12(1):80.
26. Janssen I, Rosu A. Undeveloped green space and free-time physical activity in 11 to 13-year-old children. International Journal of Behavioral Nutrition and Physical Activity. 2015;12(1):26.
27. Laxer RE, Janssen I. The proportion of youths' physical inactivity attributable to neighbourhood built environment features. International Journal of Health Geographics. 2013;12(1):31.
28. Veitch J, Salmon J, Ball K. Individual, social and physical environmental correlates of children's active free-play: a cross-sectional study. International Journal of Behavioral Nutrition and Physical Activity. 2010;7(1):11.
29. Veitch J, Bagley S, Ball K, Salmon J. Where do children usually play? A qualitative study of parents' perceptions of influences on children's active free-play. Health & Place. 2006;12(4):383-93.
30. Sterne JAC, White IR, Carlin JB, Spratt M, Royston P, Kenward MG, et al. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. The BMJ. 2009;338:b2393.
31. Brownson RC, Hoehner CM, Day K, Forsyth A, Sallis JF. Measuring the built environment for physical activity: state of the science. American journal of preventive medicine. 2009;36(4):S99-S123. e12.

32. McGinn AP, Evenson KR, Herring AH, Huston SL, Rodriguez DA. Exploring associations between physical activity and perceived and objective measures of the built environment. Journal of Urban Health. 2007;84(2):162-84.
33. Leslie E, Saelens B, Frank L, Owen N, Bauman A, Coffee N, et al. Residents' perceptions of walkability attributes in objectively different neighbourhoods: A pilot study. Health & Place. 2005;11(3):227-36.
34. Prins RG, Oenema A, van der Horst K, Brug J. Objective and perceived availability of physical activity opportunities: differences in associations with physical activity behavior among urban adolescents. International Journal of Behavioral Nutrition and Physical Activity. 2009;6(1):70.
35. Timperio A, Crawford D, Telford A, Salmon J. Perceptions about the local neighborhood and walking and cycling among children. Preventive medicine. 2004;38(1):39-47.
36. Carver A, Timperio AF, Crawford DA. Neighborhood road environments and physical activity among youth: The CLAN study. Journal of Urban Health. 2008;85(4):532.
37. Kirtland KA, Porter DE, Addy CL, Neet MJ, Williams JE, Sharpe PA, et al. Environmental measures of physical activity supports: perception versus reality. American journal of preventive medicine. 2003;24(4):323-31.
38. Ball K, Jeffery RW, Crawford DA, Roberts RJ, Salmon J, Timperio AF. Mismatch between perceived and objective measures of physical activity environments. Preventive Medicine. 2008;47(3):294-8.
39. Live where you love. Walk Score. [homepage on the Internet]. 2017. [cited 2017 August 04] Available from: https://www.walkscore.com/

40. The 10 busiest intersection in Toronto are … analysis of the intersections with the heaviest traffic of vehicles and pedestrians throws up some interesting results. The Toronto Star. [newspaper online]. [updated 2015 April 10; cited 2017 August 04]. Available from https://www.thestar.com/news/gta/transportation/2015/04/10/the-10-busiest-intersections-in-toronto-are-.html
41. City of Kingston. Kingston transportation master plan. [homepage on the internet]. 2015. [cited 2017 August 04]. Available from https://www.google.ca/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwioiIjal_DVAhVI_IMKHdTxDIIQFggoMAA&url=https%3A%2F%2Fwww.cityofkingston.ca%2Fdocuments%2F10180%2F14295%2FKingston%2BTransportation%2BMaster%2BPlan%2Fefed4ee8-b5d5-4967-9a32-50166d009354&usg=AFQjCNHhNXkkTfD45nHrHz_cIxGgyzy46Q
42. Rosenberg D, Ding D, Sallis JF, Kerr J, Norman GJ, Durant N, et al. Neighborhood environment walkability scale for youth (NEWS-Y): Reliability and relationship with physical activity. Preventive Medicine. 2009;49(2):213-8.

Chapter 4

General Discussion

4.1 Study Summary

The objectives of this thesis were: 1) to determine the associations between objective and perceived measures of pedestrian safety in the home neighbourhood with outdoor active play among 10- to 13-year-olds; and 2) to determine if the association between objectively measured pedestrian safety and outdoor active play is moderated by parents' perceptions of pedestrian safety. Unlike previous studies on this topic, which were based on children living in large metropolitan centres, this cross-sectional study was based on children (N=458) living in a mid-sized city. GIS was used to objectively measure different types of pedestrian safety within a 1 km buffer of participants' homes. Parents' perceptions of pedestrian safety were obtained through a questionnaire. Outdoor active play variable was measured over 7 consecutive days using a combination of data from activity logs, accelerometers, GPS loggers, and GIS data. Linear regression models were used to determine associations between the study variables. Several individual, family, and neighbourhood covariates were controlled for in these regression analyses.

4.2 Summary of Major Findings

A key finding was that the overall perceived and objective pedestrian safety indexes were not associated with outdoor active play. Although some of the associations for the specific domains of pedestrian safety were significant, these associations were not consistent as they were only present for some of the moderate and high risk groups for some of the domains, they did not follow dose-response patterns (e.g., significant different for moderate group but not the high group), they were not consistent with underlying theory or findings in other studies, the effect sizes were small (e.g., Cohen's d was 0.26 for objective measures of traffic volume between high and low tertiles), and they were based on cross-sectional data. Thus, it is unlikely that the few significant associations that were observed were causal in nature.

The null and positive findings observed in this thesis were inconsistent with previous studies of school-aged children. For instance, a study from Toronto, Canada found that parental concerns about fast drivers in their neighbourhood were inversely related to how long their 10-12 year olds played outdoors on weekdays ($\beta = -0.26$, $p = 0.03$).[1] It is important to note that the previous studies were conducted in larger and more densely populated cities, such as Toronto[1] and Melbourne.[2] Traffic patterns and city design are very different in Kingston, a mid-sized city with ~125,000 residents, and these large metropolitan areas. For example, whereas 46% of the population of Kingston lives in automobile-oriented suburbs, more than 80% of the population live in such areas in Canada's largest cities (e.g., Toronto, Vancouver, and Montreal).[31]

To my knowledge, this study was the first to investigate whether the association between objective measures of pedestrian safety and outdoor active play is moderated by parental perceptions of safety. Our study found that there were no interactions between the objective and perceived measures. Although literature is lacking for the pediatric population, one previous study of adults examined the association between the combination of perceived and objective measured of the built environment and physical activity.[3] Their findings were similar to ours as they found no interactions between the perceived and objective measures; however, both measures were independently associated with physical activity.[3]

Although our findings on the association between outdoor active play and pedestrian safety were not what we were expecting, the association between outdoor active play and many of the covariates were consistent with what has been previously reported. In our study, the mean daily minutes of outdoor active play was significantly higher for boys than for girls (45.5 vs. 38.3 minutes/day). Previous studies have also found similar patterns in that boys have more outdoor time and outdoor active play than girls.[4,5] Our study also found that time spent in outdoor active play was lower in the winter (25.4 minutes/day) in comparison to other seasons (i.e., 48.3 minutes/day in spring). Previous studies have found that children's overall physical activity was lower in the winter season compared to other seasons.[6-8] Our study also found that the mean daily minutes of outdoor active play for younger children was higher than in older children. Similarly, another study found that children have more outdoor play than adolescents (81.8 vs. 42.4 mins/day).[5]

4.3 Strengths

This thesis has a few noteworthy strengths. This study used objective instruments (accelerometry, GPS/GIS) to evaluate outdoor active play, instead of using children or parents' self-reported outdoor active play as was done in other literature on this topic area.[1,10,27] This is a strength because questionnaires or surveys are subject to recall bias.[28-30]

The second strength of this study was the specificity of measures for outdoor active play. Most studies have only examined the association between built environment and children's overall physical activity, rather than specific domains of physical activity and pedestrian safety. This is important because different physical activity domains (e.g., outdoor active play, organized sports, etc.) are likely differentially influenced by built environmental attributes (e.g., pedestrian safety, facilities). Furthermore, this study considered different aspects of pedestrian safety such as traffic volume, traffic speed, traffic calming, and pedestrian infrastructure. Past studies of this topic have primarily used a single measure of safety (e.g., presence of speed bumps, presence of 30 km/ hour zones),[9,10] which is problematic because pedestrian safety is a function of several variables and looking at a single variable on its own would not fully capture traffic risk.

Another strength of this thesis lies in the sampling strategy. Participants were sampled proportionally by age, sex, season, and the 12 electoral districts within Kingston, ensuring that the sample was representative of the target population.

In addition, a remarkable effort was made by the researchers to ensure a high compliance to the study procedures. For instance, participants were sent text messages or emails every morning during data collection prompting them to wear the accelerometer and GPS logger as much as possible during waking hours.

4.4 Limitations

The limitations of this study are mentioned in the following sections.

4.4.1 Internal Validity

Internal validity is the degree to which a study avoids systematic errors so that the results from the study can accurately reflect what is occurring in the population the sample is intended to represent.[11] Selection bias, information bias, and confounding are some of the most common ways in which the results of epidemiological studies can be muddled.

4.4.1.1 Selection Bias

Selection bias occurs when individuals or groups of individuals are selected in a way that is not random, ensuring that the sample will not be representative of the population of interest.[11] In this study, a selection bias would have occurred if the participants differed systematically from the population of 10- to 13- year olds in Kingston, Ontario, leading to an over- or under-estimation of the true association between the study exposure and outcome. Volunteer bias, one type of selection bias, may bias results because individuals that want to take part in the study may be different from the general population of interest.[11] To minimize the change of this bias occurring, this study ensured proportional representation by age, sex, season, and electoral districts in the city of Kingston, ON. Furthermore, our study provided monetary incentives (i.e., $40 dollars) in order to motivate a wide-range of children to engage in the study, and the interactions the research team had with the study participants suggested the monetary compensation, and not the desire to learn more about their physical activity level, was the main determinant of participation. Furthermore, the moderate-to-vigorous physical activity in our sample is very similar to what has been examined in the Canadian Health Measures Survey, which is a nationally representative survey.[12] Specifically, children from our study accumulated an average of 55 minutes per day of moderate-to-vigorous physical activity, while children from the Canadian Health Measures Survey accumulate an average of 59 minutes per day. Taken together, these observations suggest that volunteer bias was not an issue in this study.

4.4.1.2 Information Bias

Information bias happens due to random errors when measuring exposure, outcome, or covariates, leading to the misclassification of participants.[11]

4.4.1.2.1 Information Bias - Outcome Measurement

There are a number of potential sources of information bias in the outdoor active play outcome. An example would be if a participant removed their accelerometer and/or GPS logger while playing in water-based activity. The amount of outdoor active play would be underestimated on that particular day. Children may have felt inclined to increase their physical activity levels because of the devices that they were wearing for the study. However, strategies were put in place to limit this. First, children were asked to continue their habitual physical activity during the 7-day measurement period. Secondly, unlike pedometers, the GPS logger and accelerometer used in this study did not produce any feedback to the participant that might encourage them to be more active. There is no evidence that wearing an accelerometer leads to reactivity.[13,14]

4.4.1.2.2 Information Bias - Exposure Measurement

Pedestrian safety variables were measured within a 1 km distance of the home using a road network buffer based on the home address provided by the parent present at the beginning of the study. Information error could have occurred if a participant spent a large portion of their time in a secondary home during the week (e.g., step-parent's home, grandparent's home). To limit this error, participants with a second home address were asked to choose a time for their physical activity measures where they would be able stay at the same house for most if not all of the 7 day measurement period.

Information bias may have also occurred for the parental perceptions of traffic calming. as the questionnaire item asked "There are traffic slowing devices (e.g. speed humps) on our local streets". In this statement, parents may be inclined to think only about the presence of speed humps because it was the only example listed, which could have led to misclassification. Future studies should consider providing more examples of different types of traffic calming devices such (e.g., stop signs, crosswalks, and low speed zones).

4.4.1.3 Confounding Variables

A confounding variable is an extraneous third factor that is related to both the exposure and the outcome of interest and can impact the relationship of interest outside of the causal pathway.[11] In this study, we controlled for several potential confounders. However, it is possible that residual confounding, due to imprecise measurement of the confounders, could have impacted the results of this study.[11] For example, using the number of siblings alone may not be a good indicator for sibling influence. Perhaps combining or creating a composite score from the number of siblings, age of siblings and sex of siblings would provide a more valid indicator of sibling influence. Another potential variable with residual confounding is socioeconomic status, which was measured by the parent's education and household income. The study may have benefited from a more comprehensive measure of socioeconomic status. For instance, socioeconomic status could include a combination of measures such as occupational prestige, total family income, educational attainment, economic pressure / financial difficulties, and family budget. In addition, there are confounders that should have been included, but were not due to the lack of available data and time constraints. Some examples include neighbourhood appearance (e.g., graffiti), crime, and neighbourhood amenities.

4.4.2 External Validity

External validity is defined as the degree to which the study's results can be generalized to other populations.[11] This study tried to recruit a representative sample of 10-13-year-old children in Kingston, Ontario. The population of Kingston is 123,363 with a population density of 274 persons/km^2.[8] The findings may have relevance for children from similar sized cities; however, it is questionable as to whether they would be generalizable to children from rural areas or large metropolitan areas. Other cities in Canada that are similar to Kingston in size and are Guelph, ON (population 151,984), St. John, NF (population 205,955), and Barrie, ON (population 197,059) and approximately 7 million (20%) Canadian live in mid-sized cities.[15]

4.4.2.1 Causation

The main goal of this study was to determine whether parental perceptions of pedestrian safety and objective measures of pedestrian safety caused changes in outdoor active play levels among pre- and early- adolescents. Several criteria are used to help researchers determine the likelihood of causation of an observed relationship. Drawing from Bradford-Hill (1965), the five criteria often used in the field of epidemiology to determine causation are temporality, plausibility, strength of association, consistency, and dose-response relationship.[11]

4.4.2.2 Temporality

Temporality is defined as whether the information about exposure and outcome was assembled at the same period of time or whether information about the exposure was gathered prior to, or after the information about the outcome was collected.[11,16] This study was a cross-sectional design, meaning that temporality cannot be established.

4.4.2.3 Plausibility

Bradford-Hill (1965) suggests that causation is most plausible if a strong body of theoretical evidence supports the plausibility of the relationship that is found.[11,16] In this study, the perceived and objective measures of pedestrian safety were either not related or were negatively associated with outdoor active play ($p < 0.05$). Our findings were not supported by underlying theory or previous studies, where the built environment (e.g., pedestrian safety) has been found to positively influence physical activity in children.

4.4.2.4 Strength of Association

Bradford-Hill's (1965) criterion states that the stronger an association, the more likely it is not attributable to bias or confounding factors.[11,16] This study found few differences in outdoor active play in the high to low risk groups, and the few differences that existed has small effect sizes. For example, the Cohen's d for the overall perceived and objective pedestrian safety indexes were -0.02 and 0.01 respectively.

4.4.2.4 Dose-Response Relationship

If a dose-response relationship is present between the exposure and outcome of interest, this provides evidence for causation.[11] Some of the specific pedestrian safety domains were significantly associated with outdoor active play; however, these associations did not follow a dose-response pattern. For example, there was a significant difference for objective traffic calming in a moderate tertile ($\beta = -0.28$, $p = 0.008$) but not high tertile ($\beta = -0.06$, $p = 0.594$). This suggests that these findings are not causal in nature.

4.4.2.5 Consistency

The association between pedestrian safety and outdoor active play observed in our study was different from previous studies of this topic. There were no substantial evidences of causation for both perceived and objective measures of pedestrian safety on outdoor active play in children. This is because the associations of interest were opposite in direction and/or statistically insignificant in comparison to findings from previous studies.[1,2] However, in our study, there were good evidences of causation for some of the covariates such as age, sex, and season, which were consistent with past literatures. Further details on the covariates can be found in section 4.2.

4.5 Public Health Implication

The findings of this thesis have some relevant implications for public health practice. Namely, the findings suggest that changing road conditions to make them safer for pedestrians may not increase preadolescent children's outdoor active play in mid-sized cities such as Kingston. Therefore, policies, programs, and interventions aimed at increasing outdoor active play may want to focus on other known modifiable correlates of outdoor active play behaviours such as screen time,[33] and parental encouragement.[34]

This study found that there is a poor agreement between parental perceptions of pedestrian safety and objective measures. This suggests that there is a lack of awareness from parents about built environmental features in their neighbourhood, which may be a factor that contributes to parental concerns for pedestrian safety. In the future, researchers and public health professionals may want to consider highlighting the myths of traffic danger. For instance, pedestrian injuries and fatalities are rare events. This kind of awareness helps to stop the perpetuation of fears related to traffic danger among parents, which may increase children's outdoor active play.

4.6 Future Research Directions

Future studies are needed to confirm whether or not pedestrian safety is a correlate of outdoor play in mid-sized cities such as Kingston. As the literature in this topic area is based on cross-sectional studies, future studies should consider using longitudinal designs to establish the temporal nature of the relationship observed in this study. In addition, studies should consider how the domains of pedestrian safety may impact other physical activity domains and lifestyle behaviours, such as active transportation.

Future studies examining outdoor active play and pedestrian safety should also consider the specific locations where children play within their neighbourhood. Another important area of consideration for future studies is measurement. Most studies that have observed an association between pedestrian safety and physical activity have only measured perceptions of safety. There should be more research projects examining the associations and interrelations between parental concerns of pedestrian safety and the actual traffic features. This is important because the more we know about the interrelationship between perceived and objective measures of pedestrian safety, the better researchers can tailor interventions to meet the different needs of low and high-risk groups.

4.7 Summary of MSc Research Experience

Overall, my Masters' experience has increased my understanding as a professional in the field of kinesiology, public health, and epidemiology. During my first year of coursework, I had the opportunity to gain an understanding of the study of epidemiology, as well as the determinants of physical activity in children. I strengthened this knowledge as a teaching assistant for the undergraduate level courses in statistics and research methods, as well as during my second year presenting at an international conference in June of 2017 at Victoria, BC (International Society of Behavioral Nutrition and Physical Activity). These experiences have also allowed me to develop confidence in my presentation skills as well as disseminate some aspects of my research.

Outside of my course work and teaching assistant duties, my role as a research assistant for the Active Play Study involved contributing to data collection (e.g. performing an anthropometric and body measurement on participants, downloading data from devices), and cleaning and processing of data (e.g., merging data using PALMS software). By managing and analyzing the Active Play Study dataset, I gained a comprehensive understanding of SPSS statistical programming software. In order to collect pedestrian safety variables, I also gained a strong understanding of how to use the ArcGIS software. Overall, through the combination of coursework, independent study projects, writing literature reviews, interpreting results for my thesis, and teaching assistant experiences, I have developed the knowledge and skills required to work as a professional in the field of kinesiology and epidemiology.

4.8 Conclusion

In summary, this study used objective measures to capture both pedestrian safety features and outdoor active play. This study observed the independent relationship between perceived and objectively measured pedestrian safety on outdoor active play in a sample of 10- to 13-year-olds and found that overall perceived and objective measures of pedestrian safety were not associated with outdoor active play.

4.9 Reference

1. Faulkner G, Mitra R, Buliung R, Fusco C, Stone M. Children's outdoor playtime, physical activity, and parental perceptions of the neighbourhood environment. International Journal of Play. 2015;4(1):84-97.
2. Carver A, Timperio A, Hesketh K, Crawford D. Are safety-related features of the road environment associated with smaller declines in physical activity among youth? Journal of Urban Health. 2010;87(1):29-43.
3. McGinn AP, Evenson KR, Herring AH, Huston SL, Rodriguez DA. Exploring associations between physical activity and perceived and objective measures of the built environment. Journal of Urban Health. 2007;84(2):162-84.
4. Klinker CD, Schipperijn J, Kerr J, Ersbøll AK, Troelsen J. Context-specific outdoor time and physical activity among school-children across gender and age: Using accelerometers and GPS to advance methods. Frontiers in Public Health. 2014;2:20.
5. Bringolf-Isler B, Grize L, Mäder U, Ruch N, Sennhauser FH, Braun-Fahrländer C. Built environment, parents' perception, and children's vigorous outdoor play. Preventive medicine. 2010;50(5):251-6.
6. Atkin AJ, Sharp SJ, Harrison F, Brage S, Van Sluijs EM. Seasonal variation in Children’s physical activity and sedentary time. Medicine and Science in Sports and Exercise. 2016;48(3):449.
7. Mattocks C, Leary S, Ness A, Deere K, Saunders J, Kirkby J, et al. Intraindividual variation of objectively measured physical activity in children. Medicine and Science in Sports and Exercise. 2007;39(4):622-9.

8. Rich C, Griffiths LJ, Dezateux C. Seasonal variation in accelerometer-determined sedentary behaviour and physical activity in children: a review. International Journal of Behavioral Nutrition and Physical Activity. 2012;9(1):49.
9. Carver A, Timperio AF, Crawford DA. Neighborhood road environments and physical activity among youth: The CLAN study. Journal of Urban Health. 2008;85(4):532.
10. Aarts MJ, de Vries SI, van Oers HA, Schuit AJ. Outdoor play among children in relation to neighborhood characteristics: a cross-sectional neighborhood observation study. International Journal of Behavioral Nutrition and Physical Activity. 2012;9(1):98.
11. Webb P, Bain, C. Essential epidemiology: an introduction for students and health professionals: Vasa; 2011.
12. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian adults: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. Health reports. 2011;22(1):7.
13. Davis RE, Loprinzi PD. Examination of accelerometer reactivity among a population sample of children, adolescents, and adults. Journal of Physical Activity and Health. 2016;13(12):1325-32.
14. Dössegger A, Ruch N, Jimmy G, Braun-Fahrländer C, Mäder U, Hänggi J, et al. Reactivity to accelerometer measurement of children and adolescents. Medicine and Science in Sports and Exercise. 2014;46(6):1140.
15. Live where you love. Walk Score. [homepage on the Internet]. 2017. [cited 2017 August 04] Available from: https://www.walkscore.com/

16. Fedak KM, Bernal A, Capshaw ZA, Gross S. Applying the Bradford Hill criteria in the 21st century: How data integration has changed causal inference in molecular epidemiology. Emerging Themes in Epidemiology. 2015;12:14.

17. Kalish M, Banco L, Burke G, Lapidus G. Outdoor play: A survey of parent's perceptions of their child's safety. Journal of Trauma. 2010;69(4 Suppl):S218-22.

18. Weir LA, Etelson D, Brand DA. Parents' perceptions of neighborhood safety and children's physical activity. Preventive Medicine. 2006;43(3):212-7.

19. Esteban-Cornejo I, Carlson JA, Conway TL, Cain KL, Saelens BE, Frank LD, et al. Parental and adolescent perceptions of neighborhood safety related to adolescents' physical activity in their neighborhood. Research Quarterly for Exercise and Sport. 2016;87(2):191-9.

20. Davison KK, Lawson CT. Do attributes in the physical environment influence children's physical activity? A review of the literature. The International Journal of Behavior Nutrition and Physical Activity. 2006;3:19.

21. Valentine G, McKendrick J. Children's outdoor play: Exploring parental concerns about children's safety and the changing nature of childhood. Geoforum. 1997;28(2):219-35.

22. Carson V, Rosu A, Janssen I. A cross-sectional study of the environment, physical activity, and screen time among young children and their parents. BMC Public Health. 2014;14(1):61.

23. Gray CE, Barnes JD, Cowie Bonne J, Cameron C, Chaput JP, Faulkner G, et al. Results from Canada's 2014 report card on physical activity for children and youth. Journal of Physical Activity & Health. 2014;11 Suppl 1:S26-32.

24. Anderson SE, Economos CD, Must A. Active play and screen time in US children aged 4 to 11 years in relation to sociodemographic and weight status characteristics: a nationally representative cross-sectional analysis. BMC Public Health. 2008;8(1):366.

25. Mitchell C, Clark A, Gilliland J. Built environment influences of children's physical activity: Examining differences by neighbourhood size and sex. International Journal of Environmental Research and Public Health. 2016;13(1):130.

26. Fisher A, Reilly JJ, Montgomery C, Kelly LA, Williamson A, Jackson DM, et al. Seasonality in physical activity and sedentary behavior in young children. Pediatric Exercise Science. 2005;17(1):31-40.

27. Page AS, Cooper AR, Griew P, Jago R. Independent mobility, perceptions of the built environment and children's participation in play, active travel and structured exercise and sport: the PEACH Project. International Journal of Behavioral Nutrition and Physical Activity. 2010;7(1):17.

28. Sirard JR, Pate RR. Physical activity assessment in children and adolescents. Sports Medicine. 2001;31(6):439-454.

29. Ainsworth BE, Richardson MT, Jacobs DR, Leon AS, Sternfeld B. Accuracy of recall of occupational physical activity by questionnaire. Journal of Clinical Epidemiology. 1999;52(3):219-227.

30. Strath SJ, Bassett DR, Swartz AM. Comparison of the College Alumnus Questionnaire Physical Activity Index with objective monitoring. Annals of Epidemiology. 2004;14(6):409-415.

31. Gordon DLA, Janzen, M. Suburban nation? estimating the size of Canada's suburban population. Journal of Architectural and Planning Research. 2013;30(3):197–220.

32. Ding D, Sallis JF, Kerr J, Lee S, Rosenberg DE. Neighborhood environment and physical activity among youth: A review. American Journal of Preventive Medicine. 2011;41(4):442-455

33. Anderson SE, Economos CD, Must A. Active play and screen time in US children aged 4 to 11 years in relation to sociodemographic and weight status characteristics: a nationally representative cross-sectional analysis. BMC Public Health. 2008;8:366.

34. Ferrao T, Janssen I. Parental encouragement is positively associated with outdoor active play outside of school hours among 7-12 year olds. PeerJ. 2015;3:e1463.

Appendix A

Active Play Study Recruitment Advertisement

Physical Activity Levels in Kingston Children

We are looking for 10-13 year old children for this exciting opportunity to participate in a physical activity study at Queen's University!

Children can earn up to $40!

**This study will determine where children participate in physical activity.
It will also look at how different types of physical activity impact their health.**

All 10-13 year olds who live and go to school in Kingston can participate.

Participation in this study involves the following:

1) **Non-invasive physical measures (eg, height, weight, blood pressure)**
2) **Completing a survey on a computer**
3) **Wear miniature, non-intrusive activity measurement devices for 7 days**

The total time commitment for participating is around 4 hours.

For more information please contact us:

Email: XX@queensu.ca
Phone: (613)533-6000 ext. XXXXX
Website: www.xxx.ca

Physical activity study: XX@queensu.ca www.xxx.ca

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Appendix B

Active Play Study Participant Letter of Information/Consent

LETTER OF INFORMATION / CONSENT FOR CHILD

Physical Activity Levels in Kingston Children

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Research sponsor: Heart and Stroke Foundation of Canada

Purpose of the study

We want you to participate in this study. It is about children's physical activity. Children's physical activity levels are getting worse. We want to know why.

The purposes of this study are:
1. To determine how much active play, sport, and walking and biking children do.
2. To determine where children get physically active. Several locations will be looked at. These include homes, streets, playgrounds, fields, forests, schools, and arenas.
3. To determine how families, friends, and neighbourhoods affect physical activity.
4. To determine how physical activity affects health.

What will happen during the study?

You and your parent will come to Queen's University for two visits. The visits will be 8 to 11 days apart. Each visit will last about 45 minutes. Your physical activity will be measured for 7 days between the two visits.

At the first visit we will explain the study to you. We will answer any questions you have. We will measure how tall you are and how much you weigh. We will measure your belt size. We will measure your heart rate and blood pressure using a small machine. These measures should not cause any pain or discomfort.

At the end of the first visit we will give you two small electronic devices. You will wear them for 7 days. They will measure your physical activity. The first device will measure how much physical activity you get. You will wear it around your waist on a belt. The second device looks like a watch. It will record your location on a map about every 30 seconds. It will tell us where you got your physical activity.

On the 7 days your physical activity is measured you should write when you remove the electronic devices. You should also write down times you go to bed and wake up. We will give you a diary to write this down.

On the second visit to Queen's University you will return the two electronic devices. You will also answer some questions on a computer. This will take about 25 minutes. The questions will ask about things you do in your free time. The questions will also ask about your health.

Are there any risks to participating in the study?

Participating should not cause any harms. You do not have to answer questions that make you uncomfortable.

Are there any benefits to participating in the study?

The research will not benefit you directly. We hope to learn more about physical activity in children. We hope this will help to us think of ways to get children to be more active.

Payment for participating

You will be given up to $40. You will receive $10 at the end of the first visit. You will be given $20 at the start of the 2nd visit if you return the electronic devices in good condition. You will be given $10 at the end of the 2nd visit. If you drop out of study, you can keep the money you have already received.

Confidentiality and privacy

We will make every effort to keep the information we obtain from you private. When we show the research findings we will not include private information about you. The information we obtain about you will be protected on our computers.

Legally required disclosure

Although we will protect your privacy, if the police request information we may be required to give it to them.

What if I change my mind about being in the study?

All parts of a research study are voluntary. You can drop out of the study at any time before it is done. There will be no penalties if you drop out. Also, any information you gave us will be destroyed if you choose.

Questions about the study

Questions can be asked to Dr. Ian Janssen. His contact information is shown at the top of this letter. Ethical concerns can be asked to the Chair of the General Research Ethics Board at chair.GREB@queensu.ca or 613-533-6081.

This study has been granted clearance according to the recommended principles of Canadian ethics guidelines, and Queen's policies.

Physical Activity Levels in Kingston Children

CONSENT FORM FOR CHILD – Participant's Copy

I have read and understood the attached information sheet or had it explained to me. I know that there may be no direct benefit to me for participating. I know that it is my choice to participate. I have been told about the study. I have had all of my questions answered. I know that any information collected about me will be kept private. No one will know that I participated in the study except for the research team. I know I am free to drop out of the study at any time. If I drop out it will not affect me or my family. I also know that I do not have to answer questions that make me feel uncomfortable. I have received a copy of the information sheet and consent form. I agree to participate in the study.

Your full name (Printed) ___________________________________

Your signature: ____

Date: ____

Would you be willing to be contacted about a potential follow-up study, understanding that you can always decline the request?

☐ *Yes*

☐ *No*

Participant ID: ☐☐☐☐

Physical Activity Levels in Kingston Children

CONSENT FORM FOR CHILD – Research Team's Copy

I have read and understood the attached information sheet or had it explained to me. I know that there may be no direct benefit to me for participating. I know that it is my choice to participate. I have been told about the study. I have had all of my questions answered. I know that any information collected about me will be kept private. No one will know that I participated in the study except for the research team. I know I am free to drop out of the study at any time. If I drop out it will not affect me or my family. I also know that I do not have to answer questions that make me feel uncomfortable. I have received a copy of the information sheet and consent form. I agree to participate in the study.

Your full name (Printed) ___________________________________

Your signature: ____

Date: ____

Would you be willing to be contacted about a potential follow-up study, understanding that you can always decline the request?

☐ *Yes*

☐ *No*

Appendix C

Ethics Letter of Approval for this Thesis

September 22, 2015

Dr. Ian Janssen
Professor
School of Kinesiology and Health Studies
Queen's University
KHS Building
28 Division Street
Kingston, ON, K7L 3N6

GREB Romeo #: 6013818
Title: "GPHE-178-14 The Active Play Study"

Dear Dr. Janssen:

The General Research Ethics Board (GREB) has reviewed and approved your request for renewal of ethics clearance for the above-named study. This renewal is valid for one year from October 17. Prior to the next renewal date you will be sent a reminder memo and the link to ROMEO to renew for another year.

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

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example you must report changes in study procedures or implementation of new aspects into the study procedures. Your request for protocol changes will be forwarded to the appropriate GREB reviewers and/or the GREB Chair. Please report changes to GREB through either ROMEO Event Reports or the Ethics Change Form at http://www.queensu.ca/ors/researchethics/GeneralREB/forms.html.

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

Yours sincerely,

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

c.: Dr. Michael McIsaac, Co-investigator
Mr. Michael Borghese, Graduate Student
Dr. Lucie Lévesque, Chair, Unit REB
Ms. Josie Birchall, Dept. Admin.

Appendix D

GPS Watch Instructions

Instructions for Activity Monitor, Location Monitor, and Sleep & Activity Log

This study will measure your physical activity patterns over one week. In order to do this, we want you to wear an Activity Monitor and a Location Monitor for the next 7 days. We are interested in measuring your normal activity level. <u>Please do not change your normal physical activity levels during the study</u>.

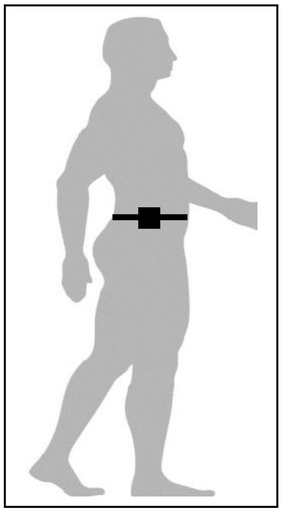
Picture of the Activity Monitor

Picture of the Location Monitor

<u>Information and Instructions for the Activity Monitor and Sleep & Activity Log</u>

An Activity Monitor is a small electronic device that records all daily activities as electronic signals. It does not need to be turned on or off. You do not need to change the batteries or recharge this device. Please start wearing the Activity Monitor as soon as your visit to the laboratory is over. We want you to keep wearing it for the 7 days and nights following your visit.

The Activity Monitor should be worn as shown in the picture to the right. You should wear it around your waist using the elastic belt we give you. It should be worn above your <u>right</u> hip. The Active Monitor should be positioned so that "RESPIRONICS" is at the top and "Actical" is at the bottom. It should be located half way between your stomach and back. You can wear it underneath or above your clothes.



It is very important that you wear the Activity Monitor as much as possible. You should take it off when you are having a bath or shower or when swimming since the Activity Monitor is not waterproof. *If there are times that you need to take the Activity Monitor off, other than when having a bath or shower, we would like you to record this on the Activity Monitor and Location Monitor Diary*. This should be recorded in the PINK columns of the diary.

We would also like you to keep the Activity Monitor on at night when you go to bed. The Activity Monitor will measure how much you move when you are sleeping. *We would like you to record what time you wake up in the morning and what time you go to bed at night on the Sleep, Organized Sports, and Outside Chores Diary*. This should be recorded in the YELLOW columns of the diary.

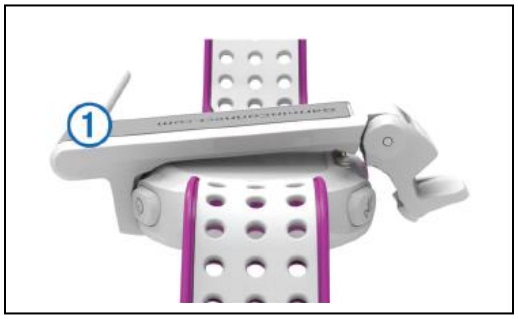
If you participate in organized sports or programs during the study (eg, hockey, soccer, karate, dance class), we would like you to record these sports and the times you participated in the Sleep, Organized Sport, and Outside Chores Diary. This should be done in the GREEN columns of the diary. Finally, *if you do any chores or work outdoors during the study (eg, shovel snow, farming, cut grass*), we would like you to record what time you did this work in the BLUE columns of the diary.

<u>Information and Instructions for the Location Monitor</u>

The Location Monitor is an electronic device that connects to satellites and records your location every few seconds. We will use the Location Monitor to determine where you are when you are being active. While you are using the Location Monitor during the study we will not know where you are. However, after the study is over the Location Monitor will tell us where you were throughout the week.

You will wear the Location Monitor on your wrist like a watch. You can wear it on your left or right wrist. You can wear the Location Monitor under long sleeved clothes such as a sweatshirt or coat.

The Location Monitor runs on a rechargeable battery that lasts for about 10 hours. We ask that you charge the Location Monitor tonight before you go to bed. You will need to do this again every night for the following 7 nights. Follow these 4 steps to charge the Location Monitor:



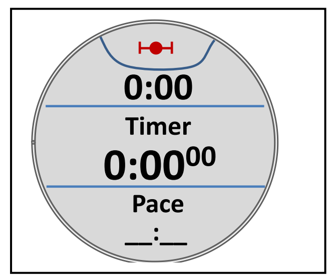
1) Plug the USB end of the charger into the USB adapter.
2) Plug the USB adapter in a regular outlet.
3) Look at the picture to the right. Align the charge posts on the charger with the contacts on the back of the Location Monitor.
   Then press the charger until it clicks.

4) Leave it plugged in overnight to charge.

You should start wearing the Location Monitor in the morning before you leave your house. On school days, put the Location Monitor on a few minutes before you leave for school. On weekends and holidays, try to put the Location Monitor on at around the same time you would do on school days. Alternatively, if you are leaving your house earlier in the day, put the Location Monitor on before you go.

When you start wearing the Location Monitor each morning, you will need to turn its recording function "on". Follow these 4 steps:

1) Press the top right button on the Location Monitor. This is button ❹ in the picture to the right.
2) Continue pressing this button until the display on the Location Monitor looks like the picture on the bottom right.
3) Press this button once more and the recording function will turn "on". A large green triangle will appear on the display for 2 seconds immediately after the recording function is turned "on". Also, the numbers under "Timer" will start to count up. Numbers may also start to appear at the top and bottom of the display once you start to walk around.



4) After the recording function is turned on, you can turn on the watch function by pressing the middle button on the left hand side of the display. This is button ❷ shown in the picture above.

Once the recording function is "on", do not press the top right button of the Location Monitor again. If you do, the recording function will turn "off". If this happens, press the top right button again to turn it back "on". You will know the recording function is "on" when the timer in the display is counting up.

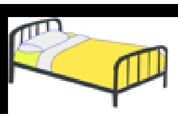
Let the recording function of the Location Monitor run continuously each day. The battery on the Location Monitor will usually run out of charge after about 10 hours. Therefore, please try to re-charge the battery for about 15 minutes in the late afternoon or early evening (eg, right after school, at supper time). After you re-charge the battery for a few minutes, please put the Location Monitor back on and turn "on" the recording function again. Right before you go to bed at night, you should take the Location Monitor off and charge it again for the next day.

If there are times that you leave home without the Location Monitor, we would like you to record this on the Activity Monitor and Location Monitor Diary. This should be recorded in the ORANGE columns of the diary.

It is important that you wear the Location Monitor as much as possible when it is turned on. Since the Location Monitor is waterproof, you can wear it when showering, bathing, or swimming. You should not wear the Location Monitor to bed at night as you should be charging it's battery at that time. If you need to take the Location Monitor off when playing organized sports, please bring it with you to where you are playing. For example, if you need to take it off to play in a basketball game, take it off at the gym and put it back on after the game is over.

Appendix E

Activity and Sleep Log

							
Day	**What time did you get out of bed in the morning?**	**What time did you go to sleep at night?**	**If you participated in organized sports or programs, what time did they start and stop?**		**What organized sports or programs did you participate in?**	**If you worked or did chores outside, what time did they start and stop?**	
			Time Start	Time Stop			
Example	7:30 am	9:30 pm	4:00 pm	4:30 pm	karate	7:50 am	8:10 am
			6:30 pm	7:30 pm	soccer		
Day 1							
Day 2							
Day 3							
Day 4							
Day 5							
Day 6							
Day 7							

Day	If you took the Activity Monitor off, what time did you take it off and put it back on? Time Off	Time Back On	What were you doing when the Activity Monitor was off?
Example	4:00 pm	4:30 pm	karate
	6:30 pm	7:30 pm	soccer
Day 1			
Day 2			
Day 3			
Day 4			
Day 5			
Day 6			
Day 7			

Appendix F

Relevant Questions from Child Survey

Participant ID

Enter 4 digit Participant ID

[ ]

How many close MALE friends do you have?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4 or more

How many close FEMALE friends do you have?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4 or more

Appendix G

Relevant Questions from Parent Survey

Participant ID

Enter 4 digit Participant ID

[ ]

You should answer the questions based on your child who is participating in this study. Choose the answers that best describe you and your child. There are no right or wrong answers.

There are a number of reasons why you might want your child to go outside to play. Show how much you agree or disagree with the following statements. Please mark one box for each line.

	Strongly Agree	Agree	Neither Agree nor Disagree	Disagree	Strongly Disagree
It is good for his or her brain	○	○	○	○	○
It is something my child finds very enjoyable	○	○	○	○	○
It helps my child relax	○	○	○	○	○
Playing outdoors with other children teaches my child to get along with others	○	○	○	○	○
It gives me an opportunity to get things done around the house (eg, chores, cooking)	○	○	○	○	○
It allows my child to be with their friends	○	○	○	○	○
Playing outdoors helps my child burn off energy	○	○	○	○	○
It is important for my child to spend time outdoors in nature	○	○	○	○	○

How would you describe your child's race? Please select all races that are relevant.

- ☐ White or Caucasian
- ☐ Hispanic or Latin American (eg, Mexican, Puerto Rican, Brazilian)
- ☐ Black or African American (eg, Kenyan, Jamaican, Somalian)
- ☐ Aboriginal or Native (eg, First Nations, Metis, Inuit)
- ☐ Asian (eg, Chinese, East Indian, Japanese, Vietnamese)
- ☐ Arabic / Middle Eastern (eg, Saudia Arabian, Israeli, Iranian)
- ☐ Other race not listed above
- ☐ Prefer not to say

How many brothers does your child have that live in the same home, including step-brothers?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4 or more

How many sisters does your child have that live in the same home, including step-sisters?

- ○ 0
- ○ 1
- ○ 2
- ○ 3
- ○ 4 or more

Are you male or female?

- ○ Male
- ○ Female

What is your current employment status?

- ○ Work full-time
- ○ Work part-time
- ○ Do not work
- ○ Prefer not to say

What is your marital status?

- ○ Married
- ○ Living common-law
- ○ Separated or divorced
- ○ Widowed
- ○ Single and never married
- ○ Prefer not to say

What is the current employment status of your spouse or common-law partner?

- ○ Work full-time
- ○ Work part-time
- ○ Do not work
- ○ I do not have a spouse or partner
- ○ Prefer not to say

What is the highest grade or level of education you have completed?

- ○ No schooling
- ○ Elementary (Grades 1-8)
- ○ High School (Grades 9-12)
- ○ Community College or Technical College or 2-year College
- ○ University or 4-year College
- ○ Graduate University (eg, master's, doctorate, medicine, law school)
- ○ Prefer not to say

During the past 12 months, what was your household income from wages and salaries (before taxes and deductions)?

- ○ Less than $25,000
- ○ $25,000 to $50,000
- ○ $50,001 to $75,000
- ○ $75,001 to $100,000
- ○ More than $100,000
- ○ Prefer not to say

Indicate how much you agree with each of these statements about road and traffic safety in your neighbourhood. Please select 1 response for each statement.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
There are major barriers to walking / cycling in my neighbourhood that make it hard for my child to get from place to place (e.g. freeways, major roads)	○	○	○	○	○
There are no lights / crossings for my child to use	○	○	○	○	○
My child would have to cross several roads to get to areas where he / she can play	○	○	○	○	○
There is heavy traffic on our local streets	○	○	○	○	○
There are traffic slowing devices (e.g. speed humps) on our local streets	○	○	○	○	○
The speed of traffic on our local streets is usually slow (50 km per hour or less)	○	○	○	○	○
Road safety is a concern in our neighbourhood	○	○	○	○	○
There are sidewalks on most streets in our neighbourhood	○	○	○	○	○
There are many parked cars on my street	○	○	○	○	○
The weather is often not suitable for my child to be outdoors (eg, too cold, too much rain)	○	○	○	○	○