Associations between Adolescents' School Travel-Physical Activity, School Travel Mode, and Neighbourhood Walkability

by

Amanda Donatienne Claudia Frazer
Bachelor of Science, University of Victoria, 2009

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Supervisory Committee

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Abstract

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Introduction: Physical activity (PA) in Canadian adolescents is low, and active travel to school is an important source of PA. Neighbourhood walkability is linked to youth PA, and may also be related to school travel behaviour. Therefore, the aim of this thesis was to explore the association between adolescents' school travel-PA, school travel mode, and walkability in urban and suburban neighbourhoods.

Methods: Adolescents (n=234; grade 8-10) were sampled from schools in a high walkability urban (n=52) and a low walkability suburban neighbourhood (n=182). PA was measured by accelerometry (ActiGraph; ≥4d 600 $\text{min}\cdot\text{d}^{-1}$), and converted from activity counts to minutes of moderate-to-vigorous PA (MVPA). Travel-PA was derived from minutes of MVPA accrued during the hour before and after school. Travel mode was self-reported (i.e., walk, bike, transit, school bus, car). Analyses were stratified by sex and travel mode (Stata v.10).

Results: Valid travel data were provided by 224 participants (49.6% girls). Prevalence of travel modes differed significantly between urban and suburban boys (χ^2=25.4, p<0.001) and girls (χ^2=21.0, p<0.001). Valid PA and travel data were available for an analytical sample (n=91, 58.2% girls). Differences in collapsed modes (active vs. passive) were not significant between cohorts for boys (χ^2=1.5, p=0.22) or girls (χ^2=0.3, p=0.61). Minutes of travel-PA were significantly higher in urban than suburban boys for both active (29.4±9.2 vs. 11.0±9.2, p<0.001) and passive travel (22.6±2.7 vs. 8.8±7.4, p<0.001). There were no significant differences in girls.

Conclusion: These results suggest that neighbourhood walkability may be associated with school travel-PA in boys, regardless of travel mode. More research is needed to understand this association in girls. The research also showed travel modes were different between neighbourhood cohorts, but when modes were collapsed into larger categories (passive and active) they were not. Future research should analyse school travel-PA by detailed travel modes whenever possible.

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1 Introduction

1.1 Overview

Historically children have walked to school as part of their weekday routine. The walk or cycle to school, defined as active travel to school, has been positively associated with increased levels of weekday physical activity (PA; Faulkner, Buliung, Flora, & Fusco, 2009) and cardiorespiratory fitness (CRF; Lubans, Boreham, Kelly, & Foster, 2011). Nevertheless, recent data from the US National Personal Transportation Survey suggests that between 1969 and 2001 active modes of school travel have decreased, while passive modes such as car or bus travel have increased (McDonald, 2007). Meanwhile, the developed world has also simultaneously moved towards a more car-dependent urban design (Sallis & Glanz, 2006).

School travel behaviour is complex and is likely influenced on a multitude of levels (Panter, Jones, & Van Sluijs, 2008). Several reviews have demonstrated that distance is the foremost determinant of school travel behaviour (Davison, Werder, & Lawson, 2008; Panter, Jones, & Van Sluijs, 2008; Pont, Ziviani, Wadley, Bennett, & Abbott, 2009). However, in order to fully understand the interplay between the various domains of influence, school travel should be viewed within a socio-ecological framework such as the conceptual model put forth by Panter and colleagues (2008). The model proposes that individual travel patterns and travel-related PA may be influenced on two primary levels: perceptual and physical.

Perceptions may impact children and youth's travel behaviours and may be linked to the influence that parents have on their daily activities (Davison et al., 2008). For example, parental perceptions of the environment, crime, and gender of the child could influence whether children are permitted to walk or cycle to school (Davison et al., 2008). In adolescents, existing evidence also supports perceptions as important in determining school travel behaviour (Nelson & Woods, 2010; Voorhees et al., 2010). Although adolescent school travel may also be associated with independent mobility (Page, Cooper, Griew, & Jago, 2010) and physical fitness (Lubans et al., 2011), it may be that the environment is the most important correlate of school travel since it is where the behaviour of school travel occurs (Wong, Faulkner, & Buliung, 2011).

The physical environment includes attributes of the built environment and a neighbourhood's level of walkability. Neighbourhood walkability represents a macro level composite measure of a community's density, diversity, and design (Saelens, Sallis, Black, & Chen, 2003). Specific components of the built environment such as street networks, traffic safety, route directness, and pedestrian infrastructure each contribute to a neighbourhood's overall walkability (Lo, 2009; McMillan, 2007; Salmon, Salmon, Crawford, Hume, & Timperio, 2007). Walkability has been defined as the collective presence or absence of built environment features that are known to support active travel in a neighbourhood, including residential density, land use diversity, intersection density, and street connectivity (Frank et al., 2010). Classified on three levels: high, mixed, and low, walkability may influence pedestrian and cyclist activity patterns including travel to and from school (Sallis & Glanz, 2006).

Studies in adults have demonstrated that a greater percentage of residents meet the daily PA requirements in high walkability neighbourhoods (Frank, Saelens, Powell, & Chapman, 2007; Saelens et al., 2003). The current research regarding walkability's association with youth PA and school travel is less clear. A recent review found walkability was significantly and positively related to children's PA, but in adolescents only specific components of walkability, such as land use mix and residential density, were routinely correlated with PA (Ding, Sallis, Kerr, Lee, & Rosenberg, 2011).

There is less research examining the association between walkability and school travel in children and youth, particularly in relation to PA from school travel (school travel-PA). Some studies have shown high neighbourhood walkability was positively associated with self-reported active travel to school (Giles-Corti et al., 2011; Kerr, Rosenberg, Sallis, Saelens, Frank, & Conway, 2006; Napier, Brown, Werner, & Gallimore, 2011). Only two studies (Stevens & Brown, 2011; Van Dyck, Cardon, Deforche, & De Bourdeaudhuij, 2009) have looked at directly-measured PA from school travel during the assumed commute between differing levels of objectively defined neighbourhood walkability. One study out of the US found higher levels of directly-measured PA during the half hour before and after school (assumed commute) in children living in a high walkability neighbourhood (Stevens & Brown, 2011). Similarly, a Belgian study (Van Dyck et al., 2009) found adolescents obtained more minutes of directly-measured school travel-PA in a highly walkable urban neighbourhood compared to adolescents in a low walkability suburban neighbourhood, though this trend was not significant. However, the same study found the opposite association in cyclists: greater minutes of directly-measured PA from cycling to school were accumulated in adolescents from the low walkability neighbourhood (Van Dyck et al., 2009).

Combining self-reported travel behaviour with directly-measured PA and walkability data could enhance the understanding of the association between school travel-PA and neighbourhood walkability, as well as its contribution to overall PA in adolescents. It may also assist in determining the association between neighbourhood walkability and school travel behaviour. This is important as the results may help to highlight how an adolescent's environment impacts his/her travel behaviour, school travel-PA, and the contribution of school travel-PA to overall PA. However, the majority of research to date has focussed on the active travel patterns and behaviours of children specifically (e.g., 5-12 years) or the broader youth demographic (e.g., 5-18 years); less research has been done specifically on adolescents. The evidence is also limited on the association between the built environment and travel behaviour in Canadian youth. Furthermore, no study to date has specifically looked at the difference in directly-measured school travel-PA between different levels of objectively defined neighbourhood walkability in Canadian adolescents.

1.2 Purpose of the Research

The purpose of this research was to explore the association between neighbourhood walkability and adolescents' directly measured school travel-PA, school travel mode, and overall PA in high walkability urban and low walkability suburban areas of Metro Vancouver, British Columbia (BC), Canada.

1.3 Research Questions

1) Does adolescents' school travel moderate-to-vigorous PA (MVPA) differ between high and low walkability school neighbourhoods?
2) Is directly measured school neighbourhood walkability a significant predictor of active travel to school?

1.4 Hypotheses

H1: Participants attending school in the high walkability urban neighbourhood will accumulate greater minutes of school travel-MVPA than participants attending school in low walkability suburban neighbourhoods.

H2: School neighbourhood walkability will be a significant predictor of active travel to school.

1.5 Operational Definitions

1) **School Travel:** The trip to or from school, self-reported via questionnaire.

2) **Overall Main Travel Mode:** Adolescents main mode of transportation to and from school ($\geqslant$ 6 trips per week), self-reported via questionnaire.

3) **School Travel-Physical Activity:** Moderate-to-vigorous physical activity accumulated during the assumed commute (hour before and hour after school) as measured objectively in minutes using accelerometry.

4) **Neighbourhood:** The 1.6 km circular buffer surrounding the participants' schools.

5) **Built Environment:** Characteristics of the built environment such as population density, land use, and intersection density that contribute to walkability in the 1.6 km circular buffer surrounding the participants' schools, directly measured through Geographic Information Systems (GIS).

6) **Walkability**: The overall capacity of a neighbourhood to support walking, typically considering population density, land use mix, and street design, classified as high walkable urban or low walkable suburban; measured by: 1) GIS variables and 2) Walk Score™.

7) **Cardiorespiratory Fitness:** An indirect measure of adolescents' physical fitness assessed directly using the 20-meter shuttle run test ("Beep Test").

8) **Urban**: A high walkability neighbourhood with diverse land use and well-connected streets, located in the urban inner city of Vancouver, BC.

9) **Suburban:** A low walkability neighbourhood composed of primarily residential land use and curvilinear street patterns, located in the suburban Metro Vancouver municipality of Surrey, BC.

10) **Adolescents:** Boys and girls enrolled in grades 8 through 10 at urban or suburban public secondary schools in Metro Vancouver at the time of measurement.

1.6 Assumptions

The assumptions for this study were that participants would respond truthfully to questionnaires, provide valid home addresses, wear accelerometers as directed, and perform to maximal exertion on the 20-metre shuttle run test. Additionally, the instruments were calibrated in line with respective manufacturers' guidelines and assumed to remain valid and reliable since the last calibration.

1.7 Delimitations

The study was delimited to male and female English speaking adolescents enrolled in grades 8 through 10 at a public urban secondary school in Vancouver, BC, and three public suburban secondary schools in Surrey, BC.

1.8 Limitations

Participants meeting the inclusion criteria were invited to complete questionnaires on their travel mode to school and self-reported PA levels, as well as to participate in the 20-metre shuttle run test and objective PA measurement using accelerometry. Limitations associated with self-report measures include potential response and recall bias (Thomas, Nelson, & Silverman, 2011). Accelerometry is limited by the potential underestimation of PA occurring in the vertical plane (e.g., cycling; Trost, McIver, & Pate, 2005), its failure to accurately capture adolescent PA in the total sample due to poor adherence to accelerometer wear protocol, and the removal of monitors during contact sports or water-based activities such as swimming. In addition, school travel-PA was measured during the assumed commute to school by using hour windows before and after school. This may not accurately capture the PA specifically from travel to or from school.

The volunteer sample may have also presented a selection bias thus limiting the study's internal validity. Limiting the sample to grades 8 through 10 adolescents in pre-determined geographic locations (high or low walkability, no mixed walkability) may threaten the study's external validity. Additionally, the outcome and exposure were measured at the same time; therefore, no cause and effect could be determined.

2 Literature Review

2.1 Introduction

Physical activity in children and youth is inversely associated with cardiometabolic risk factors such as obesity, hypertension, metabolic syndrome, and depression, with greater PA levels yielding greater benefits (Janssen & Leblanc, 2010). The Canadian Society for Exercise Physiology (CSEP) recommends that children and youth aged 5-17 years engage in at least 60 minutes of moderate-to-vigorous PA (MVPA) every day in order to achieve health benefits (CSEP, 2011). However, it is very concerning that 93% of Canadian youth fail to meet PA guidelines on a regular basis (Colley et al., 2011). Active travel to school, such as walking or cycling, has been recognized as an important contributor to youth PA (Tudor-Locke, Ainsworth, Adair, & Popkin, 2003), and may provide an opportunity to increase daily PA levels through utilitarian behaviour (Cooper, Andersen, Wedderkopp, Page, & Froberg, 2005; Cooper et al., 2003; Tudor-Locke, Ainsworth, & Popkin, 2001).

Despite these benefits, active travel to school is in decline: rates among American youth aged 5-18 years plummeted from 40.7% in 1969 to 12.9% in 2001 (McDonald, 2007). Data from Canada yields similar findings; car travel to school increased more than two-fold in both children (14.9% to 29.2%) and adolescents (14.2% and 33.5%) between 1986 and 2006 (Buliung, Mitra, & Faulkner, 2009). This is of concern as PA levels decline during adolescence (Gortmaker et al., 2012; Nader, Bradley, Houts, McRitchie, & O'Brien, 2008).

This review of literature is composed of four main sections. First, evidence will be presented on the association between active travel to school and PA. Second, determinants of active travel will be discussed, including an overview of the link between the human constructed built environment (Handy, Boarnet, Ewing, & Killingsworth, 2002), and its capacity to support pedestrian travel through "walkability" (Frank et al., 2010). Third, a conceptual framework will be presented that helps to elucidate the multiple factors associated with school travel-PA and their relationships with each other. Finally, limitations and key gaps in the research will be identified.

2.2 Active Travel to School and Physical Activity

Active travel to school (active travel) may promote a more active lifestyle (Tudor-Locke, Ainsworth, & Popkin, 2001) and improved health-related fitness in children and youth (Lubans et al., 2011). Youth who have used active travel to school (walkers and cyclists) engaged in more PA during the assumed commuting hours before and after school (Loucaides & Jago, 2008; Mendoza et al., 2011), throughout the school day (Alexander et al., 2005; Slingerland, Borghouts, & Hesselink, 2012; Tudor-Locke et al., 2003), and overall when compared to those who travelled to school using passive modes (Alexander et al., 2005; Cooper et al., 2006; Cooper, Andersen, Wedderkopp, Page, & Froberg, 2005; Cooper, Page, Foster, & Qahwaji, 2003; Duncan, Duncan, & Schofield, 2008; Loucaides & Jago, 2008; Rosenberg, Sallis, Conway, Cain, & McKenzie, 2006; Roth, Millett, & Mindell, 2012; Saksvig et al., 2007; Sirard, Riner, McIver, & Pate, 2005; Tudor-Locke et al., 2003). Some research, however, has demonstrated that among children and youth, declines in active travel are greatest in the adolescent population (Dollman & Lewis, 2007; Johansson, Laflamme, & Hasselberg, 2012; McDonald, 2007). Despite this, previous research has demonstrated positive associations between adolescents' active travel and accumulation of daily minutes of MVPA (Mendoza et al., 2011) and higher daily step counts (Abbott, Macdonald, Nambiar, & Davies, 2009). More importantly, research out of Australia found that adolescents who travelled actively to school were also more likely to use active modes of transportation to other neighbourhood destinations during their leisure time (Dollman & Lewis, 2007).

Perhaps the most compelling argument for promoting active travel to increase adolescents' PA is provided by an Australian longitudinal study. At the five-year follow-up, Carver et al. (2011) found that the association between active travel to school and MVPA had strengthened in older adolescent participants (aged 15-17 years) yet showed no association in the younger participants (aged 10-11 years). This suggests that active travel may be a more important contributor to adolescents' PA levels than to children's. Therefore, as a modifiable behaviour, active travel may be an effective means to increase adolescent PA and ongoing investigation into its determinants is warranted.

2.3 Determinants of Active Travel

School travel behaviour is likely influenced on a multitude of levels that include intrapersonal, external, and environmental factors (Davison et al., 2008). At the intrapersonal level, characteristics of the child or youth such as age, gender, and independent mobility may play a role in travel mode choice. Community aspects, such as crime, social norms, and school policy may also mediate school travel (Davison et al., 2008). Finally, attributes of a child or youth's neighbourhood, route, and distance to school are also hypothesized to mediate school travel behaviour (Panter et al., 2008).

As previously noted, several studies have found that rates of active travel were higher among boys than girls (Davison et al., 2008). It has been suggested that boys are more likely than girls to engage in active travel to school due to greater protective restrictions that parents may place on girls' mobility (Davison et al., 2008). A recent review found that independent mobility, which is defined as boys' or girls' ability to explore their neighbourhoods unaccompanied by an adult (Hillman, Adams, & Whitelegg, 1990), is subject to many factors beyond purely gender that may help to explain travel patterns (Faulkner et al., 2009). For instance, the child or youth's individual characteristics such as personal attitudes, age, and maturity level may be a greater influence on independent mobility than gender alone (Mitra, 2013). There is also mixed evidence on the association between age and active school travel, with a review finding inconsistent support for age as a correlate of active travel (Davison et al., 2008).

Studies that investigated community level influences on active travel to school have found mixed results. A recent review revealed that the relationship between crime and PA was inconsistent in children and non-existent in adolescents (Ding et al., 2011). A separate review found children were more likely to actively travel to school if there were a greater proportion of houses with street-facing windows (Davison et al., 2008), likely as this gives parents greater "peace of mind" (Ahlport, Linnan, Vaughn, Evenson, & Ward, 2008, p. 230). School policy has also been identified as a possible correlate of active travel. For example, having a school environment supportive of active modes (e.g., bike racks, walking school bus) may facilitate active travel to school (Mitra, 2013). Lastly, traffic has also been commonly cited as a barrier to active travel (Heinrich et al., 2011; Hume et al., 2009). Another study, however, found that traffic safety was not a factor when children lived within 3 km of school (D'Haese, De Meester, De Bourdeaudhuij, Deforche, & Cardon, 2011), which lends credence to distance as the main moderator of school travel behaviour (Panter et al., 2008).

Some studies found that parental perceptions of the environment are important predictors of active travel in younger children (Kerr et al., 2006; McMillan, 2007; Panter, Jones, Van Sluijs, & Griffin, 2010b). This may be attributed to the fact that, as with most youth activities, parents and family members provide a strong influence over the outcome of school travel mode (Davison et al., 2008). However, studies suggest that higher neighbourhood walkability may result in decreased perceptual barriers (Kerr et al., 2006; Napier et al., 2011). Parental perceptions, however, are hypothesized to be less influential on the travel behaviours of adolescents than of younger children (Panter et al., 2008). Therefore, the environment may indeed be pertinent to adolescent travel behaviours. As found in a recent review, objectively measured environmental features were more consistently related to adolescent PA than were perceptions (Ding et al., 2011).

2.4 Built Environment and Walkability

The built environment, defined as the human constructed portion of the physical environment (Handy, Boarnet, Ewing, & Killingsworth, 2002), is where health decisions are made and behaviours transpire. It has been identified as an important correlate of PA (Glanz & Kegler, 2004). In particular, individual features of the built environment, such as land use mix, proximity to amenities, walkability, and residential density have been identified as correlates of PA in children and youth (Ding et al., 2011), and collectively as a possible predictor of active travel to school (Davison et al., 2008).

At the community level, the built environment may influence pedestrian-based PA (Sallis & Glanz, 2006) through macro level walkability, as well as through micro level factors such as traffic, aesthetics, and pedestrian infrastructure (Gallimore, Brown, & Werner, 2011). At the macro level, neighbourhood walkability is based on population and building density, land use diversity, and design of street networks (Badland & Schofield, 2005; Saelens, Sallis, Black, et al., 2003). These factors may have a collective upstream effect on the PA levels of an area’s residents (Davison & Lawson, 2006) and may influence travel behaviour primarily through how the land is used and designed. For example, a presence of blended commercial and residential land use, proximity to locations, and connectivity of streets may increase walkable access to amenities (Saelens, Sallis, & Frank, 2003).

Neighbourhood walkability can be classified as high, low, or mixed. Dense and diverse neighbourhoods with pedestrian access to services, direct routes, and highly connected streets designed in a grid pattern are considered to have high walkability, typical of an urban design; neighbourhoods with the opposite characteristics are often located in suburban areas and are considered to have low walkability (Frank et al., 2010). Diversity, such as mixed land use, has repeatedly been found to be the most likely contributor to the walkability of a neighbourhood (Badland & Schofield, 2005). At the micro level, components of the built environment that contribute to overall walkability can also include the presence and continuity of pedestrian routes such as sidewalks, facility accessibility, safety of street crossings, traffic speed, transit options, attractiveness, and perceived or actual safety (Lo, 2009; McMillan, 2007; Salmon, Salmon, Crawford, Hume, & Timperio, 2007).

Prior to the 1950's, communities were designed to enable pedestrian-travel activities such as active travel to school. Neighbourhoods were defined by their highly mixed use of land, well-connected grid pattern streets, and urban density, which resulted in a more "walkable" urban form. This is in stark contrast to much of today's low walkable, automobile-dependent, suburban design of intricate curvilinear streets, and low density residential areas, that may discourage active travel (Sallis & Glanz, 2006). Previous research has shown that youth residing in urban areas had a greater likelihood of active travel than their peers in suburban or rural areas (Babey et al., 2009; Braza, Shoemaker, & Seeley, 2004.; Kerr et al., 2006; McDonald, 2008; Wong, Faulkner, Buliung, & Irving, 2011). Therefore, measuring the built environment and the walkability of an area is essential for empirical understanding of its association with school travel behaviour (Wong et al., 2011).

2.5 Walkability as a Correlate of Active Travel to School

Very few studies have looked at composite neighbourhood walkability and its association with school travel. Upon review, only four studies examined objectively measured walkability with school travel, and only two also directly measured school travel-PA. Therefore, the purpose of this section is to provide a critical review of the existing literature that has examined objectively measured walkability and travel to school.

Kerr and colleagues (2006) examined the association between objectively measured neighbourhood walkability (high vs. low), parental concerns, and active travel to school by children using a randomly selected sample of parents (n=259) of children 5-18 years old in Seattle, Washington. Although the authors used Geographic Information Systems (GIS) software to objectively measure neighbourhood walkability, they did not do so for the immediate neighbourhood surrounding schools. Rather, a more complex walkability index was created for each of the neighbourhoods in general, the 1 km radius surrounding each participant's home, and along the road network within the buffer segment. Travel mode to school was parent-reported for the youngest child in the household. Kerr and colleagues reported that children from neighbourhoods with greater levels of walkability were more likely to actively travel to school at least once per week.

Though Kerr et al.'s (2006) measure of walkability is considered more robust than school-level walkability alone, it was limited by the fact that no data were provided on whether children or youth living in an area with specified walkability also attended school in that same neighbourhood. In addition, parent-reported travel was not analysed by the likelihood of regular active travel school (e.g., 3 or more days per week) and therefore the true nature of school travel mode is not known. Furthermore, although it was not an objective of the study, no measure of PA was included which prevents any conclusions about the association between walkability and actual school travel-PA.

A study by Giles-Corti et al. (2011) investigated the association between school neighbourhood walkability and regular active travel to school. This study recruited a large sample (n=1132) of students in grades 5 and 7 at Western Australian elementary schools. Neighbourhood walkability, based on street connectivity, and socioeconomic status was used to categorize schools. GIS was used to directly measure walkability through a school-specific walkability index, traffic exposure, and a “PedShed” ratio of pedestrian network within a 2 km circular buffer around each school. The walkability index contained both the informal and formal pedestrian route network based on aerial photography. Within the 2 km buffer, the PedShed ratio of pedestrian network area within the buffer to the total area within the buffer was calculated. In order to accurately determine the pedestrian network, route buffers were placed over all pedestrian routes to determine the total walkable service area and then divided by the total area within the buffer for a score between 1 and 10 (i.e., least to most walkable). Distance to school was calculated in the GIS network analyst function as the shortest distance in metres between the student’s home and school boundary along the pedestrian network. Travel to school was reported by parent proxy with detailed (i.e., car, walk, bike, transit, other) modes to and from identified. The study defined regular walking as greater than 6 trips per week.

Giles-Corti et al.’s (2011) findings demonstrated that the odds of regular active travel to school were 45% higher in children attending schools located in high walkability neighbourhoods than children attending schools in low walkability neighbourhoods. This study employed a rigorous methodology for determining school-level walkability, and provided strong evidence for a positive linear association between walkability and active travel. Although this study was based in Australia and focussed on an elementary school sample, which limits its generalizability to older or international samples, it does provide a solid base for future research into school-level walkability and its influence on school travel behaviour.

In a study that directly compared school travel mode by varying neighbourhood walkability, Napier et al. (2011) demonstrated that walkability was strongly associated with children's active travel patterns. The study reported travel patterns and perceptions of grade 5 students (n=193) and their parents (n=177) in three neighbourhood types (high, low, and mixed walkability) in Utah. Neighbourhood walkability was assigned based on urban design features. For example, the high walkability community followed a "new urbanist" design free of cul-de-sacs and traffic volume, while the low walkability community was characteristic of suburban design. School travel behaviour was self-reported using detailed modes (i.e., walk, bike, car, bus) and analysed based on occasionally walking to school (≥1 trip), rather than analysed by the child's predominant mode of travel to school. Results showed that 88% of children in the high walkability neighbourhood reported walking to school occasionally, compared to only 45% in the low walkability community.

Although Napier et al.'s (2011) study provides support for a positive relationship between active travel to school and walkability, only the distance from home to school was objectively measured in GIS; the remaining components of walkability were assessed by parental perception. In order to add to the robustness of the study, further investigation using GIS in each community would be a suitable addition to the methodology. Likewise, to enhance the understanding of environment's association with travel behaviour, it would be advisable to analyse both the trip to and from school separately as well as using detailed modes of transport information to help contextualize the variation in travel patterns between each community.

Stevens and Brown (2011) also published findings from the same study as Napier et al. (2011). Stevens and Brown tested (2011) whether a community design with high walkability could encourage walking to school and result in higher levels of MVPA, compared to a low and mixed walkability community. Walkability was objectively measured using the Irvine Minnesota Inventory, which relies on trained researchers evaluating street-level differences in the built environment for all blocks between children's homes and schools. Physical activity was objectively measured by accelerometry in 30-second epochs and MVPA was evaluated based on the Freedson activity cut-points (Freedson, Pober, & Janz, 2005). Physical activity was measured for the half hour before school and the half hour after school, assuming that during this time period PA was most likely from the school commute.

Similar to the findings demonstrated by Napier and colleagues (2011), walking rates were highest in the high walkability community (Steven & Brown, 2011). Students in the high walkability community also achieved significantly more minutes of MVPA during the half hour before (1.86 minutes) and after school (2.78 minutes) than those from the low walkability community. The study design was strong in its use of direct measurement of walkability and PA. However, the study combined all school travel modes for analyses, which likely minimized differences in MVPA between neighbourhood groups (Stevens & Brown, 2011). This study may have been stronger if MVPA accrued during the assumed commute for children in each neighbourhood group had been analysed by independent travel modes (e.g., walk, bus, car).

Last, a study by Van Dyck et al. (2009) investigated the association between walkability and PA by comparing adolescents (12-18 years) living in a highly walkable urban centre (n=60) to those in a less walkable suburban community (n=60) in Belgium. Walkability was objectively assessed based on map data of connectivity and residential density, while PA was objectively measured over 7 days by pedometer.

Contrary to the hypothesized direction of association, overall PA was higher in the less walkable suburb. A subsequent analysis of the study examined PA obtained from active travel to school (walking or cycling) between communities. Though overall PA and PA from cycling to school were higher in the less walkable community, PA from walking to school was higher in the highly walkable community.

Although these findings are generally opposite to the proposed association between walkability, active travel, and PA, they must be interpreted with caution. First, it is not clear how travel patterns were assessed, whether through an adapted version of the Neighbourhood Physical Activity Questionnaire or the Flemish Neighbourhood Environmental Walkability Scale, neither of which has been validated for use in adolescent or child populations. Second, the paper provided no detail on how school travel-PA was determined. Third, the sample was small and participants were self-selected into analyses. Finally, the sample was from Belgium where cycling is common in adolescents when distance is feasible (Van Dyck et al., 2009) which limits its generalizability, particularly for a North American population where cycling to school is less common. Nevertheless, the study provides a building block for future research into differences in school travel-PA and mode between differing levels of neighbourhood walkability.

2.6 Conceptual Framework

From the existing evidence, Panter et al. (2008) proposed a conceptual framework for environmental correlates of school travel-PA in youth (see Figure 1; Appendix A). Although the framework is based on McMillan's (2005) urban form framework for school travel in elementary school children, Panter and colleagues offered a broader range of environmental factors and the addition of an adolescent stream. Since age, gender, and distance to school have been shown to moderate school travel behaviours, they were added to supplement the original McMillan framework (Davison et al., 2008; Rodríguez & Vogt, 2009; Timperio et al., 2006).

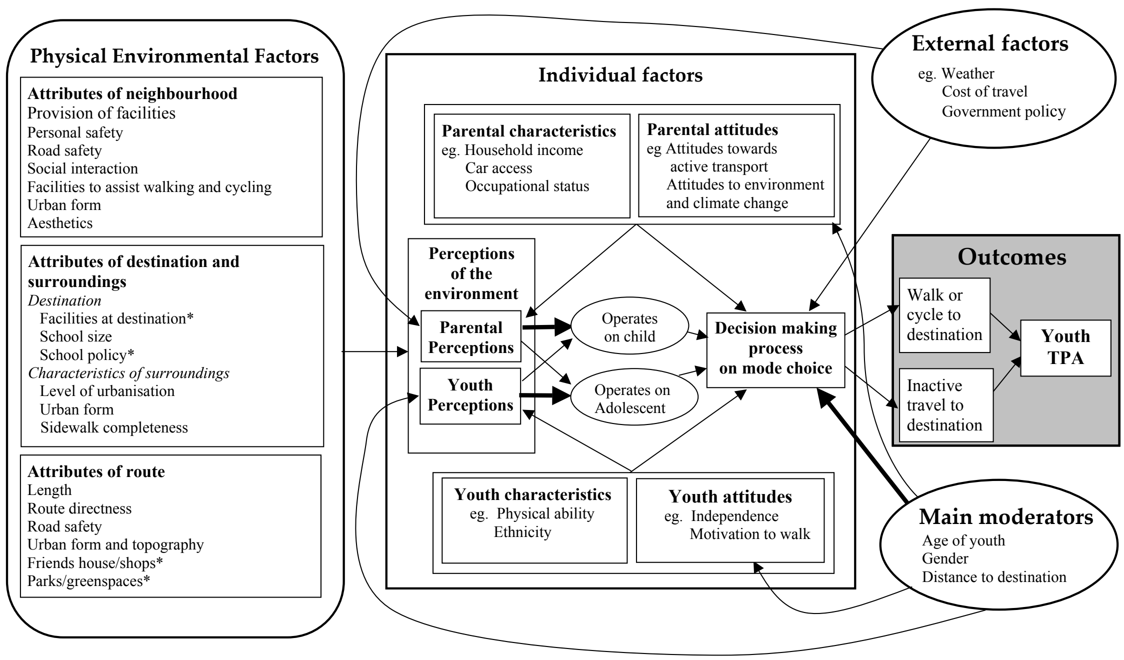

Figure 1. Panter et al.'s (2008) conceptual framework for youth physical activity from active travel to school.

In the child stream, the framework assumes that children's school travel-PA is highly influenced by individual factors. The framework posits that adolescents will be influenced by individual characteristics such as physical ability and ethnicity (Davison et al., 2008). In addition, motivation to partake in active travel and one's level of independent mobility may also influence adolescent travel behaviour (Evenson et al., 2006; McMillan, Day, & Anderson, 2006; Rodríguez & Vogt, 2009).

Panter et al.'s (2008) conceptual framework was used to guide this research. In particular, instrumentation was selected in order to measure physical environmental factors, youth characteristics, and the main moderators of travel mode. Further, to obtain data for school travel-PA, objective measurement was chosen whenever feasible.

2.7 Limitations of the Literature & Relationship to this Research

The bulk of the research to date has focussed on the active travel patterns and behaviours of children specifically (e.g., 5-12 years) or the broader youth demographic (e.g., 5-18 years); less research has been performed specifically on adolescents. The evidence is also limited on the relative influence of the physical environment on active travel in Canadian youth, with only three studies (Larsen et al., 2009; Mitra, Buliung, & Roorda, 2010; Mitra & Buliung, 2012) that have specifically examined the objectively measured built environment and active travel in Canada. In particular, these studies were each performed in Ontario, which is distinct from Metro Vancouver in both geography and climate.

The research related to adolescents is also limited regarding transport to school patterns and the built environment. In particular, there is a lack of literature related to whether neighbourhood walkability is a positive correlate of school travel-PA in adolescents. Only two previous studies (Stevens & Brown, 2011; Van Dyck et al., 2009) examined walkability with directly-measured PA across varying levels of walkability. To the best of the author's knowledge, no Canadian literature has been published on school travel-PA across varying neighbourhood walkability. Although PA from school travel has been directly measured in previous studies, only one study (Van Dyck et al., 2009) reviewed for the purposes of this thesis combined directly measured PA, school travel mode, and objective environmental assessment. Therefore, this research will aim to determine the associations between school travel-PA, school travel mode, and objectively defined walkability surrounding school neighbourhoods in Metro Vancouver adolescents.

3 Methods

3.1 Overview

This analysis is based on baseline data from two separate school-based studies: Health Promoting Secondary Schools (HPSS) and Active Streets, Active People – Junior (ASAP Jr.), performed in the fall of 2011 and 2012, respectively, and represents a collaborative research effort between the University of Victoria and University of British Columbia. This chapter will outline the research methods, procedures, and analyses performed on the dataset.

3.2 Research Design

The study is a cross-sectional descriptive comparison of two adolescent cohorts (HPSS and ASAP Jr.) attending secondary school in neighbourhoods with differing levels of walkability (as directly-measured by Walk Score™) in Metro Vancouver, British Columbia, Canada. This design was chosen to explore the association between the built environment and adolescents' school travel-based PA in a high walkability urban setting and low walkability suburban setting.

3.3 Ethics

Ethical approval was first obtained from each of the University of Victoria's Human Research Ethics Board and the University of British Columbia's Behavioural Research Ethics Board. Upon approval for each independent parent study, the Surrey and Vancouver School Board's research committees were contacted to review the complete research proposal (protocol, letter to parents, consent forms, questionnaires); consent was obtained in Spring 2011 and July 2012, for HPSS and ASAP Jr. respectively.

3.4 Participants

For the purposes of this analysis, participants were selected from two separate parent studies (HPSS and ASAP Jr.) and attended secondary school in the Metro Vancouver. This action was taken in order to select geographically diverse cohorts with differing levels of walkability (high versus low) and characteristics of the built environment that are proposed to support active modes of transportation, such as land use mix, population density, and street network design (Saelens, Sallis, & Frank, 2003). Data from the HPSS participants comprised a secondary analysis derived from a pre-existing dataset, whereas the researcher collected data from participants in ASAP Jr. in Fall 2012.

3.5 Recruitment

3.5.1 Cohort Selection

The free online software “Walk Score™” (Seattle, WA) was used to define the cohorts as low or high walkability, based on the cohort’s mean school Walk Score. The Walk Score is defined as the school’s proximity to walkable amenities within a 1.6 km circular buffer zone; previous research has validated the 1.6 km buffer zone as most effective range for the neighbourhood definition (Duncan, Aldstadt, Whalen, Melly, & Gortmaker, 2011). There were three schools (Schools 1, 2, 3) within the existing HPSS dataset that were identified as low walkability. The schools were located in close proximity to each other in the suburban municipality of Surrey, in Metro Vancouver, BC. The urban school (School 4) in downtown Vancouver was identified as a high walkability neighbourhood. School addresses were entered into Walk Score™, and the resulting score was used to confirm schools as high or low walkability.

Walk Score™ is a valid and reliable tool that estimates a neighbourhood’s walkability based on the accessibility of walkable amenities (Carr, Dunsiger, & Marcus, 2010). The software combines Google’s Asynchronous JavaScript and XML (AJAX) search with a geographical algorithm to identify neighbourhood walkability based on proximity of amenities to the imputed address. A score is then generated on a scale of 0-100 based on 13 equally weighted amenity categories, for example: restaurants, grocery stores, schools, and parks (Walk Score™, 2013). Using the Walk Score™ classification system, schools in neighbourhoods of low walkability (Walk Score of 0-49) were allocated to the low walkability, suburban cohort, while the school in an area of high walkability (Walk Score of 70-100) was allocated to the high walkability, urban cohort.

The suburban cohort was comprised of HPSS participants, which were recruited in Fall 2011 from three secondary schools located in the Surrey. Schools 1 and 2 (Walk Scores: 30, 38, respectively) were located in low walkability, suburban neighbourhoods. Despite its close proximity to these schools (3.8 km and 2.6 km, respectively), School 3's Walk Score of 62 was classified as mixed walkability. It was assumed that most of this school's catchment would have included, at least in part, low walkability areas that students may have traversed on the way to school and it was therefore included in the suburban cohort (mean Walk Score: 43.3 ± 16.7). The urban cohort was comprised of ASAP Jr. participants from School 4 (Walk Score: 98) located in Vancouver's West End. Based on the geographic settings of the HPSS and ASAP Jr. cohorts, for the purposes of this thesis they will be referred to as the suburban and urban cohorts, respectively, from this point forward.

3.5.2 Student Recruitment

For the purposes of this study, data was drawn from four Metro Vancouver secondary schools. Data from the three Surrey schools was derived from a pre-existing dataset in the larger HPSS study, whereas data from the downtown Vancouver school were collected as part of the ASAP Jr. study in Fall 2012. The participants in the current study were a convenience sample of 234 students in grades 8 through 10 from HPSS (n=182) and ASAP Jr. (n=52). The HPSS sample was comprised of students from School 1 (n=96), School 2 (n=60), and School 3 (n=26) participated in the study. The ASAP Jr. recruitment process is described below.

Initial communication with the school occurred by letters sent to the principal explaining the purpose and intent of the study, and inviting participation. Every effort was made to ensure the school that their participation in the study would come at no cost. Phone calls were made a few weeks later to follow up with the principal and answer any possible questions. Upon receiving the principal's permission, the ASAP Jr. research team liaised with schoolteachers to request time in their classes to describe the study, its purpose, invite participation and to answer any questions. A pair of trained researchers then went and spoke to all students enrolled in physical education class during their assigned course block. Students were invited to participate if they were enrolled in grades 8 through 10 for the 2012-13 school year.

Only those students with completed student assent and signed parental consent forms (Appendix B) on measurement day were permitted to participate in the study. Consent forms provided the details of the study, including the purpose, study objectives, and measurements that participating students would undergo. The forms outlined that students had the right to withdraw from the study at any time without penalty, and that data would be destroyed upon request. Students were advised that participation was entirely voluntary, and that they reserved the right to refuse participation.

3.6 Procedures

Measurements were collected during a regularly scheduled physical education block. All of the measurements were held in the school's gymnasium. Participants completed a series of questionnaires throughout the block and had anthropometric and fitness measurements taken. In the last thirty-minutes of the block, students ran a cardiorespiratory fitness (CRF) test.

3.7 Measurements

3.7.1 Participant Information

Participant's personal information was self- or parent-reported by way of the consent/assent forms. Information included the student's home address, birthdate, sex, age and grade.

3.7.2 School Travel Mode

Previous research has demonstrated that travel mode to and from school can differ between the morning and afternoon commute (Buliung et al., 2009); therefore, participants' usual travel mode to and from school was assessed separately. Participants reported school travel mode through the questions: "In an average week, how many days do you use the following ways to get to school?" and "In an average week, how many days do you use the following ways to get home from school?" (Appendix C). Each question was matched with seven response categories (walk, bike, car, school bus, transit, combination, other). Similar questions have been used in previous research to assess students' school travel mode (e.g., Chillón et al., 2010; Cooper et al., 2005; Napier, Brown, Werner, & Gallimore, 2011; Owen et al., 2012; Panter, Jones, Van Sluijs, & Griffin, 2010b).

The researcher first assessed for any participants with missing or invalid travel questionnaire data. Participants without valid travel data (such as no main mode, undefined combination or other travel modes, or incomplete responses) were excluded from analyses. Participants with < 5 or ≥ 6 trips to school and/or < 5 or ≥ 6 trips from school were also visually assessed, and main modes were recoded to "main travel mode to school" if ≥ 3 trips to school and "main travel mode from school" if ≥ 3 trips from school per week used the same mode of transport (e.g., walk, bus, car). An overall main travel mode was also calculated for all school travel, defined as ≥ 6 cumulative trips to school and from school using the same mode of transport.

3.7.3 Physical Activity

Objective PA data were obtained using ActiGraph (Pensacola, FL) accelerometers from HPSS (GT1M and GT3X) and ASAP Jr. (GT3X+). The ActiGraph accelerometer is a reliable tool for measuring PA levels (Trost et al., 2005) and has been validated for use in child and youth populations (Puyau, Adolph, Vohra, & Butte, 2002). ActiGraph monitors measure changes in acceleration collected at a pre-set frequency in hertz (Hz) and summed across a pre-determined time frame known as an “epoch” (Chen & Bassett, 2005); accelerations over the epoch are summed and converted to activity “counts” (Kim, Beets, & Welk, 2012). For the purposes of this study, HPSS data were collected at 15-second epochs, while ASAP Jr. data were collected at 30Hz and reintegrated from raw counts to 15-second epochs at analyses. The 15-second epoch was chosen to capture the intermittent nature of youths’ PA (Trost et al., 2005).

The monitors were distributed during the measurement block, and were initialized to begin collecting data at midnight of the following day. At the end of the measurement block, trained research staff distributed an accelerometer log to each student and instructed participants to complete the activity log, recording accelerometer on and off time. At this time, participants were instructed to wear the accelerometer on the elastic belt provided above the right hip for 6 (HPSS) or 7 (ASAP Jr.) consecutive days, during waking hours, except when bathing, swimming, or engaging in contact sport.

At the end of the measurement period, accelerometers were collected by trained research staff and downloaded into ActiLife (v.6.4.3) for analyses. All accelerometer files were visually inspected prior to processing. Accelerometer files were then assessed for 4 valid days, which may or may not have included weekend days. A valid day was defined as ≥600 minutes of wear time, with periods of non-wear defined as a minimum of 60 minutes with zero activity counts allowing for 1-2 minutes of less than 100 counts per minute (Troiano et al., 2008). Participants with less than 4 valid days of accelerometry data were excluded from analysis. Activity cut-points (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008) were then applied to determine intensity of movement.

The primary outcome for this analysis was mean minutes of travel-related MVPA (school travel-PA), defined as the number of minutes when ≥ 536 activity counts per minute (CPM) were accumulated during the assumed school commuting hours (i.e., hour before and hour after school). Previous research has used similar time windows to objectively measure PA from school travel (Cooper et al., 2005; Owen et al., 2012a; Saksvig et al., 2007b; Southward, Page, Wheeler, & Cooper, 2012). The assumed commuting hour before school was defined as the 60 minutes immediately prior to the school start bell (i.e. School 1 8:36 am, School 2 8:00 am, School 3 8:30 am, School 4 8:35 am). The assumed commuting hour after school was defined as the 60 minutes immediately following the school dismissal bell (i.e. School 1: 2:55 pm; School 2: 3:45 pm; School 3: 2:39 pm; School 4: 3:03 pm). Daily means for minutes of MVPA were calculated for all 7 days, weekdays only, and during the hour before and after school. Data were exported to Microsoft Excel for further analysis.

3.7.4 PAQ-A

Participants self-reported PA levels for the previous 7 days using the Physical Activity Questionnaire for Adolescents (PAQ-A; Kowalski, Crocker, & Donen, 2004), which has suitable convergent validity (Kowalski, Crocker, & Kowalski, 1997) and reliability (Janz, Lutuchy, Wenthe, & Levy, 2008). The PAQ-A is a 7-day recall questionnaire designed to provide a general measurement of adolescents' PA. The survey is comprised of 8-items scored on a five point Likert-scale with a score of 1 representing low PA, and a score of 5 representing high PA. Composite scores were calculated for each participant with a valid PAQ (all questions accurate and complete) according to the PAQ scoring process (Kowalski et al., 2004), and standardized by sex and age (Voss, Ogunleye, & Sandercock, 2013). Mean PAQ z-scores were then used to compare the two cohorts. The PAQ was self-administered during the measurement block with members of the research team on-hand to answer any questions and to certify its completion.

3.7.5 Anthropometrics

Two trained researchers measured students' anthropometrics. The researchers operated in tandem; one person was designated as the primary tester, and the second was on hand to assist, confirming each measurement and recording the results. Participants were measured in regular gym clothing and without shoes.

Standing stature (to nearest 0.1 cm) was measured using a portable stadiometer with the head stretched in the Frankfort plane. The measurement was performed twice in order to ensure accuracy. In the case that a height difference of $\geq$ 0.4 cm was found, the measurements were repeated until the difference was less than 0.4 cm, at which point the median value was recorded.

Body mass (to nearest 0.1 kg) using a portable Seca digital weight scale, placed onto a firm surface such as wood, or concrete, but not carpet. Due to the sensitive nature of weight, measurements were taken in a semi-private area away from other students. A piece of paper was also used to conceal the scale's display screen from the participant, allowing only the researchers to view the result. This process was performed twice in order to ensure accuracy. In the case that a weight difference of $\geq$ 0.2 kg was found, the measurements were repeated until the difference was less than 0.2 kg, at which point the median value was recorded.

From the height and weight measurements, body mass index (BMI) was calculated ($\frac{kg}{m^2}$) for all participants and converted to z-scores according to World Health Organization (WHO) growth charts (de Onis, Onyango, Borghi, Nishida, & Siekmann, 2007). The International Obesity Task Force's (IOTF) age- and sex-specific cut-points for normal (including underweight), overweight, or obese were then applied to classify the participants in each cohort by BMI category (Cole, Bellizzi, Flegal, & Dietz, 2000).

Waist circumference was measured to the nearest millimetre at the natural waist with flexible, anthropometric tape. To ensure accuracy, two trials were recorded. In the case that a difference of ≥ 0.2 cm was found, the measurements were repeated until the difference was less than 0.2 cm, at which point the lesser of the two values was used for analysis. Waist circumference was then converted to z-scores for all participants (Katzmarzyk, 2004).

3.7.6 Cardiorespiratory Fitness

Adolescents' CRF levels were indirectly measured by the 20-metre shuttle run test (20mSRT), an incremental multi-stage fitness test designed for field-testing (Leger, Merceir, Gadoury, & Lambert, 1988). The 20mSRT is a valid and reliable field-test to measure adolescent CRF (Castro-Piñero et al., 2010; Liu, Plowman, & Looney, 1992; Voss & Sandercock, 2009). Participants received standardized instructions from both the test's recorded mp3 and by a member of the research team to "run back and forth across the course in time with the beep," and to run "as long as possible." Participants were matched to members of the research team at a 4:1 ratio.

Participants ran back and forth on a 20-metre course. A pre-recorded tape emitted a beep to pace the participants, and they must have reached and pivoted at the 20m line at or before the time the sound was emitted. The test began at a running speed of 8.5 km/h, and increased by 0.5

km/h intervals at each minute of the test. Each minute, and subsequent increase of 0.5 km/h in running speed, equals one stage. The test was over when participants failed to keep pace with the beeps, marked by failing to reach the 20m line before the sound of the beep in 2 consecutive shuttles, or at the point of volitional exhaustion (Leger et al., 1988). After participants completed their maximum number of shuttles, the researcher they were matched with told the participant their score which was then reported to the research coordinator for recording.

Individual scores were converted to age- and sex-standardized z-scores according to global norms (Olds, Tomkinson, Léger, & Cazorla, 2006). A positive z-score denoted that an individual had a greater than the mean score for aerobic fitness, while negative z-score denoted an aerobic fitness level below the mean.

3.7.7 Built Environment

School neighbourhoods: Exact school locations were obtained from DMTI Spatial CanMap Streetfiles v.2011.3 (Markham, Ontario, Canada; accessed through Abacus v.1.0 British Columbia Research Libraries' Data Service) and mapped in Geographic Information Systems (GIS) software (ArcGIS™ v. 10.0; ESRI®, Environmental Systems Research Institute, Inc., Redlands, CA). To capture built environment (BE) features within each school's immediate neighbourhood, a 1.6 km circular buffer was drawn around each school location to delineate suitable walking distance, which is in line with previous research (Larsen et al., 2009). Since students from the three suburban schools were combined for analyses, and because the three suburban schools were close in proximity to each other, the three suburban school buffers were dissolved into one buffer for further calculations (see Figure 3).

Population density: Census of Canada 2011 population statistics by census block were mapped in ArcGIS™ v. 10.0 (*Combined Dissemination Block Digital Cartographic File and*

Geographic Attribute File, 2011; accessed through Abacus v.1.0 British Columbia Research Libraries' Data Service). The Census block data were clipped with the urban and suburban school buffer, and the following were calculated for each neighbourhood: total population density per buffer area, population density per km^2, total private dwelling count per buffer area, and population per private dwelling.

Land use: Land use data were obtained from DMTI Spatial CanMap Streetfiles v.2011.3. Data were available for the following land use categories: commercial, government and industrial, parks and recreation, residential, resource and industrial, waterbody, and open area. The land use data were clipped by the urban and suburban school buffer, and the following were calculated for each neighbourhood: total buffer area (km^2), total area of each type of land use (km^2), and relative area of each type of land use (%).

Road network and intersection density: Detailed road network data (DMTI Spatial CanMap Streetfiles v.2011.3) were mapped in ArcGIS™ v. 10.0. Data were available for the following road categories: principal highway, major road, local road, and trails and alleyways. Roads were classified as primary highways if they were part of the highway network, despite having portions where the speed limit decreased to residential limits (i.e. 50 km/h). Major roads were identified as main arterials or collector roads, while local roads were identified as roads in a city subdivision. The trail network was comprised of local trails and alleyways including lanes. The road network data were clipped with the urban and suburban school buffer, and the following were calculated for each neighbourhood: total street network length (km) per buffer area, total street network length by street type (km) per buffer area, and proportion of street types per total street network per buffer area (%).

Intersection density was determined using the street network data (DMTI Spatial CanMap Streetfiles v.2011.3). Any adjoining road segment with at least three segments (valence) was deemed an intersection (valence 3+). The intersection layer was clipped with the urban and suburban school buffer and the following were determined: number of intersections (valence 3+) per buffer area and per km^2, number of 4-way intersections (valence 4+) per buffer area and per km^2, and ratio of 4-way intersections (valence 4+) to all intersections (valence 3+) per buffer area.

Distance to school: Participant addresses were geocoded (allocation of latitude and longitude equivalent of postal address) using the 10.0 North America Geocode service in ArcGIS™ v. 10.0. Addresses were matched at the Canada rooftop or Canada street level. If a participant's address could not be geocoded due to an incomplete or incorrect postal address, the participant was excluded from any distance calculations. Exact school locations were obtained from DMTI Spatial CanMap Streetfiles v.2011.3. The ArcGIS™ Network Analyst tool was used to calculate shortest distance (km) between participants' homes and school using the street network (DMTI Spatial CanMap Streetfiles v.2011.3).

WalkScore™: For each participant, a Walk Score was obtained by entering the full residential address into the online tool (Walk Score™, Seattle, WA). The same protocol was followed for calculating individual-level scores as was done for the school level (i.e., 0-50: low walkable, 70-100: high walkable, 90-100: "walker's paradise").

3.8 Data Management and Treatment

All data entry, management, and treatment were performed in Microsoft Excel 2010 (Excel; Microsoft Corporation; Santa Rosa, CA), and raw data were stored in secured locations at the University of Victoria (HPSS only) and the Centre for Hip Health and Mobility

(Vancouver, BC). Participants' full name, home address, school and grade were entered into a database with a corresponding unique ID number. Trained research staff entered data into the Excel database and performed routine checks to ensure data points were entered correctly. Participants with missing or ineligible data were still entered into the database with empty cells marking unavailable data points. In order to probe for possible entry errors, the following cleaning procedures were followed: double entry of all physical data, cross-checking of data against raw recordings, and a randomly selected review of 5% (n=12) of the sample's questionnaire data. Two members of the research staff checked physical data, and research staff compared the database entries against the original questionnaire files to ensure the data were accurately entered.

The Excel database for physical, questionnaire, and accelerometry data was prepared prior to uploading to statistical software for analyses. Any error fields, such as "FALSE" or "#DIV/0," were removed from each database during data preparation in order to avoid any miscalculations that would have occurred by importing these fields into the statistical software with a value of zero rather than a blank cell.

3.9 Statistical Analysis

All statistical analyses were performed in *Stata: Data Analysis and Statistical Software* version 10.0 for Windows (StataCorp LP; College Station, TX). The HPSS and ASAP Jr. datasets were uploaded to Stata and merged via unique participant identifier (ID), combining all physical data (e.g., height, weight, waist circumference, fitness), questionnaire data (e.g., travel mode), physical activity (self-reported and accelerometry), and built environment data (e.g., Walk Scores, distance to school). Significance was set at $p < 0.05$ for all analyses.

3.9.1 Descriptive Statistics

Means (± SD) and/or frequency statistics were calculated for each variable, including raw values and z-scores where applicable. Statistics were initially run between cohorts, and then further stratified by sex. This was done in order to account for physiological differences between boys and girls that occur during adolescence. It was particularly important to account for differences in CRF, as $\dot{V}O_2$ max increases in boys from pre-puberty through to adulthood, but in girls $\dot{V}O_2$ max increases only until puberty, thus providing distinct advantage to boys during CRF measurement (Malina, Bouchard, & Bar-Or, 2004). Additionally, it has been well-documented that boys are more active than girls during adolescence (Nader et al., 2008), which may result in further sex differences for CRF.

3.9.2 Between-Group Differences

Stratified by sex, independent sample t-tests were used to assess differences between cohorts for descriptive statistics. Differences between cohorts in all days, weekday, and travel MVPA were analysed through a series of two-way ANOVAS. In the case of a significant ($p<0.05$), or approaching significant ($p<0.10$) interaction effect, Bonferroni-adjusted pairwise comparisons were performed to assess direction of the interaction effect ($p<0.025$).

3.9.3 Logistic Regression

Two consecutive multivariate logistic regression models were run to predict active travel as a main mode of school travel. Both models included cohort (neighbourhood type), sex, age, distance to school, Walk Score, and fitness variables. The second model employed the same variables and added minutes of MVPA, restricting the model to only those participants with valid accelerometry data (n=84).

3.9.4 Linear Regression

A multiple linear regression was performed in order to explore the relative strength of the relationship between school travel-PA on overall levels of PA. Prior to running the model, a correlative matrix was run for BMI z-score, CRF z-score, against 7-day MVPA and weekday MVPA for both boys and girls to determine whether or not to adjust the model. The regression model was then adjusted for BMI and CRF for both boys and girls.

4 Results

4.1 Overview

This chapter presents the results of the study. Since the sample for this study was drawn from two separate parent studies and not all participants completed each protocol, the chapter is presented in three main sections. Part one (4.2) describes main sample descriptive characteristics and prevalence of self-reported travel modes to and from school (n=224). Part two presents (4.3) PA results from a sub-sample of participants with 4 valid days of accelerometry. Part three (4.4) presents cohort differences in the built environment and predictors of active travel. A comprehensive flow chart outlining sampling and exclusion procedures can be found in Figure 2.

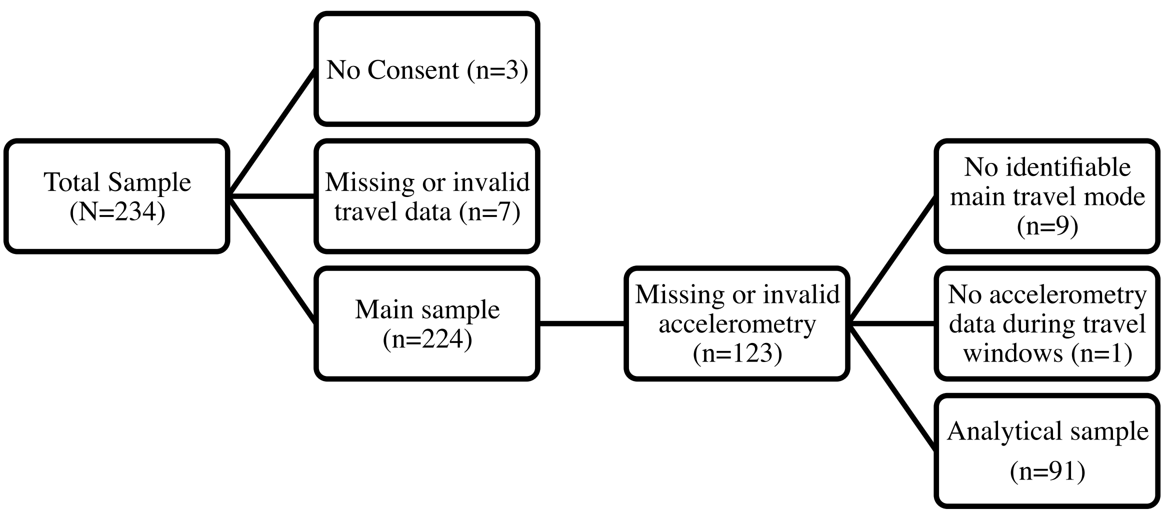

Figure 2. Participant sampling and exclusion from study.

4.2 Main Sample

4.2.1 Demographics

Participants were a convenience sample of students recruited from the HPSS and ASAP Jr. studies during the falls of 2011 and 2012, respectively. Descriptive characteristics for the total sample (n=224) are found in Table 1. Participants were 49.6% female and between 12 and 16 years of age. Participants were significantly older in the suburban cohort than in the urban cohort. Due to the significant difference in age, analyses for anthropometric and fitness data were standardized by age and sex (z-scores).

Table 1

Main Sample Descriptive Characteristics (Mean ± SD)

	Boys			**Girls**		
	Suburban (n=86)	Urban (n=27)		Suburban (n=93)	Urban (n=18)	
Age (yrs)	**14.7 ± 0.3**	**13.3 ± 0.7**	*	**14.7 ± 0.4**	**13.4 ± 0.8**	*
Body Mass (kg)	63.3 ± 11.7	58.8 ± 12.4	‡	59.0 ± 12.4	53.7 ± 12.8	‡
Stature (cm)	**173.3 ± 7.5**	**161.9 ± 6.6**	◊	161.9 ± 6.6	163.1± 6.9	
Stature *z*-score[a]	**0.42 ± 1.0**	**1.1 ± 1.0**	†	**-0.0 ± 1.0**	**0.6 ± 0.8**	◊
BMI ($kg·m^{-2}$)	21.1± 3.3	20.4 ± 3.8		**22.5 ± 4.5**	**20.0 ± 3.9**	◊
BMI *z*-score[a]	0.2 ± 1.2	0.3 ± 1.2		0.5 ± 1.1	0.0 ± 1.2	
% ow/obese[b]	*21.2*	*33.3*		*29.04*	*16.7*	
χ^2	*1.8, p=0.4*			*1.4, p=0.5*		
Waist (cm)	72.7 ± 8.2	71.2 ± 10.0		72.3 ± 9.6	68.3 ± 2.3	
Waist *z*-score[c]	0.2 ± 1.2	0.2 ± 2.6		0.6 ± 1.4	0.5 ± 1.5	
20mSRT (laps)	62 ± 20	59 ± 20		49 ± 15	44 ± 17	
20mSRT *z*-score[d]	-0.3 ± 0.1	-0.03 ± 0.8		-0.2 ± 0.8	0.1 ± 0.9	
PAQ score[e, f]	2.9 ±0.5	3.1 ±0.8		2.4 ± 0.5	2.7 ±0.7	‡
PAQ *z*-score[g]	0.0 ±0.6	0.2 ± 1.1		-0.0 ± 0.8	0.2 ±1.3	

Bold differences are significant at p<0.05 or less within sex, between-cohort; * $p < 0.001$; † $p < 0.01$; ◊ $p < 0.05$; ‡ $p<0.10$

[a] Based on WHO global reference data (de Onis, 2007)

[b] ow – overweight, BMI weight classification per International Obesity Task Force criteria (Cole et al., 2007).

[c] Based on Canadian reference data (Katzmarzyk, 2004)

[d] Based on global reference data (Olds et al., 2007)

[e] PAQ scored on a 5-point scale, with 1 representing low PA and 5 representing high PA (Kowalski, 2004)

[f] PAQ only available for 37 boys & 49 girls in suburban cohort

[g] Based on UK reference data (Voss et al., 2013)

4.2.2 School Travel Modes

There was a significant difference between cohorts in both travel mode to school and travel mode from school (≥ 3 trips/week) for boys and girls (Table 2). More urban boys (51.9%) and girls (55.6%) reported walking compared with suburban boys (43.0%) and girls (32.3%). The same pattern was seen for travel mode from school. However, both cohorts reported increased walking and decreased car travel during the afternoon commute compared to the morning commute. Suburban boys and girls increased walking behaviour (11% and 12%, respectively) and decreased car travel (14%) more than urban boys and girls.

Table 2

Travel Mode Frequencies Stratified by Sex and Cohort

	Boys		**Girls**	
	Suburban (n=86)	Urban (n=27)	Suburban (n=93)	Urban (n=18)
Mode to School (% (n))				
Walk	43.0 (37)	51.9 (14)	32.3 (30)	55.6 (10)
Cycle	1.2 (1)	3.7 (1)	1.1 (1)	0 (0)
Public Transit	2.3 (2)	29.6 (8)	3.2 (3)	27.8 (5)
School Bus	0 (0)	0 (0)	1.1 (1)	0 (0)
Car	53.5 (46)	14.8 (4)	62.4 (58)	16.7 (3)
χ^2	*25.4, p<0.001*		*21.0, p<0.001*	
Mode from School (% (n))				
Walk	54.7 (47)	59.3 (16)	43.0 (40)	61.1 (11)
Cycle	1.2 (1)	3.7 (1)	1.1 (1)	0 (0)
Public Transit	3.5 (3)	25.9 (7)	6.5 (6)	33.3 (6)
School Bus	1.2 (1)	7.4 (2)	1.1 (1)	0 (0)
Car	39.5 (34)	3.7 (1)	48.4 (45)	5.6 (1)
χ^2	*24.1, p<0.001*		*18.2, p=0.001*	
Overall Main Mode (%(n)) [a,b]				
Active	48.1 (37)	42.3 (11)	63.1 (53)	47.1 (8)
Passive	51.9 (40)	57.7 (15)	36.9 (31)	52.9 (9)
χ^2	*1.5, p=0.22*		*0.3, p =0.61*	

[a] Available for suburban (n=77) and urban boys (n=26)
[b] Available for suburban (n=84) and urban girls (n=17)

Since a limited number of participants reported cycling for transportation (n=6) or taking the school bus (n=5), walking and cycling were recoded as “active” travel; school bus, transit and car were also combined as “passive” travel for further analyses. Differences in mode frequencies were no longer significant between cohorts after travel modes were combined.

4.3 Analytical Sample

Physical activity was measured directly by accelerometry for the total sample; however, valid data were only available for 101 participants (45% of total; 46.6% girls). These participants made up a sub-sample (“analytical sample”) for subsequent analyses. Overall, there were no significant differences between the analytical sample (n=101) and individuals without accelerometry data (n=123) in terms of BMI z-score (0.38 ± 1.2 vs. 0.2 ± 1.1, p=0.35), CRF z-score (-0.3 ± 0.8 vs. -0.1 ± 0.8, p=0.10), or PAQ z-score (0.1 ± 1.0 vs. -0.01 ± 0.8, p=0.37). A sub-sample with valid accelerometry and travel data (n=91; 58.2% girls) were used to answer research question 1. Descriptive sample characteristics for boys and girls in the analytical sub-sample are reported in Table 3. Participants without accelerometry data during the hour travel windows (n=1), or without an identifiable overall main travel mode (n=9) were excluded from further analyses.

4.3.1 Travel, Self-Reported Physical Activity & Fitness

Over half the boys in the analytical sample reported active travel as their main travel mode (≥ 6 trips; 60.5%), while only 40.7% of girls reported the same. Overall rates of active and passive travel were not statistically different in boys (χ^2=1.5, p=0.22) or girls (χ^2=0.3, p=0.61) between cohorts. There were no differences between cohorts for self-reported PA in boys or CRF in girls. Among passive travellers, mean 20mSRT z-scores in urban boys indicated higher CRF (t=-2.01, p=0.01).

Table 3

Analytical Sample Descriptive Characteristics (Mean ± SD) by Sex, Travel Mode, and Cohort

	Boys				**Girls**			
	Active		Passive		Active		Passive	
	Suburban (n=17)	Urban (n=6)	Suburban (n=10)	Urban (n=5)	Suburban (n=18)	Urban (n=3)	Suburban (n=28)	Urban (n=4)
Body Mass (kg)	61.5±8.6	58.3±11.2	**65.0±8.4**	**52.7±9.9** ◊	56.9±5.9	54.9±2.3	58.9±16.3	51.8±13.9
Stature *z*-score[a]	**0.3±0.8**	**1.3±1.5** ◊	1.1±1.1	0.9±0.9	**-0.3±0.7**	**1.1±0.8** †	-0.01±0.8	0.4±0.8
BMI *z*-score[a]	0.1±1.0	0.1±1.1	0.0±1.4	-0.3±1.3	0.5±0.7	-0.5±0.9	0.3±1.5	-0.2 ±1.3
20m SRT *z*-score[b]	-0.1±0.8	-0.1±0.5	**-0.3±0.4**	**0.4±0.6** †	-0.4± 0.8	0.3±1.4	-0.3±0.7	0.0±0.3
PAQ *z*-score[c]	0.0±0.5	-0.4±1.1	0.3±0.5	-0.0±0.5	0.5±1.0	-0.1±1.4	**-0.6±0.7**	**0.7±0.3** †
Distance (km)[d]	1.3±0.8	1.5±0.5	2.4±1.5	2.3±0.9	1.1±0.7	1.2±0.1	2.7±1.4	2.3±0.4
Walk Score[e]	**36.5±11.4**	**96.0±3.5** *	**36.9±11.1**	**94.6±3.9** *	**41.1±22.9**	**95.0±2.0** *	**39.2±21.4**	**93.3±6.7** *
Wear Time (min·d^{-1})	826.8±67.6	836.9±107.6	816.5±57.1	772.2±72.2	825.4±75.5	824.2±34.3	817.2±50.5	828.6±37.7
Meets PA (n)%))[f]	9 (53)	4 (66)	2 (20)	2 (40)	6 (32)	0 (0)	1 (4)	0 (0)
MVPA (min·d^{-1})								
7d Week	61.5±21.1	72.2±27.0	**47.4±19.1**	**76.6± 32.0** ◊	50.9±18.8	39.8±9.5	32.5±13.97	45.3±4.4 ‡
Weekday	67.1±29.5	77.2±28.3	59.0±29.1	74.5±19.0	54.7±20.8	54.6±11.0	52.5±24.8	58.6±30.7
Commute	**11.0±9.2**	**29.4±9.2** *	**8.8±7.4**	**22.6±2.7** *	12.3±7.7	16.7±3.7	12.7±11.5	16.6±2.2

Bold differences are significant at p<0.05 or less within sex & mode, between-cohort; * p < 0.001; † p < 0.01; ◊ p < 0.05; ‡ p <0.10 differences approaching significance

[a] Based on WHO global reference data (De Onis et al., 2007)
[b] Based on global reference data (Olds et al., 2006)
[c] Based on UK reference data (Voss et al., 2013)
[d] Distance from home to school
[e] Calculated based on home address
[f] Based on Canadian PA guidelines of 60 min·d^{-1} (Tremblay et al., 2011)

4.3.2 Physical Activity

School Travel Mode and Physical Activity

Among boys, both urban active (t=-4.22, p=0.00) and urban passive travellers (t=-4.00, p=0.00) were significantly more active during the assumed school commute (hour before and hour after school) when compared to suburban boys; there were no significant differences in school travel-PA in girls. In boys, mean MVPA averaged across the week (7-day MVPA) was significantly higher in urban passive travellers compared to suburban passive travellers (t=-2.2, p=0.04). Analysis between cohorts found that more urban boys met PA guidelines (54.5%) than suburban boys (40.7%), while no urban girls and less than a quarter (14.9%) of suburban girls met PA guidelines.

To investigate any possible interactions between cohort and travel mode on the outcome of MVPA, two-way Analysis of Co-Variance (ANCOVA) was performed. Age was significantly and negatively correlated with school travel MVPA in boys (r=-0.34, p=0.03), thus was added as a covariate to both boys' and girls' models for consistency. Three sets of ANCOVAs were run for boys and for girls to examine the interaction between travel mode and neighbourhood type on the outcome of MVPA across 7 days, weekdays only, and the school commute. The results demonstrate the presence of a significant interaction effect between neighbourhood type and travel mode in girls (F=5.40, p=0.02). Upon Bonferroni post-hoc comparison, the interaction was not significant (t=-1.8, p=0.08) at the corrected significance value of p<0.025. When looking at the outcome of school travel-PA, no significant interaction effects were found between neighbourhood type and travel mode. In girls, no significant main effects were found either. In boys, however, there was a significant main effect for neighbourhood type (F=29.51, p<0.001) and an approaching significant main effect for travel mode (*F*=2.96, *p*=0.09). The results of post-hoc analysis can be found in Table 3.

Contribution of School Travel-Physical Activity to Overall Physical Activity

The relative contribution of MVPA from school travel to overall levels of MVPA on weekdays was explored through linear regression (Table 4). A correlative matrix was run for BMI z-score, 20mSRT z-score, 7-day MVPA, and weekday MVPA, which identified a significant association in girls between 7-day MVPA and 20mSRT (*p*=0.005), and approached significance for BMI and 7-day MVPA in boys (*p*=0.08) and girls (*p*=0.06). The model was therefore adjusted for BMI z-score and 20mSRT z-score. In both boys and girls, school travel-PA was not a significant predictor of weekday MVPA.

Table 4

Multiple Linear Regression of School Travel-PA to Weekday MVPA

	Boys		**Girls**	
Outcome: weekday MVPA ($min \cdot d^{-1}$)	β (95% CI)	*p*	β (95% CI)	*p*
Travel MVPA ($min \cdot d^{-1}$)	**0.95 (0.12, 1.78)**	**0.027***	0.11 (-0.55, 0.78)	0.734
BMI z-score [a]	0.50 (-7.93, 8.93)	0.905	3.98 (-1.93, 9.90)	0.183
20mSRT z-score [b]	7.50 (-6.50, 21.50)	0.284	2.92 (-4.86, 10.70)	0.455
Model R^2	*0.164*	*0.103*	*0.039*	*0.542*

[a] Based on WHO global reference data (De Onis et al., 2007)
[b] Based on global reference data (Olds et al., 2006)

4.4 Built Environment

Spatial Analysis

Geographic Information System analysis identified differences in the built environment of the two cohorts. Figure 3 displays differences in the urban design surrounding each school at a 1.6 km radius. Suburban road networks were comprised of a mix of primarily curvilinear streets and main arterials, whereas the urban road network represented a grid pattern. Spatial analysis found higher population density, greater land use diversity and intersection density surrounding the urban school than suburban schools (Table 5). The suburban buffer was composed of more residential area compared to the urban buffer zone, while the urban buffer contained a higher percentage of parks and recreational area. Within the urban buffer, much of the land use was classified as a waterbody or parks and recreational since neither the ocean nor Stanley Park was clipped out for analysis. Despite urban form differences, the proportion of students living within 1.6 km of school did not vary between urban and suburban cohorts (63% vs. 64%, respectively).

Table 5

Built Environment Characteristics Within the School Neighbourhood[‡]

	Urban	**Suburban**
Total Area (km^2)	8.04	22.7
Population Density [¢]		
Total Residents within buffer (n) [¥]	61346	92111
Total Residents per km^2 [¥]	7630	4058
Total Private Dwellings within buffer (n)[¥]	43762	28681
Total Private Dwellings per km^2 (n)[¥]	5443	1263
Averages Persons per Dwelling	1	3
Land Use (km^2)% total buffer area) [§]		
Commercial	0.1 (0.7)	0.1 (0.4)
Government & Industrial	0.1 (1.4)	0.2 (1.0)
Parks & Recreational	2.3 (29.2)	0.4 (1.6)
Residential	2.1 (26.0)	18.2 (80.1)
Resource and Industrial	0.5 (6.3)	1.6 (7.2)
Waterbody	2.9 (35.7)	0 (0.0)
Open Area	0.1 (0.7)	2.2 (9.7)
Intersection Density (per buffer area (km^2)) [§¥]		
Total Intersections (Valence 3+) (n)[¥]	60 (479)	58 (1313)
Total 4-way or more (Valence 4+) per buffer area (n)[¥]	32 (257)	13 (289)
Ratio 4-way intersection: All intersections (3+) (n)	1: 1.9	1: 4.5
Road Network [§¥]		
Total Street Network (km)	97.9	282.3
Principal Highway (km) % in buffer area))	5.0 (5.2)	23.4 (8.3)
Major Road[°] (km) % in buffer area))	10.3 (10.5)	27.1 (9.6)
Local Road (km) % in buffer area))	44.7 (45.7)	221.0 (78.3)
Trails & Alleyways (km) % in buffer area))	37.6 (38.5)	11.0 (3.9)
Students living within buffer (%(n))	63% (32)	64% (111)

[‡]Within 1.6 km circular buffer
[¢]Based on Canadian Census Data 2011
[¥]Estimated based on area including waterbody
[§]Based on DTMI Spatial CanMap Streetfiles
[°]Major roads or main arterials

4.4.1 Predicting Active Travel to School

Multivariable logistic regression models were run to predict active travel (Table 6). The results from Model 1 indicate that cohort was not a significant predictor of active travel. However, the odds of active travel decreased by 79% for each additional kilometer in distance between home and school. Conversely, odds of active travel increased by 82% with each standard deviation increase in fitness. Model 2 was restricted to participants with valid home addresses and valid accelerometry. Again, cohort was not a significant predictor of active travel, although increased distance to school decreased odds of active travel by 77%.

Table 6

Multivariate Logistic Regression Models Predicting Active Travel as Main Travel Mode

	OR (95% CI)	*p*
Model 1 (n=174)[a]		
Cohort		
Suburban	1.00 (referent)	
Urban	1.08 (0.13, 8.65)	0.946
Sex		
Girls	1.00 (referent)	
Boys	1.71 (0.80, 3.67)	0.167
Age (yrs)	1.24 (0.52, 2.96)	0.625
Distance (km)	**0.21 (0.12, 0.35)**	**0.000***
Walk Score	1.01 (0.98, 1.03)	0.650
20mSRT (z-score)	**1.82 (1.12, 2.95)**	**0.016***
Model 2 (n=84)[b]		
Cohort		
Suburban	1.00 (referent)	
Urban	2.69 (0.09, 81.18)	0.568
Sex		
Girls	1.00 (referent)	
Boys	1.90 (0.52, 7.00)	0.331
Age (yrs)	3.43 (0.80, 14.70)	0.096
Distance (km)	**0.23 (0.12, 0.46)**	**0.000***
Walk Score	1.00 (0.97, 1.04)	0.828
20mSRT (z-score)	2.13 (0.92, 4.94)	0.078
MVPA ($min \cdot d^{-1}$)[c]	1.01 (0.98, 1.03)	0.623

[a] Participants with valid addresses and fitness data
[b] Participants with valid addresses, fitness, and accelerometer data
[c] Weekday MVPA

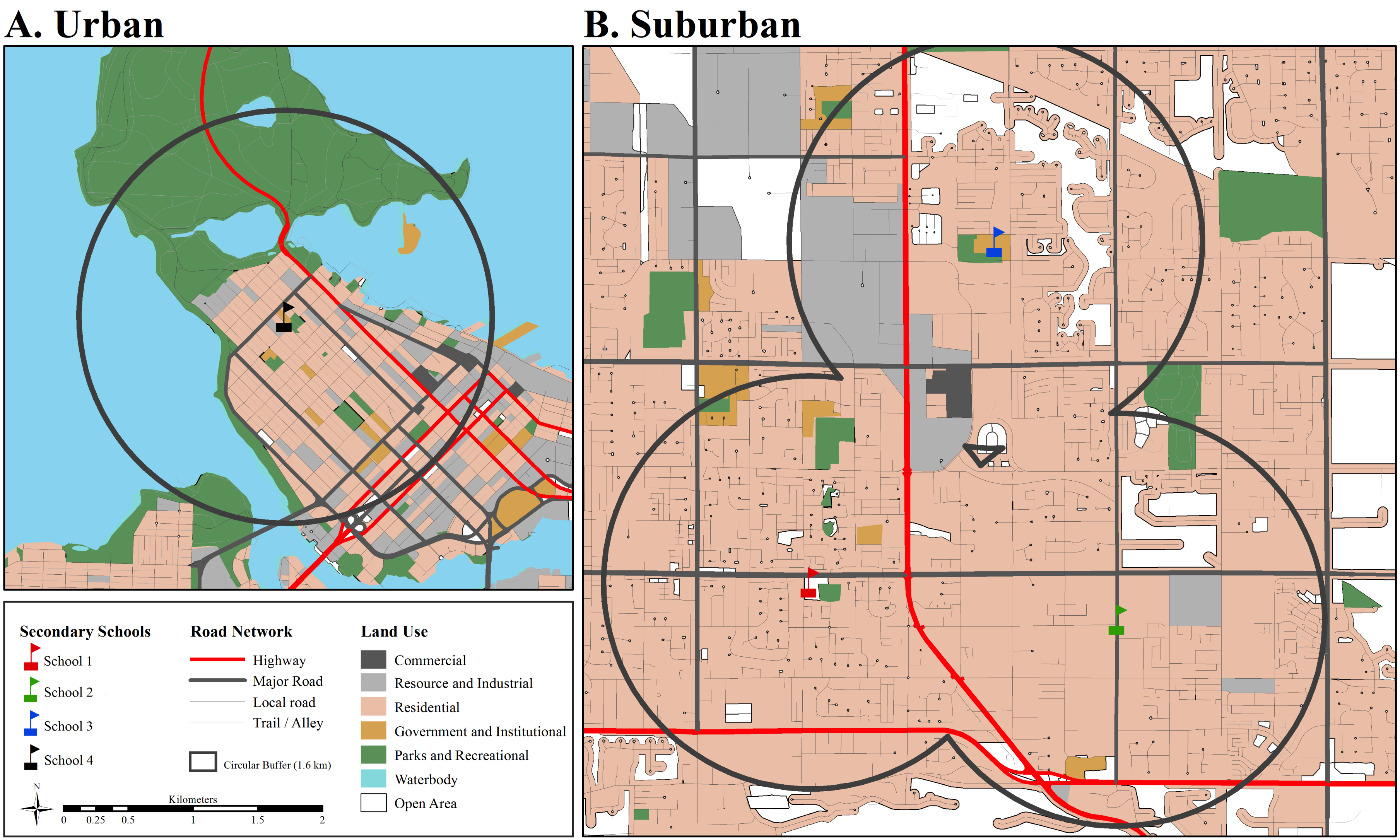

Figure 3. Map of urban and suburban school neighbourhoods within a 1.6 km circular buffer.

5 Discussion

5.1 Overview

The primary objective of this study was to examine whether school travel-PA differed between an urban cohort in a highly walkable neighbourhood and a suburban cohort in a low walkable neighbourhood. This chapter discusses the outcome of the analyses in relation to the existing body of literature. Specifically, differences in school travel-PA and travel mode between the cohorts will be discussed. The chapter also addresses the study's secondary objective: determining whether neighbourhood walkability was a predictor of active travel to school. Connections will be made between school travel behaviour and walkability characteristics surrounding each school neighbourhood. Lastly, limitations of the study and opportunities for future research are presented alongside implications for public health.

5.2 Cohort and Sex Differences in School Travel-PA

The primary aim of this study was to compare school travel-PA between adolescents from an urban area and suburban area. The main findings of this research support the primary hypothesis of the study in boys, but not in girls. Mean minutes of MVPA from the school commute were significantly higher in urban boys than suburban boys, irrespective of travel mode. Differences between urban and suburban boys were noteworthy for both active and passive travel groups. Although significant differences were not found in girls, there appeared to be a trend toward greater mean minutes of MVPA during the school commute for urban girls than suburban girls.

There is limited research to explain why youth in urban settings would accumulate more activity during school commuting hours irrespective of whether they used active or passive modes of travel. In two previous studies, one found similar results (Stevens & Brown, 2011) and the other found similar results for walkers only (Van Dyck et al., 2009). Stevens and Brown (2011) showed that, in line with the current study's results, children in a high walkability (urban) neighbourhood obtained marginally more minutes of MVPA during the half hour before and half hour after school (with an assumed commute) compared to children in less walkable neighbourhoods in Utah, which is geographically distinct from Metro Vancouver. They assessed PA from the school commute without stratifying by school travel mode. Despite the different methodology, the study found significant differences in school travel-PA between communities. These results support the premise represented in the current study, that community design may influence PA during the school commute.

Nonetheless, Stevens and Brown's (2011) findings did not account for mode of travel to school. Instead they sought to show community differences in PA. Furthermore, it is important to note that their sample consisted of 9-10 year olds; distances to school are typically lower for elementary school students compared with secondary school students, which may favour active travel (Davison et al., 2008) and thus to some degree explain their findings. Though the shorter distance may be beneficial for active travel (Davison et al., 2008), the opportunity to accumulate greater minutes of school travel-PA may be less than for adolescents who typically must travel longer distances to attend secondary school.

The only other study that has investigated adolescents' directly measured PA from school travel between objectively measured high and low walkability areas is by Van Dyck et al. (2009), who employed a design similar to that of the current study. They compared objectively measured steps assessed by pedometer during the trip to school between urban and suburban adolescents in Belgium. When comparing walking to school between communities, the urban participants obtained greater minutes of PA from the trip to school than suburban participants, which is aligned with the results of the current study. It is of note that they also found a significant negative association between walkability and school travel-PA in cyclists, though this finding is not particularly relevant to the results of the current study since the prevalence of cycling to school was rare in this study's sample.

Although the results of Van Dyck et al.'s (2009) research support the findings from the current study, a few key differences must be acknowledged. First, it was unclear how they measured PA obtained from school travel. Participants were asked to complete an activity log and fill out a series of questionnaires, though no indication was provided on how these data were used to determine that the PA was indeed from the school commute. Thus, it is difficult to draw an accurate comparison between the two studies. Second, the study found a difference (though not significant) in mean minutes of PA between urban and suburban walkers. This was more relative to the current study given that unlike in Belgium, where their study took place, cycling to school is rare among Canadian youth (Buliung et al., 2009). Therefore, a trend towards increased minutes of PA from walking to school in urban adolescents compared to suburban adolescents provides support for the findings of the current study.

5.2.1 School Travel-PA and Contribution to Overall PA

In the current study, urban boys were more active than suburban boys during the school commute, and even the urban boys who used passive means of travel were significantly more active across the day than the suburban boys. This was unexpected since other studies have shown active travellers accumulated more minutes of MVPA during school travel (Loucaides & Jago, 2008; Sirard et al., 2005), and were more active overall than passive travellers (Cooper et al., 2003; Cooper et al., 2005). These findings may be an artefact of measurement, possibly due to the small and highly active sample, or the method of travel mode analyses. The absence of differences in girls' school travel-PA between active and passive travellers was also unexpected. However, as with the boys, urban girls that used passive means to get to school also appeared to have higher 7-day MVPA levels, although this trend was not significant.

As previously noted, urban boys engaged in substantially greater minutes of MVPA during the school commuting time period than suburban boys, regardless of travel mode. During this travel window, urban boys using active travel modes achieved nearly half the recommended minutes of MVPA and boys using passive travel achieved over a third of the daily-recommended minimum of MVPA (CSEP, 2011). These data link the school commute in urban boys as an important contributor to overall PA levels as shown by others (Cooper et al., 2005, 2003; Saksvig et al., 2007). Our analyses, however, showed that when adjusting for BMI z-score and 20mSRT z-score, school travel-PA was not a significant predictor of weekday PA in boys or girls. This outcome is contrary to those from a large population-based study in England that showed walking to school was associated with greater weekday MVPA and accounted for 25% to 40% of average time spent in MVPA (Van Sluijs et al., 2009), The current study's limited sample size may have affected the regression analyses outcome, although other factors such as the categorization of public transit users as passive travel users and the use of hour-long travel windows could also have influenced the outcome.

5.2.2 Categorization of Public Transit as Passive Travel to School

Physical activity from passive travel to school may have been misrepresented in the urban cohort: only four boys rode in a car on the trip to or from school, while the remaining passive travellers used public transit. Although previous research has frequently categorized bus or train travel as a "passive" mode (Mota et al., 2007; Panter, Jones, Van Sluijs, & Griffin, 2011; Panter, Jones, Van Sluijs, & Griffin, 2010), two more recent studies (Owen et al., 2012b; Pabayo et al.,

2012) have either analysed public transit to and from school separately from other passive modes (Owen et al., 2012) or categorized it as an active mode of school travel (Pabayo et al., 2012).

For example, the “Raising healthy Eating Active Living Kids in Alberta” (REAL Kids) study, Pabayo et al. (2012) argued that public transit is a form of active travel to school since users are likely to walk to and from transit stops before reaching their destination. Their analyses demonstrated that public bus users took the most steps during the school commute and throughout the day compared to all other travel groups. Similarly, Owen et al. (2012) analysed public transit use separate from active (walk/cycle) and car modes. Their findings showed that during school travel windows, public transit users were slightly more active than walkers and far more active than car users, engaging in over 20 more minutes of MVPA. Categorization of public transit as passive travel to school in the current study was not ideal given the walk to and from transit locations. However, due to the small number of suburban transit and urban car users in the sample, these modes could not be analysed independently in this study.

5.2.3 Objectively Measured Travel Using Hour Windows

Another possible mechanism that may help explain the absence of difference in school travel-PA between active and passive travellers, as well as explain the urban boys’ high level of school travel-PA, was the use of hour-long travel windows to directly measure school travel-PA. This method is likely an oversimplified means of measuring school travel-PA and may be accounting for PA that is not associated with the school commute, such as participation in a morning or after school sports team, club, or activity. Previous studies have used hour windows to directly-measure PA from school travel (Cooper et al., 2005; Van Sluijs et al., 2009), while some studies have used more conservative half-hour windows (Stevens & Brown, 2011) or more liberal 2-hour windows (Owen et al., 2012; Saksvig et al., 2007). These methods, however, are limited as they fail to differentiate between PA from school travel and PA from other sources. In this study, PA from other sources was not controlled for and may have been falsely identified as MVPA from school travel.

The research team observed that the urban school in this study appeared to have an open-gym policy before school that may have led to students arriving early and being active during the assumed commuting window. However, such a policy could not be verified, nor is it known whether this was communicated to the students; therefore one can only speculate that this may have confounded the school travel analyses. In future, researchers would be advised to obtain details of any such school policies or potential clubs/activities that may occur during the assumed school commute.

However, the convergent validity of using the hour-window before and after school to measure school travel-PA was investigated in a sub-sample from the urban cohort (n=24) (Frazer, Voss, McKay, & Naylor, 2013; Appendix D). MVPA during each hour window was compared to MVPA during actual self-reported travel times that were recorded in travel diaries. Trips were only included in analyses if they were considered routine school travel, which excluded any time spent in clubs, sports, or early or late travel to school. The findings demonstrated that approximately half of the MVPA during the hour-windows was explained by actual school travel-PA. Nevertheless, both methods were able to detect significant differences in MVPA between travel modes in the expected direction (i.e. walkers were most active, car users least active). These findings suggest that either method may be used to rank school travel-PA according to travel mode, but that a one hour-window is likely to capture both school travel-PA as well as PA from other activities.

The addition of Global Positioning System (GPS) monitors may provide a more precise measure of school travel-PA as their use may enable researchers to objectively identify actual time spent in school travel-PA, trip duration, and location of travel-PA. GPS data have been successfully paired with accelerometers in previous studies to determine children's level and location of PA during the school commute (Cooper et al., 2010; Southward, Page, Wheeler, & Cooper, 2012). Whenever possible, future research should consider using GPS, accelerometry, and travel diaries instead of crude travel windows to objectively measure school travel-PA.

5.3 Prevalence of School Travel Modes and Mode Shifting

Prevalence of detailed modes of travel to and from school was substantially different between urban and suburban adolescents in this study. Prior to collapsing modes into "active" or "passive" categories, more urban boys and girls walked to school (52% and 56% vs. 43% and 32%, respectively) and used public transit (30%, 28% vs. 2%, 3%) than suburban boys and girls. Similar results have been found in other studies that support these findings (Napier et al., 2011; Marwa & Muhajarine, 2012; Van Dyck et al., 2009).

Though school travel mode varied between neighbourhoods for both the morning and afternoon commute, there was also an observed shift in travel patterns between the morning and afternoon for both cohorts in this study. For instance, the prevalence of suburban walkers increased 12% in boys and 11% in girls for trip home from school compared to the trip to school. Similar results were also found in urban adolescents, although the increase in walking prevalence was lower (boys: 7%, girls: 6%) than in suburban adolescents. These findings support those of Buliung et al. (2009), who found that children and youth reported more walking for the afternoon trip compared to the morning trip in the Greater Toronto Area. The shift in travel mode choice between the morning and afternoon has been shown to be associated with either parental travel patterns (McDonald, 2007) or perceived parental convenience (Faulkner, Richichi, Buliung, Fusco, & Moola, 2010), but is unknown in the context of the current study. However, the prevalence of shifting travel modes in the current study, particularly in the suburban cohort, are in line with previous work that found characteristics of the built environment were more influential on predicting walking to school than walking home from school (Larsen et al., 2009). Therefore, another possible mechanism for shifting travel modes may also be the built environment.

5.4 Built Environment and Implications on School Travel Mode

A recent systematic review suggested that the built environment along an individual's route to school may be an important factor in school travel behaviour (Wong et al., 2011). Although the current study did not measure individual routes to school, students travelling to school would have traversed parts of the school neighbourhood's built environment during their commute. The neighbourhood surrounding the schools were described in this study, thus enabling the researcher to speculate on the association between school travel behaviour and characteristics of the built environment, such as population density, land use diversity, and road network design.

5.4.1 Population Density

Population density, in terms of both residents per buffer area as well as private dwellings per buffer area, was notably higher in the urban school neighbourhood than in the suburban neighbourhood. According to the 2011 Census of Canada (Statistics Canada, 2013), the city of Vancouver is the most densely populated area per square kilometre in the country. The city has an urban population of 5291 per km^2, compared to 1480 persons per km^2 in suburban Surrey

(Statistics Canada, 2013). However, both of the neighbourhoods measured in the current study were more densely populated than the city average.

In accordance with previous work, this study also found that the frequency of walking to school was greater in adolescents attending an urban school in a densely populated region of the city. Specifically, previous research found that living in areas with high population density, characteristic of urban areas, was strongly associated with walking to school (Mitra et al., 2010), and increased the likelihood of active travel to school when distance was taken into account (Braza, Shoemaker, & Seeley, 2004; Kerr et al., 2006). However, this association is generally inconsistent in the literature (Wong et al., 2011).

There are several possible mechanisms that may explain why higher population densities may contribute to greater rates of walking to school. First, fewer parents may restrict their children's mobility over safety concerns (Davison et al., 2008). Previous research showed that likelihood of walking to school increased when there were more street facing windows, characteristic of densely populated areas, providing more "eyes on the street" (McMillan, 2007, p. 75) and in areas "where other people also walked" (Mitra & Buliung, 2012, p. 58). It may be that an association between urban density and urban adolescents' travel behaviour in the current study was due to better public visibility and the presence of others on the street. While in Surrey, the lower population density may have had an opposite association with travel behaviour.

Public transit use was also substantially greater in urban adolescents (29%) than suburban adolescents (4%). This may be related to increased accessibility to transit in the city's urban core. For instance, in the Greater Toronto Area urban adolescents reported using transit at rates two-to-three times greater than their suburban peers (Buliung et al., 2009). Intuitively, it would appear that transit availability may be positively associated with population density; therefore, higher transit use by urban adolescents in the current study may be indirectly related to population density. As previously noted, transit use for school travel has been identified as a significant contributor to school travel-PA and overall PA (Owen et al., 2012). However, to date only two studies (Owen et al., 2012; Pabayo et al., 2012) have examined transit use for school travel and its association with PA. More research is needed into public transit as a potentially active mode of school travel.

5.4.2 Land Use Diversity

The diversity of a neighbourhood is measured by its presence of blended commercial and residential land use (Saelens et al., 2003). The urban school neighbourhood in the current study had a diverse landscape mixing commercial, residential, parkland, and the ocean all within the 1.6 km buffer. The suburban neighbourhood, on the other hand, was primarily residential with minimal commercial and recreational use, and therefore had less walkable destinations. The presence of diverse land use has previously been positively correlated with walking to destinations (Kerr, Frank, Sallis, & Chapman, 2007) and transport-related PA in youth (Ding et al., 2011). This may help to explain why mean levels of MVPA in urban boys were exceeding the daily minimum levels of PA.

Furthermore, research has shown that diverse land use was significantly related to school travel mode in children (Panter et al., 2010) and that land use diversity surrounding the school neighbourhood at a 1.6 km buffer was a positive predictor of active travel (Larsen et al., 2009). The results of the current study, when using detailed travel mode information, reflect Larsen et al.'s findings, with more adolescents walking to school in the diverse urban neighbourhood than the suburban neighbourhood. It appeared that land use diversity was a contributing factor to adolescents' school travel behaviour. The diverse urban landscape in this study may have offered greater visual appeal or reduced parental safety concerns because of business related activities and thus influenced adolescents' school travel patterns. In particular, the urban school was located on a commercial use road comprised of shop and restaurants, was beside a residential neighbourhood, and was within walking distance of the park and ocean.

It is also noteworthy that there was a vast park space in close proximity to the urban school that may have contributed to the higher overall PA levels found in the urban boys. Other research has identified parks as an important correlate of regular PA in urban adolescents (Babey et al., 2008), with more boys using parks than girls (Cohen et al., 2006). During measurement at the urban school, a physical education class of boys, many of whom were participants in this study, were observed using the park space for a class jog. Though this study does not provide empirical evidence to support the hypothesis that the presence of the park space was a correlate of boys' PA, it is worthy of future investigation.

5.4.3 Road Network Design

Neighbourhoods can be defined by their road network design: a well-connected grid network associated with high intersection density in urban areas or the intricate network of curvilinear streets with low intersection density often found in suburban neighbourhoods. This urban grid network may facilitate active travel behaviours, while a curvilinear suburban network may inhibit it (Sallis & Glanz, 2006). The urban school neighbourhood in this study had greater intersection and road network density than the suburban school neighbourhood, which may help explain why walking to school frequency was higher in the urban cohort. Additionally, the urban school neighbourhood represented a core grid design and had a high proportion of 4-valence intersections; this may have encouraged active travel in the urban cohort. Similar findings were seen in research on rural American adolescents, where active travel rates were higher in school neighbourhoods with greater intersection densities (Dalton et al., 2011). Other research has also shown that high intersection density was associated with a greater chance of walking to school in American youth (Schlossberg, Greene, Phillips, Johnson, & Parker, 2006).

Only one previous study, conducted in Ontario, has looked at intersection density at the school neighbourhood level, as was done in this study, and no association with travel mode to school was found for adolescents (Larsen et al., 2009). However, an association was found for travel from school. This may be because school travel mode was predicted based on the school neighbourhood and not the actual route to school. Nevertheless, a recent review suggested that the majority of evidence to date has found no meaningful positive associations between intersection density and active travel to school (Wong et al., 2011). This may be due to the absence of a standardized method to assess intersection density. However, it may also be the result of geographic, socioeconomic, and climate diversity mediating the influence of the built environment across regions.

Instead of assessing intersection density as a predictor of active travel itself, measuring its association with car travel to school may be more appropriate. For instance, it has been suggested that car travel is favoured in areas where the routes are less direct, as a result of the curvilinear street design typical of suburban areas (Sallis & Glanz, 2006). Similar support has been shown by a systematic review, where decreased directness of the route to school was associated with increased rates of passive travel (Wong et al., 2011). Therefore, if intersection design is negatively correlated with car travel to school it may be a positive correlate of other travel modes, such as public transit.

The suburban school neighbourhood in the present study had less direct routes to school given the predominantly curvilinear design of the road network with many cul-de-sacs.

Coincidently, car travel to and from school was also highest in this area while transit use was lowest. This may be the result of curvilinear streets frequently being car-centric due in part to the low network connectivity and indirect routes that limited intersection density often provides (Sallis & Glanz, 2006).

In the current study, two of the three suburban schools were located on or near a major road, and had higher rates of car travel compared to the urban school. Though the literature is generally mixed (Braza et al., 2005; Kerr et al., 2006; Larsen et al., 2009; Lin & Chang, 2010; Panter et al., 2010; Schlossberg et al., 2007), some evidence also points to indirect routes to school as a positive predictor of active travel, except when located near a busy road (Panter et al., 2010). It may be that low traffic-flow residential roads, typical of the suburban neighbourhood in the current study, may force cars onto major roads in order to reach a destination thereby increasing the volume and speed of traffic along an adolescent's potential route to school. Intuitively, this may in turn decrease the likelihood of active travel. Conversely, the urban neighbourhood's high density of residential roads may also positively influence active travel patterns due in part to fewer cars on the road, dispersed car volume, and potential for less fear of injury.

A study by Panter et al. (2010) also found that high connectivity, a characteristic of the urban school neighbourhood in the current study, increased the likelihood of walking to school. The longer block lengths associated with low connectivity, as seen in the current study's suburban neighbourhood, have previously been shown to have a negative effect on school travel in children (Lin & Chang, 2009). Therefore, the short block sizes and high connectivity along the urban grid may offer students an alternative route to school that is indirect without adding substantial time to their school journeys. Students may simply walk a block or two off the most direct route to school in order to travel along a local road, trail, or alleyway to school instead of along the major road with higher traffic volume. Whereas in the suburban neighbourhood, the curvilinear street design may restrict access to alternative routes. Moreover, the limited availability of trails or alleyways may also impede pedestrian travel to school since taking an alternate route would likely add time to the school journey. However, the association between active travel and street-level variables such as block length, the density of street segments, and traffic remains relatively inconsistent in the literature (Wong et al., 2011) and more research is needed.

5.5 Walkability as a Predictor of Active Travel to School

A secondary objective of this study was to investigate whether directly measured school neighbourhood walkability was a significant predictor of active travel to school and no such relationship was found. Since analysis was restricted to only those with valid accelerometry data, and detailed travel modes were combined into an overall main mode category, differences in travel modes disappeared between cohorts. Specifically, when detailed travel modes, that had related to higher rates of walking to and from school in the urban (high walkability) cohort, were combined into an overall main mode, only 46% of urban boys and 47% of urban girls used active travel, compared to 48% of suburban boys and 63% of suburban girls. Thus, when main mode was put into the regression model, the outcome did not support the hypothesis that walkability would predict active travel to school. Instead, while accounting for sex, age, cohort, Walk Score, CRF, and MVPA, distance was the only significant predictor of active travel to school. The likelihood of active travel decreased with each additional kilometre of distance between home and school. These results are in line with those reported in a systematic review that found distance was the only consistently reported environmental predictor of active travel to school (Wong et al., 2011).

Not surprisingly, in the current study adolescents reporting active travel lived closer than those reporting passive means of travel. Reasonable distances for walking to school have been identified as 1.5 km or less from home to school (D'Haese et al., 2011) and in the current sample, mean distance to school for active travellers was 1.5 km or less regardless of sex or cohort. Even though rates of walking were originally greater in the current study's urban sample, the difference in travel modes disappeared after transit and car modes were categorized as passive travel for analyses. For this reason, other factors may have had less influence on the outcome of active travel analyses than the mode when it was analysed independently.

Despite having higher individual Walk Scores in the urban cohort, it was not a significant predictor of active travel to school. Although a previous study found walkability was a positive predictor of active travel (Kerr et al., 2006), in this study it was not. However, Kerr's study used a walkability index calculated in GIS software, while the current study used the online tool Walk Score™. Walk Score™ simply estimates density and access of walkable amenities. It is a proxy measure of overall neighbourhood walkability, and does not account for transit access (Carr, Dunsiger, & Marcus, 2010b). Therefore Walk Scores should be interpreted with caution.

5.6 Active Travel to School and Implications for Physical Activity

Physical activity in Canadian youth is low, particularly in adolescents and girls (Colley et al., 2010). Active travel may be a way to increase PA levels during the week (Cooper et al., 2005; Cooper et al., 2003; Tudor-Locke et al., 2001). While this study was unable to show school travel-PA as a significant predictor of weekday MVPA, active travel to school should not be dismissed as a potentially important behaviour to increase adolescent PA levels.

The current study showed that suburban boys and girls using active travel accumulated 15 and 33 more minutes, respectively, of MVPA overall than suburban passive travellers. Although actual minutes of MVPA during the assumed commute were minimal in all active travel groups except urban boys, minutes of MVPA during these windows contributed towards one-sixth or more of the 60 minute per day recommendation (CSEP, 2011); these results are supported in the literature (Cooper et al, 2005; Sirard et al., 2005).

The results of the current study also showed that urban boys using passive travel were significantly more active than suburban boys using passive travel; the same trend was seen among boys using active travel although it was not significant. These differences among passive travellers may be the result of public transit users categorized as passive rather than active. However, the trend towards urban boys using active travel being more active overall is in line with the literature (Cooper et al., 2003; Cooper et al., 2006). As suggested by others (Faulkner et al., 2009), it may be that active travel to school itself is not a major contributor to overall PA levels, rather it may act as a catalyst for increased PA throughout the day. Conversely, it may also be that adolescents who are already more active tend to engage in active travel. Nevertheless, with alarmingly low PA rates in Canadian youth, active travel to school is a behaviour that will increase PA during the journey to school when compared to the sedentary behaviour of riding in a car (Cooper et al., 2003).

The study also showed that in the total sample, fewer girls walked to and from school than boys in the suburban cohort. This is in line with previous research that found girls were less likely to use active travel to school than boys (Chillón et al., 2010). Girls in the analytical sample also generally engaged in less PA on weekdays than boys. Between urban and suburban girls, weekday PA was not significantly different between travel modes. This suggests that active travel may be less influential in girl's PA levels on weekdays. However, it is noteworthy that the direction of the relationship between cohort walkability and 7-day MVPA in girls was opposite than that found in boys. Meaning, MVPA across a 7-day span was lower in urban girls than suburban girls using active travel, whereas urban boys were more active than suburban boys using active travel.

However, only a fraction of girls met daily PA guidelines in this study, compared to the higher rates found among boys. In urban and suburban boys using active travel, over half met PA guidelines, compared to lower rates found in those using passive travel. In girls, meeting PA guidelines was higher in suburban girls using active travel, and no girls in the urban cohort met PA guidelines. Gender has been associated with PA, and girls' PA levels tend to be lower than boys (Nader et al., 2008), which is well aligned with the results of the current study. These findings may be due to the small sample of urban girls, or it may also be that this sample was highly active, possibly biasing outcomes. Therefore, the results should be viewed carefully.

5.7 Limitations of the Research

The current study is not without limitation and as a result, the findings in this thesis should be interpreted with caution. The primary limitations of the study include: cross-sectional design, small sample size, possible over or underestimation of PA, simplified analysis of travel mode, and school level GIS analyses.

First and foremost, the study was cross-sectional and therefore addressing the direction of causality in the findings is not possible. In addition, the small sample, particularly in the urban cohort, may have biased the results. This may have limited the study as potential effects may have been dismissed due to the conservative level of significance set *a priori*. Conversely, the small and highly active sample may also have led to over or underestimating the magnitude of an association in certain cases (Hackshaw, 2008).

School travel-PA was measured over 4 days by accelerometry. Although accelerometers can directly measure differing levels of free-living PA (Evenson et al., 2008), several limitations still exist. First, PA is inherently underestimated in the vertical plane for activities such as cycling. It is also underestimated in students who play contact or water-based sports since the accelerometer must be removed during these activities. As a result, the monitor does not account for that portion of time, much of which is likely spent in MVPA. Second, accelerometer data must be validated prior to analyses. In this study, accelerometer data were processed with a minimum of 4 valid days of recording. However, this method is based on the inclusion of at least 1 weekend day. Since no school travel occurs on weekends, the relevance of measuring a weekend day when assessing the contribution of school travel-PA to overall PA is likely unnecessary. A more robust approach may be to validate accelerometer data based on 3 valid weekdays and restrict analysis to school travel-PA's contribution to PA levels on weekdays alone.

The analysis of school travel modes as simplified overall main modes was likely a key limitation in this study. Specifically, once modes to and from school were sorted based on main modes, a proportion of students without an identifiable main mode were excluded from analyses, possibly biasing the outcome. Furthermore, the allocation of travel modes into active or passive categories was a limitation as it likely underrepresented actual active travel on the way to the transit stop. Simplified main modes fail to account for the true association between a specific mode and any particular outcome of interest.

Lastly, the study is limited by its GIS measures of the built environment at the school level alone. This study used a 1.6 km circular buffer around the school to delineate the school neighbourhood in each cohort. This was likely an oversimplification for describing the built environment characteristics that may be correlated with adolescents' travel to school, especially since the specific routes adolescents take to school and the built environment surrounding their homes was unknown. The current study also used the online tool Walk Score™ to identify school and residential level walkability. However, Walk Scores are proxy measures of overall neighbourhood walkability and they may not be relevant to children and youth.

5.8 Strengths of the Research and Implications for Future Research

This was the first Canadian study to examine differences in adolescents' objectively measured school travel-PA using objectively defined urban and suburban areas. The study is assumed to be the first to show that differences in boys' PA during the commuting time period were present for the urban and suburban neighbourhood cohorts despite boys using the same travel modality. Furthermore, there were higher proportions of walkers and transit users in the urban cohort than suburban cohort, which is well aligned with previous Canadian research that reported similar prevalence in travel modes (Buliung et al., 2009). This is an important finding as it suggests that neighbourhood design may be associated with differences not only in school travel mode, but also the proportion of daily PA obtained from the assumed commuting period. Furthermore, the study provides an opportunity for further research into the effects of varying levels of urban design on adolescent travel patterns. Specifically, there is an opportunity to explore public transit as a possible active travel mode, rather than it's more traditional allocation as a passive mode.

Future research would be advised to use a longitudinal design in a population-based study that would ideally evaluate changes in the built environment over time and its association with school travel behaviour. Additionally, future research should consider using a combination of GPS, accelerometry, and travel diaries in order to more accurately measure PA obtained during the school commute and its relative contribution to overall PA levels. The built environment should also be measured at both the school and route level accounting for macro level walkability and micro level characteristics whenever possible. Furthermore, using GPS monitors to accurately measure a child or youth's route to school will likely provide a greater understanding of the environmental characteristics that may influence school travel behaviour.

Finally, other work has previously identified parental and individual perceptions of the built environment as greater predictors of active travel to school than the built environment itself (Kerr et al., 2006; McMillan, 2007; Panter, Jones, Van Sluijs, & Griffin, 2010b). Ultimately, it may be that the built environment is not the primary determinant of travel mode, rather it may be the culmination of factors such as perceptions, gender, weather, school policy, child maturity, the environment, and distance to school that shape school travel behaviour. Therefore, future research should combine measurement of each of these domains in an attempt to understand the true nature of school travel behaviour.

5.9 Conclusion

In conclusion, the data presented in this thesis suggest that there is a difference in school travel-PA between urban and suburban boys even when analysed by the same travel mode. There was no difference found in girls, thus more work needs to be done in order to understand the relationship between urban and suburban design and its association with school travel-PA in girls. Furthermore, the study was not able to show school travel-PA as a significant predictor of weekday PA, although PA levels tended to be greater on weekdays than over a 7-day span, particularly in active travellers.

The study was also unable to show cohort or individual level walkability based on home address as predictors for active travel to school when distance to school was taken into account. Nonetheless, the study did find that urban adolescents walked more, used transit more, and used a car less for school travel than suburban adolescents. The built environment data and supporting literature suggested that school travel patterns between the two cohorts may have been associated with their respective neighbourhood designs. It is hypothesized that urban design may decrease car travel and promote the use of other potentially more active modes. The intriguing differences found in this study between the prevalence of urban transit use, and suburban car use, requires further investigation into its association with adolescents' PA. Especially since the presence of walking connections that are often associated with transit routes, suggests that an effective public transit network "helps promote [PA]" in its users (Frank & Raine, 2007, p.7) and the same may be true for adolescents.

Furthermore, the Global Advocacy for Physical Activity ([GAPA]; 2011) has identified active travel itself, and built environments designed to support active travel, as two of the seven best investments for PA promotion and the prevention of non-communicable disease. In particular, GAPA considers active travel as the "most practical and sustainable way to increase [PA] levels on a daily basis" (p. 2). Given the current crisis in Canada of low adolescent PA levels (Colley et al., 2011), utilitarian travel behaviour (walking to school or taking public transit) may be a viable means to increasing PA levels and should continue to be explored.

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Appendix A: Permission to Display the Panter et al. (2009) Framework

Dear Amanda,

I authorize you to include Panter et al.'s 2009 Conceptual Framework for the Environmental Determinants of Active Travel in your thesis <Associations of Neighbourhood Walkability on Adolescents' School Travel-Related Physical Activity and School Travel Mode >. I am aware that I/we are granting an irrevocable non-exclusive license allowing the Library and Archives Canada to reproduce, loan, distribute or sell copies of this thesis by any means and in any form or format to make it available to interested persons.

Best wishes,

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Appendix B: ASAP Jr. Consent Form

Active Streets, Active People (ASAP): An Integrated Community Partnership to Enhance Physical Activity and Active Transportation to School in Children and Youth

Consent and Assent Forms

Principal Investigator: **Dr. Heather McKay, PhD**
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THE UNIVERSITY OF BRITISH COLUMBIA

Active Streets, Active People (ASAP): An Integrated Community Partnership to Enhance Physical Activity and Active Transportation to School in Children and Youth

Consent and Assent Forms

Introduction

Thank you for taking the time to read this information. You and your parents/legal guardians are being invited to take part in a research study entitled: "Active Streets, Active People: An Integrated Community Partnership to Enhance Physical Activity and Active Transportation to School in Children and Youth". The purpose of this study is to understand supporting and limiting factors of neighbourhood design that influence children and youths' ability to be active in their neighbourhood and use active forms of transportation to school.

Your participation is entirely voluntary, so it is up to you to decide whether or not to take part in this study. Before you decide, it is important for you to understand what the research involves. This consent form will tell you about the study, why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts.

If you wish to participate, you and your parents/legal guardians will be asked to sign the last 2 pages of this form. If you do decide to take part in this study, you or your parents/legal guardians are still free to withdraw at any time and without giving any reasons for your decision. If you or parents/legal guardians do not wish for you to participate, you do not have to provide any reason for the decision not to participate.

It would be useful to us if you would return this form to your school even if you do not wish to take part. That way we know that your consent form did not get lost and that you had an opportunity to think about taking part. There is a check box on the consent form that will enable you to indicate your choice.

Please take time to read the following information carefully and to discuss it with your family before you decide.

Who is conducting this study?
Dr. Heather McKay, Dr. Christine Voss, and Dr. Joanie Sims Gould from the University of British Columbia and the Centre for Hip Health and Mobility are conducting this study.

Background
Physical activity is important for health in children and youth. Well-designed neighbourhoods may provide children and youth with direct opportunities to play outside and actively transport to school. We have partnered with the City of Vancouver and your school to find out what aspects of your neighbourhood supports or limits your ability to be physically active and use active modes of transportation to school. Examples include sidewalks, bike paths and inviting landscapes.

What is the purpose of the study?
The main objective of this study is to evaluate overall physical activity, outdoor physical activity and active transportation to school before and after changes to neighbourhood streets and environments.

Who can participate in this study?
You can participate in this study if you are currently attending grades 4-10 at a public school in Downtown Vancouver (Elsie Roy Elementary, Lord Roberts Elementary, Britannia Elementary, Lord Strathcona Elementary, Admiral Seymour Elementary, Britannia Secondary, and King George Secondary).

What does the study involve?
This study is taking place in public schools in downtown Vancouver, especially in neighbourhoods surrounding the Comox-Helmcken Greenway. We plan to enrol approximately 1000 children and youth attending Grades 4-10 in Fall 2012. It will take approximately 3 years to complete the study from the time you agree to participate.

Procedures:
Your continued participation will involve the same group-based testing session at your school once every fall for the next three years (September-November 2012-2014). The measurement session will take approximately 75-90 minutes, or the equivalent of one school block. Together with your school and teacher, we will choose a suitable block for your session so that we do not disrupt your teacher's and your own timetable unnecessarily. All of our research staff is very experienced and knowledgeable in all of the following measurements, and they will explain to you why they are important to our research project. You will undergo the following assessments:

1. **Anthropometry**: We will measure your height, sitting height, weight, waist circumference and hip circumference. Although the measurement is group-based, these measurements will be taken in a semi-private setting that is away from other students within the same measurement block. We will not share your results with anybody else at your school. These measurements will take approximately *10 minutes* to complete.

2. **<u>Cardiorespiratory fitness:</u>** You will be asked to take part in the 20-metre shuttle run test, or “beep test”. As part of this test, you will be required to run 20 metre laps in time with a clearly audible “beep”. Every minute, the required running speed increases, and we ask you to keep running until you become too tired to continue. You will be given clear instructions and demonstrations as to how to take part. As this is a test to maximal exertion, it is extremely important you and your parents/legal guardians tell us if you have any existing medical conditions that would endanger your health during such a running test, or if your doctor has ever said that you should not take part in physical activity. You do not need to do the running test if this is the case. This measurement will take approximately *15-20 minutes* to complete.

3. **<u>Musculoskeletal Fitness</u>**: You will be asked to perform a handgrip strength test, which requires you to squeeze a hand-held dynamometer as hard as you can. We will also measure your best attempts of a standing long jump and your vertical jump height. You will be given clear instructions and demonstrations as to how to take part. These measurements will take approximately *10 minutes* to complete.

4. **<u>Blood Pressure</u>:** Before we will measure your blood pressure, we will ask you to rest for about 5 minutes, sitting in a chair. We will need to touch your upper arm to know where exactly to place the blood pressure cuff, which is essentially a thick belt that is placed around your upper arm. Once we start the measurement, the cuff will inflate and will squeeze your upper arm. Then it will deflate and you may be able to feel your pulse. We will repeat the procedure one more time after 1 minute. Some people find having their blood pressure measured uncomfortable, but it is not painful. There will be plenty of opportunities to ask questions about this measurement and you can of course choose not to proceed with the blood pressure measurement. This measurement will take approximately *10 minutes* to complete.

5. **<u>Questionnaires</u>**: You will be asked to complete some questionnaires about your participation in physical activity and sport, how you normally travel to and from school, and your opinions and beliefs regarding your neighbourhood. You will be given clear instructions on how to complete the questionnaires, and research staff will always be present to answer any questions or to help you with completing your questionnaires. These questionnaires will take approximately *30 minutes* to complete.

6. **<u>Motion sensors</u>**: We would like to measure your physical activity patterns over the course of a week. We will ask you to wear two small, lightweight motion sensors, which are attached to an elastic and adjustable belt around your waist. You will be asked to wear the belt every day, once you get up until the time you go to bed (approximately 12 hours or more) for 7 consecutive days. We would also like you to record any times when you did not wear them in a log (i.e. taking a shower or sleeping). We will fit you with a belt and motion sensors at the end of the school-based measurement session, and will provide detailed instructions on how to wear them and how to complete the log. At the same time, we will also be able to answer

any questions or concerns you may have. It will take approximately *10 minutes* to provide instructions and a further *7 days* to wear the motion sensors.

The first motion sensor is called an “accelerometer”. They use the same technology as the motion sensor lights for houses and are activated by movement. The purpose of the accelerometer is to get an idea of your physical activity patterns over the course of a week. The second motion sensor is a global positioning system unit, also known as a “GPS monitor”. The GPS device helps us understand where you participate in physical activity and how you travel around your neighbourhood. The GPS monitor continually records your location, but it is important that you understand that we never know your location in ‘real-time’, that is, we never know your location during the time you are wearing the GPS monitor. We only have access to this information once you return the GPS monitor to us, and we will not share your individual movement patterns with others. We commonly use these motion sensors to measure physical activity, and both motion sensors are safe, non-invasive and there are no direct harms associated with wearing them. However, if you have further questions about either technology or how we use your results, please feel free to contact **Dr. Christine Voss at (604) 787-6750** or christine.voss@hiphealth.ca.

7. **Family Demographics Questionnaire**: If you decide to take part in this study, we will ask your parents/legal guardians to complete a questionnaire at home to provide some information about your family, as well as what their own opinions are regarding your neighbourhood. We will also offer your parents/legal guardians the opportunity to report their own physical activity and transportation patterns. Completion of these questionnaires is voluntary, but your parents’/legal guardians’ information is very important to us as it may affect study outcomes. Please be assured that all information will remain strictly confidential. It will take approximately *35-60 minutes* to complete the questionnaires, depending on how many answers your parents/legal guardians choose to provide.

How much of my time is required?

If you agree to participate in this study, the following amount of your time is required at each of the three measurement sessions during the next 3 years:

- 75-90 minutes total for each measurement session during a school block that is least disruptive to your teacher’s and your own timetable
- Approximately 5 minutes each day for seven days to complete the activity log

Therefore, the total amount of time required is approximately *6.25 hours* over the course of three years.

What are the possible harms and side effects of participating?

Exercise to maximal exertion, such as we propose for the “beep test”, may carry health risks for people who have specific underlying medical conditions. Examples include high blood pressure, heart conditions, severe asthma or specific bone and joint problems. It is extremely important you and your parent/legal guardian alert us on this consent form to any such condition so that we can make sure you do not take part in the “beep test” on measurement day. You can still participate in all other aspects of the study, including the other fitness tests.

We will take extreme care to ensure your and your family's identity is protected throughout and after your participation in this study. During the study period, you will be asked to carry the GPS device and accelerometer with you wherever you travel. Information recorded by the GPS device can include personal locations (i.e. home), however confidentiality is of upmost concern and no information that discloses your identity will be released. There are no physical harms or side effects associated with either device.

What are the benefits of participating in this study?

No one knows whether or not you will benefit from this study. There may or may not be direct benefits to you and your family from taking part in this study. We hope that the new knowledge we obtain from this study can be used in the future to help promote physical activity and active transportation to school in children and youth.

What happens if I decide to withdraw my consent to participate?

Your participation in this research is entirely voluntary. You may withdraw from this study at any time and no reason for withdrawal needs to be provided. If you decide to enter the study and to withdraw at any time in the future, there will be no penalty or loss of benefits to which you are otherwise entitled, and withdrawal will in no way affect your child's status or opportunities at school. If you choose to enter the study and then decide to withdraw at a later time, all data collected about you during your enrolment in the study will be retained for analysis. You do not waive any of your legal rights by signing this consent form. If you wish to withdraw please contact Dr. Christine Voss at (604) 787-6750.

What happens after the study is finished?

Following measurement in the fall (2012-2014), you will be provided with a one-page summary of your results the following spring. Once the study is concluded, you will receive a one-page summary of the general findings of the study.

What will the study cost me?

You will not incur any personal expenses as a result of participating in the study. You will be entered into a draw for a $50 gift card from Mountain Equipment Co-op as compensation for your time, regardless of whether you complete the study, whether you withdraw early, or submit incomplete questionnaires.

Will my taking part in this study be kept confidential?

The study coordinator will have access to your name and phone number for the purposes of contacting you to remind you to bring PE strip on assessment day and to remind you to return your motion sensors and activity log. Your identity will remain confidential as all individual records and results will be analysed and referred to by number code only. Files are kept in locked filing cabinets at the Robert H. N. Ho Research Centre, Vancouver General Hospital, which is a secured building with restricted access. Only those directly involved in the study (the *Active Streets, Active People* Research Team) will have access to your records and results. You will not be referred to by name in any reports or research papers. Your individual results will remain confidential, as they will not be discussed with anyone outside the research team. However, records identifying you may be inspected in the presence of the investigator, or by representatives of the UBC Research Ethics Board, for the purpose of monitoring the research.

Who do I contact if I have questions about the study during my participation?
Please be assured that you may ask questions at any time. We will be glad to discuss your participation and results with you and your family when they have become available and we welcome your comments and suggestions. Should you have any concerns about this study or wish further information please contact Dr. Christine Voss at **(604) 787-6750**, or Dr. Joanie Sims-Gould at (604) 875-4111 ext. 21715.

Who do I contact if I have any questions or concerns about my rights as a participant during the study?
Signing this consent form does in no way limit your legal rights against the sponsors, investigators or anyone else. If you have any concerns about your rights as a research participant and/or your experiences while participating in this study, contact the Office of Research Services, University of British Columbia, at (604) 822-8598. You may verify ethical approval of this study or raise any concerns you might have about your rights or treatment as a participant in this study by contacting UBC Office of Research Services at (604) 822-8598.

Active Streets, Active People Jr.
Parent Consent Form – Fall 2012

Please return this page to your school. If you wish to take part in the project, please sign below and complete both pages of this form. Keep the information letter.

<u>Parent/Legal Guardian Consent Statement</u>:

I/We, ____ the parents/guardian of
(*Please print the first and last name of one or both parents/legal guardians*)

____ state that (**<u>please tick</u>**)
(*Please print child's first and last name*)

☐ We do not wish to take part **<u>OR</u>** ☐ We wish to take part and agree to the following:

- I/We have read and understood all pages of the information letter and consent form, and understand the proposed procedures, benefits and possible risks.
- I/We have had sufficient time to consider the information provided and to ask for advice if necessary.
- I/We have had the opportunity to ask questions and have had satisfactory responses to my/our questions.
- I/We understand that all of the information collected will be kept confidential and that results will only be used for scientific objectives.
- I/We understand that participation in this study is voluntary and that I/we or our child are completely free to refuse to participate or withdraw from this study at any time without jeopardising our child's status or opportunities at school.
- I/We understand that I/we are not waiving any of my/our legal rights as a result of signing this consent form.
- I/We understand that there is no guarantee that this study will provide us, or my child any benefits.
- I/We understand that my/our signature below indicates that I/we agree for you to call, text or email me/my child as a reminder to bring PE strip to measurement days and as a reminder to return the motion sensors and questionnaires.
- I/We understand that my/our signature below indicates that I/we agree to be contacted to provide information regarding our family, my/our perceptions regarding the neighbourhood and physical activity levels, and I understand that I do not have to answer some or all of these questions in order for my child to participate in the study.
- I/We understand that it is my/our responsibility to inform the researchers in the space provided below if my child cannot take part in the beep test due to a medical conditions or other reasons.
- I/We understand that we will receive a signed copy of this consent form.
- **I/We understand that my/our signature below indicates that I/we consent for our child to participate in the *Active Streets, Active People Study.***

______________________________ ______________________________ ______________
Signature of Parent/Legal Guardian Printed name of the Parent/Legal Guardian Date (dd/mm/yyyy)

My child cannot take part in the beep test because: ______________________

- -

______________________________ ______________________________ ______________
Signature of Principal Investigator or Designate Printed name of Principal Investigator or Designate Date (dd/mm/yyyy)

Active Streets, Active People Jr.
Child Assent Form – Fall 2012

Please return this page to your school. If you wish to take part in the project, please sign below and complete both pages of this form. Keep the information letter.

Child's Statement:

- I understand the contents of this information letter and consent form.
- I understand what my participation in this study involves (anthropometry, fitness, questionnaires and wearing motion sensors for 7 days).
- I have had sufficient time to decide if I want to take part in this study.
- I have had the opportunity to ask questions about this study and had satisfactory responses to my questions.
- I have discussed my choice with my parents/legal guardians.
- I voluntarily agree to participate in the *Active Streets, Active People* Study for the next three years.
- I understand that if I want to I can stop being in the research study at any time and I will still be able to participate in activities at my school.

______________________________ ______________________________ ______________

Signature of Child Printed name of the Child Date (dd/mm/yyyy)

Active Streets, Active People Jr.
Student Contact Information – Fall 2012

First Name: ___________________________________ Middle Initial: ___________

Last Name: ___________________________________ Gender: ________________

School:__________________________________ Current Grade: _____

Date of Birth: __________________
(mm/dd/yyyy)

Home Address: ____
(House #, Street,
City, Postal Code) ____

Family Home Phone Number: ________________________

Cell Phone Numbers Child: ___________________ Parent/Legal Guardian:_______________

Email Child: ___________________ Parent/Legal Guardian:_______________

Appendix C: School Travel Questionnaire

ID: ______________

Checked by: __________

Transportation

Date: ____________ (dd/mm/yyyy)

We are trying to find out about how you normally get to places.

Remember: There is no right or wrong answer –this is not a test. Please answer all the questions as honestly and accurately as you can – this is very important.

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1. In an average week, how many days do you use the following ways to get to and from school? *(For example: If you always ride the school bus to and from school, you would fill in the "5" circle for the "School bus" option in both columns)*

Days per week TO school

Walk	①	②	③	④	⑤
Bike	①	②	③	④	⑤
Car	①	②	③	④	⑤
School bus	①	②	③	④	⑤
Public transit	①	②	③	④	⑤
Combination (for example, you walk to the bus) ________________	①	②	③	④	⑤
Other (please explain): ________________	①	②	③	④	⑤

Days per week FROM school

Walk	①	②	③	④	⑤
Bike	①	②	③	④	⑤
Car	①	②	③	④	⑤
School bus	①	②	③	④	⑤
Public transit	①	②	③	④	⑤
Combination (for example, you walk home from the bus) ________________	①	②	③	④	⑤
Other (please explain): ________________	①	②	③	④	⑤

Appendix D: 3rd International Conference on Ambulatory Monitoring of Physical Activity and Movement (ICAMPAM) Abstract

TITLE: Is accelerometry really measuring travel-related physical activity during the hour before and after school?

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BACKGROUND: Physical activity (PA) from active travel to and from school is commonly inferred by windowing accelerometry data during the hrs before and after school. However, no study has validated this method against travel diaries.

PURPOSE: To investigate the convergent validity of using the hr-window before and after school to measure travel PA (against travel diaries), and to establish if either method describes between-travel-mode differences in travel PA.

METHODS: Forty-nine students (13.8±0.6 yrs) attending a public high school in downtown Vancouver participated in a school-based study in fall 2012. Students were instructed to wear an accelerometer (GT3X+) on the right waist for the next 7d and to complete a travel diary, indicating: travel mode and start/stop times (hh:mm) for trips to and from school on each school-day. Students providing accelerometry data and travel diaries for at least one 'routine' school-day (no clubs and/or early or late travel to and from school) were included for analyses (n=24, 42% girls). Accelerometry files (1s epoch) were windowed (hr before, hr after, travel to, travel from) and uniaxial counts were converted to moderate-to-vigorous PA (MVPA; Evenson et al., '08) using ActiLife (v. 6.4.3).

RESULTS: MVPA during the actual trip to and from school explained 66% ($p<0.01$) and 49% ($p=0.01$) of MVPA during the hr windows before and after school, respectively. Using transit was most commonly reported for travel to (53%) and from (45%) school, followed by walking (29%, 41%) and car use (18%, 14%). There were significant between travel-group differences in MVPA during the hr before ($F=11.05$, $p<0.01$) and during the actual trip to school ($F=5.82$, $p=0.02$); by either method, walkers were most active (20.3±9 min, 11.2±6 min, respectively) compared with transit (11±1.9 min, 6.8±3 min) and car users (3.4±0.8 min, 0.8±0.4 min). After school, MVPA was only different between travel modes during the hr after school window ($F=5.71$, $p=0.01$), but not the actual trip from school ($F=1.27$, $p=0.31$). In the hr after school, walkers were more active (16.2±5 min) than transit (11.6±3 min) and car users (7.5±4 min). It made no difference whether MVPA was calculated based on accelerometry data from 'routine' days vs. any weekdays for the hr before ($t=1.65$, $p=0.12$) or after school ($t=1.62$, $p=0.12$).

CONCLUSION: Windowing accelerometry data during the hr before and after school may be used to crudely estimate travel PA. However, those who seek a precise estimate of travel PA may wish to consider including travel diaries or Global Positioning Systems. Why PA before and after school differs by travel mode - irrespectively of travel PA - warrants exploration.

Presented at ICAMPAM June 2013