Environmental Correlates of Physical Activity among Children, Adolescents, and Parents

by

Stephen Grant Samuel Hunter

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Abstract

Background: Most Canadians are inactive. Given insufficient physical activity is linked to multiple chronic diseases and mortality, increasing physical activity has become a public health priority. To inform future interventions, modifiable correlates and determinants of physical activity need to be identified. Local, national, and international policy documents have highlighted the importance of creating active living environments that promote regular physical activity. While several behvioural settings exist, neighbourhoods provide opportunities for both structured and unstructured physical activity opportunities for multiple ages. However, before modifying existing environments or developing new active living environments, it is first important to consider the features that promote physical activity. Further, for active living environments to have a sustainable impact, identifying features that promote physical activity across multiple ages groups is important. Therefore, the overall purpose of this dissertation is to identify environmental correlates of physical activity across multiple age groups (preschool children, school-aged children, adolescents, adults) within the neighbourhood setting.

Methods: Three studies were conducted. In study one, parents were surveyed regarding the features of their neighbourhood environment that they perceived as important to their own physical activity as well as their children's physical activity and parent-child coactivity. In study two, associations of objectively measured walkability and parental perceptions of the environment with children's physical activity (i.e., daily step counts, parent reported physical activity) were examined using data from the SHAPES of Things to Come project. In study three, the longitudinal associations between the objectively measured built environment surrounding schools and self-reported physical activity and active mode of transport among adolescents were examined using data from the COMPASS project.

Results: In study 1, several neighbourhood features, related to destinations, design, social, safety and aesthetics, were identified by the majority of parents as important for their own physical activity, their child's active play, and parent-child coactivity. There were several significant differences in the proportions of parents who identified features as relevant between activity types (parent physical activity, child active play, parent-child coactivity). Few differences were observed by household income. In study two, objectively measured walkability was not associated with children's steps or parent reported physical activity. However, significant associations were observed for neighbourhood aesthetics and traffic hazards with parental reported physical activity, along with walking and cycling infrastructure during the winter months. In study 3, significant associations were observed between retail-, park-, and recreation center- densities along with Walk Scores in the school neighbourhood environment with adolescent MVPA and active school travel. Students attending schools in environments considered very walkable had an increased likelihood of active school travel and maintained higher MVPA over time.

Conclusion: Across all three studies, there is evidence to suggest features that support walking is important for preschool children's active play, parents' recreational physical activity and coactivity with their children, along with school-aged children's parent reported physical activity, and adolescent's self-reported active school travel and MVPA. Finding ways to incorporate features that support walking into home and school neighbourhoods could promote physical activity across age groups. More longitudinal research that accounts for behavioural and context-specificity, multiple activity settings and their characteristics, and intra- and inter-personal characteristics is needed

Preface

This thesis is an original work by Stephen Hunter. The research projects, of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, "SPACES", Pro00090456, May 15, 2019; "SHAPES of Things to Come", Pro00003747, February 19, 2009; and from the University of Waterloo Research Ethics Board "COMPASS", original ethics number 17264 (current ethics number 30018), December 23, 2011.

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This could not have been achieved without any of you

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Glossary of Terms

1. Physical activity: Any bodily movement produced by skeletal muscles that results in energy expenditure (Caspersen et al., 1985).
2. Light-intensity physical activity (LPA): Light-intensity physical activities do not result in sweat production or shortness of breath. For children aged 0-5 years, examples of LPA include slow walking, hopping, jumping, skipping at an easy pace (Dwyer et al., 2011) . For children and youth, some examples include slow walking, croquet, mild stretching, personal hygiene, playing with animals, walking the dog, and billiards. For adults and older adults, examples include slow walking, light household tasks such as groceries, washing dishes or cooking, childcare, croquet, mild stretching, personal hygiene, and light gardening or watering plants (CSEP, 2017).
3. Moderate-intensity physical activity (MPA): Generally, moderate intensity physical activity is intense enough to elevate the heart rate. A person can talk but not sing during activities of this intensity. For early years children, examples of MPA could be slow running or jogging, dancing, or climbing (Dwyer et al., 2011). For children and youth, examples of MPA include active recreation (e.g., hiking, skateboarding, rollerblading, or canoeing), active transportation (e.g., cycling or brisk walking), household chores and yard work (e.g., sweeping or pushing a lawn mower) and playing games that require catching and throwing (e.g., baseball or football). For adults, examples of MPA include walking briskly (3 miles per hour), water aerobics, cycling slower than 10 miles per hour, tennis (doubles), ballroom dancing, general gardening, and household chores (e.g., vacuuming, washing the floor or climbing stairs)(Canadian Society for Exercise Physiology, 2017).

4. Vigorous-intensity physical activity (VPA): Generally during vigorous intensity physical activity, heart rate increases substantially, body temperature increases quickly, and a person cannot say more than a few words without pausing for a breath. For early years children, an example of VPA would be running or jogging quickly, rough and tumble play with hard effort, or riding a tricycle, bike, or scooter with hard effort (Dwyer et al., 2011). Examples of VPA for children and youth include active games that involve running and chasing (e.g., tag or flag football), fast bicycle riding, jumping rope, martial arts, running, sports (e.g., ice or field hockey, basketball, swimming, soccer, tennis or gymnastics, vigorous dancing, cross-country skiing, and aerobics). For adults, examples of VPA include race walking, fast walking for exercise, jogging or running, swimming laps/fast swimming, tennis (singles), aerobic dancing, bicycling 10 miles per hour or faster, jumping rope, heavy gardening (continuous digging or hoeing), hiking uphill or with a heavy backpack (Canadian Society for Exercise Physiology, 2017).
5. Moderate- to vigorous-intensity physical activity (MVPA): For all age groups, MVPA is a combination of moderate intensity physical activity and vigorous intensity physical activity (see definitions for moderate intensity physical activity and vigorous intensity physical activity).
6. Physical inactivity: An insufficient physical activity level to meet present physical activity guidelines (Tremblay, Aubert, et al., 2017).
7. Active play: A form of gross motor or total body movement in which young children exert energy in a freely chosen, fun, and unstructured manner (Truelove et al., 2017).
8. Built environment: A term referring to the physical form and character of communities. Consists of three elements: transportation systems (i.e., streets and roads, bus and rail

systems, bike lanes, trails), land use patterns (i.e., spatial arrangement of structures and other physical features), and urban design (i.e., design and styling of buildings, streets, and other elements) (Frank et al., 2003) p.217).

9. Early years: In accordance with the Canadian 24-Hour Movement Guidelines for the Early Years, the 'early years' represent a period in a child's life when they are between the ages of 0-4 years.
10. Preschoolers or Preschool Children: In accordance with the Canadian 24-Hour Movement Guidelines for the Early Years preschoolers are children who are between the ages of 3-4 years old.
11. School-aged children: In accordance with the Canadian 24-Hour Movement Guidelines, children are defined as being aged 5 to 11 years.
12. Adolescents: defined as children between the ages of 12-17 years.
13. Adults: In accordance with the physical activity guidelines, adults refer to the population who are between the ages of 18 and 64 years. Parents are adults over the age of 18 with a dependent child.
14. Correlates: A variable that has been studied with the intention that it predicts an outcome of interest (e.g., physical activity). Correlates are typically produced by cross-sectional studies where causality cannot be determined (Bauman et al., 2002).
15. Determinant: A causal factor that when changed, a change in the outcome of interest (e.g., physical activity) also occurs. Determinants are typically produced by longitudinal or experimental designs (Bauman et al., 2002; Atkin et al., 2016)

Chapter 1: Introduction

The World Health Organization has identified physical inactivity as the fourth leading risk factor for mortality (World Health Organization, 2009). Prevalence estimates indicate most Canadians are not active enough for optimal health benefits (Public Health Agency of Canada, 2016). Given physical activity patterns are established during the early years (ages 0 to 4.99 years) and appear to track throughout childhood (ages 5 to 17.99 years) and adulthood (ages 18+ years) (Telama, 2009), most Canadian children are at an elevated risk for future chronic disease and premature death (Lee et al., 2012). Therefore, it is important for healthy physical activity patterns to be established during childhood and adolescence.

According to ecological models, there are multiple sources of influence that play a role in shaping human behaviour (Sallis et al., 2008). Within these models, intra-individual (e.g., attitude, self-efficacy), and extra-individual (e.g., significant others, schools, built environment, government policies) factors play a role in shaping behaviour (McLeroy et al., 1988). For successful behaviour change to occur, it has been recommended that interventions target multiple levels of the model (McLeroy et al., 1988). However, such interventions would be fairly resource intensive and complex, therefore, population health approaches tend to focus on intervening at distal levels (e.g., neighbourhood environment) as they have the potential to benefit larger proportions of people.

Modifying existing, and/or creating new neighbourhoods that encourage physical activity is one strategy that may yield health benefits for large proportions of people. To create such neighbourhoods, it is first necessary to identify modifiable features that relate to physical activity. Due to developmental and lifestyle differences between children in their early years, children, adolescents, and adults, it is important to identify environmental correlates that are specific to each age group. An environment containing features that promote physical activity across multiple age groups may facilitate healthy physical activity habits throughout the lifespan.

Purpose

The overall purpose of this dissertation is to examine the environmental correlates of physical activity among preschool children (3 to 4 years), school-aged children (aged 6-10 years), adolescents (aged 13 to 18 years), and parents (adults with preschool children).

Main Objectives and Hypotheses

Study 1: Objectives

The primary objective was to identify neighbourhood features that were important for parents' sport, recreation, and leisure time physical activity; preschool children's active play; and co-participation in physical activity. A secondary objective was to examine whether important neighbourhood features differ based on type of physical activity among parents (sport, recreation, and leisure time physical activity vs active play vs coactivity). A tertiary objective was to examine whether important correlates differ based on household income.

Study 1: Hypotheses

Based on the concept of behavioral specificity, it was anticipated that important environmental features will differ between types of physical activity being examined. For co-participation it was anticipated that child-friendly features will be identified as important for co-participation in physical activity. Further, it was hypothesized that important features will vary based on household income.

Study 2: Objectives

The primary objective was to examine associations between parental perceptions and objectively measured walkability, with children's daily step counts and parent reported physical activity. The secondary objective was to examine whether environment-physical activity associations were modified by objectively measured socioeconomic status and seasonality.

Study 2: Hypotheses

Children living in environments with favourable attributes would have higher daily step counts compared to children living in neighbourhoods their parents perceive as being unfavourable. Associations would be stronger among children from higher socioeconomic status, and among those who were recruited in the non-winter months.

Study 3: Objectives

The objectives of this study were to 1) examine changes in adolescent moderate- to vigorous–intensity physical activity (MVPA) and active school travel over a four-year period, 2) examine the associations between the built environment surrounding the school and adolescents' MVPA and active school travel, and 3) examine whether the built environment moderates adolescent MVPA and active travel over time.

Study 3: Hypothesis

Adolescents attending schools with favourable environments will have higher levels of MVPA and be more likely to engage in active school travel.

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Chapter 2: Literature Review

The Relationship between Physical Activity and Health

Overview

The benefits of regular participation in physical activity have been globally supported over several years. Physical inactivity has been linked with deleterious health and has become one of the top four behavioural risk factors for chronic disease. As physical inactivity is defined as failure to meet physical activity recommendation (Tremblay, Aubert, et al., 2017), it is important to understand the physical activity recommendations for each age group that are required for optimal health. The remainder of this section draws from key systematic reviews that have informed Canada's physical activity recommendations to summarize the health benefits associated with physical activity for the early years, school-aged children and youth, and adults.

Early years

The early years represents a period during a child's life that is characterized by rapid cognitive, social, and physical development (Berk, 2014). It is during these formative years that children start to engage in basic forms of physical activity such as tummy time, walking, and running (Berk, 2014). As previous research has shown, physical activity levels tend to track throughout childhood, adolescence, and into adulthood (Telama et al., 2014). Therefore, encouraging physical activity during the early years may be important for maintaining a physically active lifestyle. More importantly, promotion of physical activity during these years may help yield immediate health benefits (Carson et al., 2017) and maintain a healthy lifestyle free of chronic disease.

Following the release of physical activity guidelines for the early years in the United Kingdom (Department of Health Physical Activity Health Improvement and Protection, 2011) and Australia (Australian Government, 2010), Canada released their first set of physical activity guidelines for the early years in 2012 (Tremblay et al., 2012). A major part of guideline development process and support for the new physical activity recommendations came from a systematic review led by Timmons et al. (2012). This review summarized the relationship between physical activity and adiposity, bone health, motor development, psychosocial health, cognitive development, cardio-metabolic health, and risks for infants, toddlers, and preschoolers (Timmons et al., 2012). The results suggested that physical activity had favourable associations with adiposity, motor development, and cognitive development for infants. For toddlers, evidence suggested physical activity was favourably associated with bone and skeletal health. Lastly, physical activity was favourably associated with adiposity, motor skill development, psychosocial health, and cardiometabolic health indictors for preschoolers (Timmons et al., 2012). Although results from the Timmons et al. (2012) review suggest favourable associations exist between physical activity and multiple health indicators throughout the early years, it is important to note that the available evidence consisted of only 22 studies. As a result, it was acknowledged that the body of literature was still in its early stages (Tremblay et al., 2012).

Five years later, Carson et al. (2017) performed an updated systematic review summarizing 96 studies that had looked at the relationship between physical activity and adiposity, motor development, psychosocial health, cognitive development, fitness, bone and skeletal health, cardiometabolic health, and risks in the early years. As such, the Carson et al. (2017) systematic review serves as the most up to date summary of the relationship between physical activity and multiple health indicators during the early years. The findings from this systematic review suggest physical activity (MVPA) has favourable associations with multiple health indicators, with consistent favourable associations (>60% studies) for motor development, cognitive development, fitness, and bone and skeletal health (Carson et al., 2017). Further, the results from this systematic review provided the empirical evidence to support the physical activity component of the 24-Hour Movement Behaviour Guidelines (Tremblay, Chaput, et al., 2017), which recommends:

1. Infants being physically active several times a day in a variety of ways, particularly through interactive floor-based play, with more being better. For those not yet mobile, this includes at least 30 minutes of tummy time spread throughout the day while awake.
2. Toddlers spend at least 180 minutes in a variety of physical activities at any intensity, including energetic play, spread throughout the day. With more being better.
3. Preschoolers spend at least 180 minutes in variety of physical activities spread throughout the day, of which at least 60 minutes is energetic play. With more being better.

Despite the authors of both reviews acknowledging the literature as being in its early stages, there appears to be sufficient evidence linking physical activity to enhanced health during the early years. Therefore, from a public health perspective it is important to encourage and promote young families with infants, toddlers, and preschoolers to meet these physical activity recommendations.

School-aged children and adolescents

Canada released its first set of physical activity guidelines for children and youth in 2002 (Government of Canada, 2002). A steppingstone approach was recommended, where children start by adding 30 minutes of MVPA (20 min MPA, 10 min VPA) per day toward achieving at least 60 minutes of MPA, and 30 minutes of VPA per day (Government of Canada, 2002). These guidelines also cited the multiple health benefits associated with regular physical activity such as muscle and bone strengthening, maintaining flexibility, achieving healthy weight, promoting good posture and balance, improving fitness, meeting new friends, strengthening the heart, improving physical self-esteem, increasing relaxation, and enhancing overall healthy growth and development (Government of Canada, 2002). Five years later, a narrative review by Janssen (2007) was performed to update the body of literature. Based largely on the favourable associations between physical activity and cardiometabolic health, mental health, musculoskeletal health, and muscular strength and endurance reported by Strong et al. (2005), Janssen (2007) advocated for Canadian guidelines to be increased to at least 60 minutes of physical activity per day.

In 2011, Canada released its new physical activity guidelines which recommended children and youth accumulate:

1. At least 60 minutes of MVPA per day
2. At least 30 minutes of VPA three days a week
3. Resistance training at least three days a week

These guidelines were largely based on the systematic review performed by Janssen and Leblanc (2010) which found favourable associations between physical activity and bone strength, aerobic fitness, muscular strength and endurance, self-concept, anxiety, depressive symptoms, and psychological distress. In addition, meta-analyses performed around the same time found favourable associations between physical activity and cognitive outcomes (Fedewa & Ahn, 2011) and mental health (Ahn & Fedewa, 2011).

In 2016 Canada updated their physical activity guidelines in the form of the new Canadian 24-Hour Movement Guidelines for Children and Youth (Tremblay et al., 2016). The physical activity component of the Canadian 24-Hour Movement Guidelines for Children and

Youth were based on a large systematic review performed by Poitras et al. (2016). This systematic review summarized the relationship between objectively measured physical activity and a variety of health indicators (Poitras et al., 2016). The findings from this review suggest objectively measured physical activity had favourable associations with physical, psycho-social, and cognitive health. These associations were more consistent with MVPA, while LPA appeared to be beneficial for cardiometabolic health (Poitras et al., 2016). To reflect the updated research, the Canadian 24-Hour Movement Guidelines for Children and Youth recommend:

1. 60 minutes of MVPA per day
2. Three days a week of VPA
3. Three days a week of resistance activities
4. A "STEP" component recommending children and youth engage in several hours of a variety of structured and unstructured light physical activities.

Overall, there appears to be large amount of evidence to support a favourable relationship exists between physical activity (mostly MVPA) and a variety of health indicators and outcomes in school-aged children and youth. Further, the acknowledgement of the health benefits associated with LPA in the new guidelines may be important for justifying environmental interventions that target walking in this age group (e.g., active transport interventions).

Adults

In 1998, the Public Health Agency of Canada partnered with the Canadian Society for Exercise Physiology to release its first set of physical activity guidelines for adults (Health Canada, 1998). Here it was recommended adults accumulate:

1. At least 60 minutes of daily physical activity

2. A mixture of endurance, flexibility, and strength activities

Within these guidelines the benefits of regular physical activity were outlined which included better health, improved fitness, better posture and balance, better self-esteem, weight control, stronger muscles and bones, feeling more energetic, relaxation and reduced stress, and continued independent living (Health Canada, 1998). Further, physical inactivity was associated with premature death, heart disease, obesity, high blood-pressure, adult-onset diabetes, osteoporosis, stroke, depression, and colon cancer (Health Canada, 1998). While no reference was made to any systematic review to inform the guidelines, several organizations who supported the recommendations were listed (e.g., Canadian Cancer Society, Canadian Diabetes Association, the Heart and Stroke Foundation of Canada, Obesity Canada, the Osteoporosis Society of Canada) (Health Canada, 1998).

Ten years later, Warburton et al. (2010) performed a systematic review that synthesized the relationship between physical activity and premature all-cause mortality and seven chronic diseases (i.e., cardiovascular disease, stroke, hypertension, colon and breast cancer, type 2 diabetes, and osteoporosis). The primary purpose of their review was to corroborate that the recommendations from the 1998 physical activity guidelines and determine whether dose-response relationships existed. Their findings suggested that 30 minutes of MVPA on most days of the week was sufficient in reducing the risk for all-cause mortality and the seven chronic diseases. Further, a dose-response relationship was observed between physical activity and the seven chronic diseases listed above, thus corroborating the "more is better" approach in the physical activity guidelines. The results from this systematic review informed the updated physical activity guidelines (Tremblay et al., 2011), which recommend:

1. At least 150 minutes of MVPA (aerobic) per week in bouts of at least 10 minutes

2. Muscle and bone strengthening activities for major muscle groups twice a week

In 2020 the Canadian 24-Hour Movement Guidelines for Adults were released (Ross et al., 2020). The physical activity recommendations were based on umbrella systematic reviews for resistance training (El-Kotob et al., 2020) and balance and functional training (McLaughlin et al., 2020) as well as the previously released guidelines report in the United States (2018 Physical Activity Guidelines Advisory Committee, 2018). This body of evidence informed the recommendations which saw the addition of light intensity physical activity recommendations and the removal of the recommendation that physical activity should be performed in bouts of at least 10 minutes (Ross et al., 2020). To reflect the updated research, the Canadian 24-Hour Movement Guidelines for Adults aged 18-64 years recommend:

5. 150 minutes of MVPA per week
6. Two days a week of resistance activities
7. Several hours of light physical activities and standing.

Overall, it appears that within the adult literature physical activity has favourable associations with multiple health indicators, as well as a reduction in risk for several chronic diseases and all-cause mortality. Further, it appears that even small increments of physical activity have demonstrated a favourable association with all-cause mortality (Warburton et al., 2010). More recently, the paradigm shifted toward the entire 24-hour day and compositional analysis which have provided evidence that reallocating time from other movement behaviours (LPA, sedentary time, sleep) into MVPA was favourable for health and all-cause mortality (Janssen et al., 2020). Further, reallocating time spent sedentary to LPA was also beneficial for health and all-cause mortality (Janssen et al., 2020).

Summary

The reviewed literature suggests that physical activity has favourable associations with multiple health indicators, chronic diseases, and all-cause mortality (Timmons et al., 2012; Carson et al., 2017; Janssen & LeBlanc, 2010; Poitras et al., 2016; Warburton et al., 2010(Janssen et al., 2020)). While MVPA remains the most consistent for greater health benefits, the incorporation of LPA recommendations in the early years, school-aged children and youth, and adult guidelines provides a sound justification for interventions targeting walking, steps count, or total physical activity. Taken together, it appears that any improvement in physical activity is associated with either favourable associations or has no detrimental associations with health regardless of age, with evidence from the adult literature suggesting more favourable improvements stemming from the reallocation of time spent sedentary to LPA or any behaviour to MVPA (Janssen et al., 2020). As such, investigating the correlates of physical activity is important for the development of successful physical activity interventions to increase the proportion of Canadians meeting physical activity recommendations.

Physical Activity Surveillance and Tracking

Overview

Establishing clear physical activity guidelines is important for many reasons. They provide health care professionals with evidence-based benchmarks that can be used for recommendations to clients. Further, they provide the public with targets to aim for to improve or maintain their health. Additionally, they provide researchers with benchmarks to continually update evidence, and provide population estimates on the proportions of people who meet the physical activity guidelines. This section will summarize the literature (largely drawing from nationally representative studies, such as Statistic’s Canada Canadian Health Measures survey

(CHMS) to provide current evidence of proportions meeting physical activity guidelines in each age group.

Preschoolers

Prevalence estimates from a large nationally representative sample of Canadian preschoolers (n=803) indicate 61.8% met the physical activity recommendations of achieving 180 minutes of physical activity, including at least 60 minutes of MVPA per day (Chaput et al., 2017). However, there is still a large proportion of preschoolers who do not achieve sufficient physical activity for optimal health and development. As there is evidence to support the tracking of physical activity from early childhood into late childhood (Jones et al., 2013), it is of upmost importance to try and find ways to get more preschool children achieving the recommended amounts of physical activity.

Children and adolescents

Recent data based on the 2016-17 Canadian Health Measures Survey indicated that 39% of Canadian children (47%) and adolescents (31%) met the physical activity recommendations of the Canadian 24-Hour Movement Guidelines for Children and Youth (Statistics Canada, 2019). Data from pedometers indicate 41% of 5-19-year-olds took enough steps (>12,000) to achieve recommended physical activity levels (ParticipACTION, 2020). Self-reported estimates of daily physical activity among children and youth also remain low, where 26.5%, 24%, 21%, 18%, and 16% of grade 6, 7, 8, 9, and 10 students, respectively, reported they had been active seven days over a typical week for at least 60 minutes per day (Janssen, 2016). Further, in 2014 only 20% of grade 6 to 10 students reported engaging in at least 60 minutes of MVPA per day, a proportion that has been relatively stable since 2002 (Janssen, 2016). Slightly higher estimates among adolescents were reported in the 2014 Cannabis, Obesity, Mental health, Physical activity, Alcohol use, Sedentary behaviour, and Smoking (COMPASS) survey. For instance, of the 35, 927 grade 9 to 12 students who completed the survey, just under half (49.3%) met the recommendation of 60 minutes MVPA daily (Harvey et al., 2017). Overall, it is apparent a large proportion of Canadian children and youth are not achieving enough daily physical activity. Given this evidence, it is important to identify strategies that increase physical activity during childhood and adolescence.

Adults and parents

Based on recent CHMS data (Cycle 6: 2018-2019), it was estimated that 49% of adults take at least 7500 steps per day, a threshold considered to be physically active (ParticipACTION, 2021). Slightly more than half (56%) of adults achieved greater than 3 hours per day of LPA, and slightly less than half (49%) achieved 150 minutes of MVPA per week (ParticipACTION, 2021). Together, it appears there is a large proportion of Canadian adults who do not engage in sufficient physical activity for optimal health benefits.

Even more worrisome is the physical activity levels of parents. For instance, the majority of studies in a 2008 systematic review suggested that parents had lower levels of physical activity compared to non-parents (Bellows-Riecken & Rhodes, 2008). At the time of the review, only a few studies had explored whether types of physical activity (e.g., exercise, household activities) differed between parents and non-parents. A recent review of physical activity trajectories across the life course (Irinja et al., 2019) highlighted one study that found having children during adulthood was associated with an increased likelihood of having a declining physical activity trajectory (Rovio et al., 2018). Bellows-Reicken & Rhodes (2008) suggested that household activities appear to replace leisure time physical activity among parents and is likely due to a change in roles associated with parenthood. Though it was noted that most studies in their review (24/25) measured physical activity subjectively, which presents challenges in determining an accurate estimate of the difference in duration of physical activity between parents and non-parents.

Recent Canadian studies with large nationally representative samples and accelerometer-derived physical activity have confirmed these relationships (Adamo et al., 2012; Gaston et al., 2014). For instance, in the first cycle of the CHMS (2007-09), mothers of young children (< 6 years years) had 54 minutes per week less of accelerometer derived MVPA than women without dependent children, and though not significant, fathers had 40 fewer minutes than men without dependent children. Both mothers and fathers of young children were less likely to achieve physical activity recommendations compared to adults with no dependent children (Adamo et al., 2012). In the second cycle of the CHMS (2009-11), similar associations for MVPA were found, however it appeared that participants with at least one dependent child (<16 years) engaged in significantly more minutes of LPA per day (mothers = 47 min; fathers = 40 min) compared to participants without a dependent child (Gaston et al., 2014).

Given there is more consistent evidence that health benefits for adults occur with more MVPA (Janssen et al., 2020), it is important to understand how to incorporate more MVPA into the lives of parents, particularly those of young children. Identifying settings that could promote MVPA of both parents and their children could help guide intervention efforts, while reducing some of the perceived barriers that have been previously reported by parents.

Summary

There appears to be an age-related decline in the proportion of children who meet the physical activity recommendations (preschool children: 61%; school-aged children; 47%; adolescents: 31%). Estimates suggest slightly more adults are meeting guidelines (49%) though the proportion of parents achieving recommended amounts of physical activity may be less. Regardless, it appears there are a large proportion of Canadians across all ages who are not meeting physical activity recommendations. As such, finding ways to increase the proportion of Canadians who meet physical activity recommendations is imperative.

Ecological Models for Physical Activity Research

Overview

Generally, ecological models acknowledge that multiple sources of influence are embedded within several different levels both internal and external to an individual that influence behavior. Internal sources of influence can be divided up into biological factors (e.g., sex, ethnicity) and psychological factors (e.g., self-efficacy, attitude) (Spence & Lee, 2003). While external sources are often embedded within interpersonal (e.g., parents, teachers, peers, colleagues), organizational (e.g., daycare, school, work), community (e.g., geographic region, political boundary) and policy (e.g., municipal, provincial, national) levels. One differentiating feature of ecological models from most other behavioural models and theories is they incorporate sources of influence that are outside the immediate environment and distal to the individual (e.g., community, public policy) (Bronfenbrenner, 1979; Spence & Lee, 2003; Sallis & Owen, 2015). For instance, Bronfenbrenner’s (1979) ecological theory of human development suggests that the environment can be classified into multiple interconnected layers or “systems” (i.e., micro-, meso-, exo-, and macro- systems). Although the social cognitive theory also includes sources of influence distal to the individual, specifically environmental factors that may influence behaviour (Bandura, 1986), Rhodes et al. (2019) acknowledge that the social cognitive theory along with other traditional behaviour theories may be more suitable for predicting and explaining volitional physical activity (e.g., active recreation) rather than other domains (e.g., active transport).Given the complexity of physical activity, ecological models are useful as they can be behaviour specific, encompass traditional behaviour theories, as well as an array of influences that act to shape behaviour. The main argument against most ecological models is their lack of theoretical underpinnings to explain behaviour. However, Spence and Lee (2003) articulate how these varying sources of influence interact and provide five testable hypotheses to advance research. In this dissertation, the data for studies 2 and 3 were previous collected, making it difficult to adequately assess components of social cognitive theory, the hypotheses described by Spence and Lee (2003), or components of other theories such as human activity theory (Mitra et al., 2014) and behavioural choice theory (Epstein, 1998) among others (Rhodes et al., 2019). Additionally, study 1 focused on the behaviors of preschool children who do not have the cognitive capacity to report on key social cognitive theory constructs, such as self-efficacy. As a result, this work will instead be guided by some key principles of ecological models.

Principles of Ecological Models

Regardless of the health behavior of interest, Sallis & Owen (2015) have highlighted five key principles of ecological models that can be generalized across behaviours. The first principle, though already stated in the paragraph above, is there are multiple levels of influence on health behaviours. Further, it is suggested that sociocultural factors and physical environments may apply to more than one level (e.g., organizational and community levels). In terms of physical activity there is enough evidence to support this first principle. For instance, a systematic review of reviews on the correlates and determinants of physical activity across the life course found associations to be reported at all levels of the ecological model (Bauman et al., 2012).

The second principle suggests environmental contexts are significant determinants of health behaviours. Moreover, behavioural settings (e.g., neighbourhoods, school environment, workplace environment, home environment; (Sallis et al., 2006) can serve as potential targets for interventions. A recent example to support this principle was a systematic review of the quantitative and qualitative literature related to the school environment and physical activity (Morton et al., 2016). Aspects of both the social (e.g., teacher support) and physical environment (e.g., intramurals, equipment) of schools appeared to be associated with adolescents' physical activity (Morton et al., 2016).

Principle three suggests the presence of cross-level interactions. For example, physical activity determinants, correlates, and interventions may have differential effects based on biological and psychological factors (Sallis et al., 2006; Spence & Lee, 2003). While this principle is often less studied in terms of physical activity research and remains a criticism of the literature (Bauman et al., 2012; Ding et al., 2012), Ding et al. (2012) found a significant interaction between the built environment and psychosocial status. Others have found interactive effects between availability of recreational infrastructure with enjoyment and self-efficacy for MVPA (Cerin et al., 2008). The emergence of advanced statistics such as multi-level modeling and moderation analyses can help observational researchers test whether interactions exist among multiple levels. Further, these interaction analyses can help us understand associations among sub-populations (e.g., males vs females, low vs high SES) (Bauman et al., 2002), which could help develop more appropriate interventions.

The fourth principle calls for ecological models to be behavior specific. The levels above serve as a general template that can be molded to better suit the behavior of interest. For instance, Spence and Lee (2003) created the ecological model for physical activity which is based on the template that was first developed by Wachs (1992). The ecological model for physical activity further specifies the potential role that biological and genetic factors, psychological factors, and physical ecology have in influencing physical activity. Further, while the model proposed by Wachs (1992) suggested that all environmental factors have an indirect effect on behavior, the ecological model for physical activity suggests both direct, and indirect effects on physical activity are plausible (Spence & Lee, 2003). Following this model, calls were made for specificity of ecological models and conceptual matching of correlates and behavior (Giles-Corti et al., 2005). Giles-Corti et al. (2005) presented an example distinguishing the ecological factors related to recreational walking in the neighbourhood from transport-related walking in the neighbourhood. Shortly after, Sallis et al. (2006) constructed an ecological model aligning factors within the policy environment, behavior settings, and perceived environment with four physical activity domains (household activities, active recreation, active transport, and occupational activities). This model has since been adapted for sedentary behaviour (Owen et al., 2011).

Lastly, the fifth principle is that multilevel interventions should be more effective in changing behaviours. Closely tied to the first principle – there are multiple levels of influence, the fifth principle suggests that an intervention that targets several levels will have a greater chance at behavior change than an intervention targeting just one level. For instance, a systematic review examining the effectiveness of physical activity interventions found strong support for multi-component interventions and interventions targeting the school plus family or community settings among adolescents, compared to single component and single setting interventions (van Sluijs et al., 2007).

Summary

Ecological models have become widely used in research studying the correlates and determinants of health behavior. While it is suggested that intervening on multiple levels will have the highest chance of success (principle 5), this is resource intensive and may not always be practical. Therefore, from a population health perspective, intervening at distal levels of the ecological model may be a more practical solution as it can yield benefits to a larger proportion of people (Rose, 2001). One particular setting embedded within the distal levels of the ecological model and that has received attention for promoting physical activity is the neighbourhood environment (World Health Organization, 2016). Therefore, the focus of this dissertation is on features of the neighbourhood environment that are important for promoting physical activity. As previously mentioned, though this dissertation will not test the hypotheses by Spence and Lee (2003), it addresses several general principles of ecological models. For instance, principle three is addressed through moderation analyses, which is used to test whether interactions exist (study 1 [socioeconomic status] study 2 [seasonality, socioeconomic status – neighbourhood features]; Additionally, studies one and three address principle four by examining the environmental correlates of specific modes of physical activity (study 1 [parents' active recreation, preschool children's' active play, parent-child coactivity] study 3 [adolescent MVPA and active school travel). The ecological theory of human development acknowledges that the interactions and influences between the environments (i.e., micro-, meso-, exo-, macro- systems) and the individual are dynamic, interconnected, and change over time (e.g., ecological transitions) (Bronfenbrenner, 1979). However, such an investigation would require longitudinal data from the early years into the adolescence. In the absence of such data, this dissertation examines three different age groups (preschool children, school-aged children, and adolescents). Nonetheless, the findings from this dissertation may be particularly helpful for identifying target populations or communities and guiding the development of tailored interventions and initiatives.

The Environment and Physical Activity

Overview

Modifying and creating environments to support active living has been recognized in local (The City of Edmonton, 2010), national (Public Health Agency of Canada, 2017), and international (World Health Organization, 2016) documents as one strategy to increase physical activity. However, it is first important to understand which modifiable features of the environment will have the largest impact on physical activity. Further, it is also important to consider how the environment is associated with physical activity across different age groups. For instance, some features may be beneficial for early years children, but deter physical activity in older children. The next section will summarize the associations between the environment and physical activity for each age group.

Early years

The early years represents children’s first exposure to settings outside of the home setting. However, the evidence regarding the relationship between aspects of the environment is limited in comparison to older age groups (Carlin et al., 2017; Davison & Lawson, 2006; Ding et al., 2011). In one of the earlier, more comprehensive systematic reviews in children aged 3 to 18 years, only 3/33 studies included samples with children under 5 years old (Davison & Lawson, 2006). Among these studies, maternal perceptions of neighbourhood crime was unrelated to parent reported outdoor play (Burdette & Whitaker, 2005); the number of play spaces within walking distance was positively associated with directly observed physical activity (Sallis et al., 1993); and children were observed to be least active outside during the hotter months (Baranowski et al., 1993).

An updated review of the neighbourhood correlates of children aged 3 to 18 years was performed by Ding et al. (2011) and included 103 studies. Only one study was found that wasn't captured in the Davison 2006 review. Pfeiffer et al. (2009), found that increased distance to a park was negatively associated with preschoolers MVPA, while park safety appeared to be unrelated.

One of the largest systematic reviews examining the correlates and determinants of physical activity in children aged 0-6 years was published in 2016 and included 130 studies published between 1900 and 2015 (Bingham et al., 2016). Several significant associations between aspects of the physical environment and physical activity were reported - many of which were with TPA (Bingham et al., 2016). For instance, positive associations were reported for having a yard to play in near their home (Marino et al., 2012), neighbourhood vegetation (Grigsby-Toussaint et al., 2011), more visits to active play spaces (Hinkley et al., 2012), higher neighbourhood disorder (Kimbro et al., 2011), and living in public housing (Kimbro et al., 2011). Negative associations were reported for living in an apartment with weekend hours of outdoor play (Kimbro et al., 2011). Additionally, having no footpaths in the neighbourhood and more visits to active play spaces were associated with lower weekday and weekend physical activity among girls, respectively (Hinkley et al., 2012). Several studies also reported null associations. For instance, having a safe place to play (McKee et al., 2012), access to convenient play spaces (Marino et al., 2012), visits to shopping centers (Hinkley et al., 2012), frequency of visits to active play spaces (Hinkley et al., 2012), environmental barriers, concerns about safety, and park availability (van Sluijs et al., 2013) were all unrelated to TPA. Only one study reported a statistically significant association for MVPA in which having other neighborhood children to play with was negatively associated with MVPA (van Sluijs et al., 2013).

One article that was missed in this systematic review, but is important to this dissertation is by Carson et al. (2014). Carson et al. (2014) used a theoretical framework developed by Pikora et al. (2003) to guide their analysis and is one of only a few Canadian studies that have examined environmental correlates of physical activity in early years children. Though no associations were found to be significant, the authors point out that this could be a result of using parental reports versus objective measures such as accelerometry (Carson et al., 2014).

An umbrella systematic review was recently published and focused on the environmental correlates of physical activity throughout the life course (Carlin et al., 2017). Within this review, they summarized the findings from two systematic reviews that focused solely on early years children (De Craemer et al., 2012; Hinkley et al., 2008). Positive associations were reported between access/presence of parks/playgrounds/open space with both overall physical activity (limited evidence) and MVPA (probable evidence). In contrast, the presence of streetlights was reported to have a negative association with MVPA (probable evidence). While several other aspects such as neighbourhood safety and aesthetics were reported to have null associations.

Finally, a recent systematic review by Terron-Perez et al. (2021) summarizing much of the literature pertaining to the physical environment – physical activity associations found several neighbourhood variables were researched, with presence of greenery (mixed +/null), traffic safety (+), and recreational facilities (mixed +/null) being studied the most (> 5 studies). Among some of the more recent studies, the results were contradictory (Eichinger et al., 2017; Benjamin-Nelson et al., 2019; Lu et al., 2019). For instance, Eichinger et al. (2017) found (perceived) traffic safety to be positively associated with accelerometer derived physical activity, whereas Lu et al. (2019) and Terron- Perez et al. (2018) found no association with accelerometer derived physical activity and active travel, respectively. Lu et al. (2019) found recreational physical activity facilities to be positively associated with physical activity, whereas Eichinger et al. (2017) did not. Similarly, Benjamin-Nelson et al. (2019) found a positive association with greenery (objective) and physical activity, whereas Eichinger et al. (2017) did not.

One study that was not included in any of the systematic reviews to date examined the relationship between the objectively measured built environment and preschoolers' accelerometer derived physical activity in Edmonton (Ezeugwu et al., 2020). This study included neighbourhood size, commercial land use, street connectivity, road measures, trails, sidewalks, destinations, crime, and recreational spaces. Of these, road percentage, greenspace percentage, neighborhood area, expressway percentage, park percentage, and neighbourhood crime were considered important for physical activity (nonwinter LPA). However, only expressway percentage was significantly associated with physical activity (nonwinter MVPA).

Combined it appears that there is evidence to support a positive association exists between having play spaces (e.g., park, playground) and traffic safety with physical activity in preschool children. However, there is very little consistency in the research regarding the environmental correlates of physical activity in this age group. Therefore, the associations that are presented here should be interpreted with caution, as more research is needed to confirm and build on these findings.

School-aged children

In the review led by Sallis et al. (2000) which examined the correlates of children and adolescent physical activity, it appeared that correlates of what they deemed the physical environment were understudied in comparison to correlates embedded within intrapersonal and interpersonal levels of the ecological model. Only 4/54 studies on correlates of children's physical activity included aspects of the built environment. Access to facilities/programs showed a positive relationship with physical activity in 3/4 of the observed associations. Neighbourhood safety was unrelated to children's physical activity in 1/1 study. Other variables within the physical environment such as rural residence and season were also included in this review, however their association were deemed inconclusive (Sallis et al., 2000).

The systematic review led by Davison and Lawson (2006) summarized the literature between 1990 and 2006 regarding aspects of the objective and perceived environment with children's physical activity. Like the review by Sallis et al. (2000), most studies focused on availability and proximity to recreational infrastructure and perceived neighbourhood safety. Positive associations were observed between the availability of recreational facilities and physical activity in 3/3 studies. While null associations were observed between the proximity to parks and playgrounds in 2/3 studies. Null associations were also observed between perceived safety and physical activity 3/3 studies. Other features that were examined more than once included presence of controlled crossings, street connectivity, and traffic density. Of these, the presence of controlled crossings had a positive association with physical activity in 2/2 studies, while traffic density had a negative association with physical activity in 2/2 studies. All other environmental attributes were either mixed or examined in only one study.

Five years later Ding et al. (2011) performed a systematic review as an update to Davison & Lawson (2006). In their review, Ding et al. (2011) stratified associations between objective- and subjectively- measured environmental attributes with both objectively- and subjectively-measured physical activity outcomes. As such, it was evident that the associations varied by the type of measure that was used. For instance, the majority (8/9) of objectively measured environmental variables included in this review showed null associations with objectively measured physical activity. In contrast, positive associations were primarily observed (9/11) between objectively measured environmental variables and subjectively reported physical activity. The overall summary scores (percent of positive associations/total associations) revealed that recreational facilities, destinations, residential density, walkability, traffic density, pedestrian safety structures, and vegetation all had consistent (> 50% of associations), positive associations with physical activity (combined objectively measured and subjective reports).

In terms of the perceived environment, all environmental variables (7/7) had primarily null associations with objectively measured physical activity. However, perceived recreational facilities, land-use, residential density, street connectivity, walking/biking facilities, traffic speed/volume, traffic safety, crime safety, general safety and general safety all had consistent positive associations with subjective physical activity (Ding et al., 2011). However, there were also several instances where null associations were also reported between the perceived environment and subjective physical activity (11/13) (Ding et al., 2011). Together, it appears that most reviewed associations between the perceived environment and subjective physical activity are mixed as null/positive. Only pedestrian safety structures and street connectivity had more positive associations than null associations (Ding et al., 2011).

Building on the review by Ding et al. (2011), Timperio et al. (2015) performed an update of the literature between 2011 and 2014. In this review, associations were stratified by measurement type (objective vs subjective), as well as by physical activity mode (overall/leisure physical activity vs transport related physical activity). Aspects of the neighbourhood environment appeared to be associated more often with transport related physical activity than overall or leisure based physical activity. The strongest evidence was for a positive association between objectively measured distance to school and subjective reports of transport related physical activity, this was observed in 10/11 associations. There was also some additional evidence suggesting a positive relationship between perceived walking/cycling infrastructure (5/14 associations) and pedestrian safety infrastructure (2/6 associations) with self-reports of transport physical activity, however this was less consistent. Most associations with overall/leisure physical activity appeared to be null (Timperio et al., 2015). The authors suggested that future research continue to match environmental correlates with appropriate behaviours, as well as examine interactions among various levels of the ecological model (e.g., socioeconomic status, parental physical activity)(Timperio et al., 2015).

In 2015, McGrath et al. (2015) performed a meta-analysis of studies that used objective measures of the built environment and MVPA. Age was found to be a moderator of these associations, in which negative associations between features that supported walking only (e.g., intersection density, road density, street width, traffic lights, walkability), as well as walking and playing (e.g., park percentage/area, parks and playgrounds within 400 m) with MVPA were observed among 9-year-olds. The effect sizes were larger than those observed for features that promoted playing only (e.g., parks, playgrounds, and recreational facilities within 800 m, 1.6 km, and 2 km), which was negative for girls and unclear for boys. The authors theorized that children of this age group may not be granted the independent mobility to travel to destinations that are nearby and therefore are unable to utilize walkable environments and recreational spaces in their local neighbourhood.

An umbrella systematic review by Carlin et al. (2017), summarized the findings from seven systematic reviews published between 2004 and 2016. Out of the 67 environmental variables, only three were reported as having an association with overall physical activity. For instance, based on the findings from the Ferreira et al. (2007) review, access/distance/proximity to destinations was assigned a negative association, while living in a coastal location was assigned a positive association. The other environmental variable deemed to have a positive association with overall physical activity was walkability, based on the review by Ding et al. (2011). Three other environmental variables (footpath conditions/available shelters, neighbourhood safety, neighbourhood disorder) were reported as having null associations among all reviews. All other environmental variables were said to have mixed associations with children's physical activity. Despite the associations that were reported it is important to note that the strength of evidence was deemed limited (i.e., based mainly on cross-sectional studies, insufficient evidence to determine direction of association).

Recent systematic reviews have summarized the trends in associations between the neighbourhood environment and outdoor play and time (Lambert et al., 2019; Lee et al., 2021), and active school travel (Ikeda et al., 2018). Although outdoor play may be more specific and conceptually matched with the neighbourhood environment, the findings from these reviews are similar to those of general physical activity. For instance, evidence has suggested neighbourhood recreational spaces (e.g., parks and playgrounds) are either positively or not associated with time spent in outdoor play (Lambert et al., 2019; Lee et al., 2021). Nonetheless, neighbourhood greenness and lower traffic volumes appeared to be consistently favourable for outdoor play (Lambert et al., 2019). Others have found parental perceptions of the social environment (e.g., neighbourhood cohesion) to be consistently associated with outdoor play, whereas perceptions of the physical environment are not (Boxberger & Reimers, 2019). Further, limited evidence around other neighbourhood features such as intersection density, residential density, sidewalks, traffic speeds, traffic lights, and traffic calming measures were reported (Lambert et al., 2019; Lee et al., 2021), but have shown to be important for active transport (Ikeda et al., 2018).Overall, there appears to be few studies that have focused on similar aspects of the neighbourhood environment and outdoor play (Boxberger & Reimers, 2019; Lambert et al., 2019; Lee et al., 2021) which makes it challenging to draw firm conclusions regarding their impact on children's outdoor play. The literature pertaining to neighbourhood environment and children's active school travel appears more consistent (Ikeda et al., 2018).

Based on the reviewed literature, it appears that recreational infrastructure (access/proximity/availability) had shown the most consistent associations with children's physical activity. However, as objective measures of both the environment and physical activity become more common, these associations seemed to become less consistent as most of the newer research has reported null associations. One potential reason for the lack of associations could be due to the inability of objective measures to capture the environment context and type of physical activity (e.g., active play in the neighbourhood), though the trends are generally similar for the outdoor play literature. Other areas that appear to be related to certain modes of physical activity include transport infrastructure such as walkability, walking/biking facilities, and traffic. While features related to neighbourhood safety appear to be consistently unrelated to children's general physical activity, they could impact physical activity indirectly through outdoor play (Boxberger & Reimers, 2019), active transport (Ikeda et al., 2018), or independent mobility (Marzi et al., 2018). More research accounting for these different domains of physical activity is needed to get a better understanding of the impact of the neighbourhood environment.

Adolescents

As with school-aged children, environmental correlates were relatively understudied among adolescents compared to factors embedded in intra- and inter- personal levels of the ecological model within the systematic review by Sallis et al. (2000). Only 7/54 studies included in their review examined correlates within the physical environment. Of these, only opportunities to exercise had a positive association with adolescent's physical activity, though this finding was based on the results of only one study. While having equipment/supplies available appeared to be unrelated in 4/5 studies.

The review by Davison and Lawson (2006) expanded on the review by Sallis et al. (2000) and provided an update to the work in the field. Within their review, Davison and Lawson (2006) found the availability of recreational facilities and having equipment/and play structures at school were positively associated with physical activity in 5/6, and 2/2 studies respectively. Further, having access to destinations was positively associated with physical activity in 2/3 studies. Thus, these findings supported those that were reported previously by Sallis et al. (2000). In addition, aspects of safety and neighbourhood disorder were commonly explored in adolescents. Though most of these aspects were supported by only one study, significant associations were observed among roaming dogs, social disorder/stranger danger, physical disorder/tidiness, and neighbourhood aesthetics with physical activity. The most consistent association was reported between area deprivation and crime and physical activity, in which higher area deprivation and crime was negatively associated with physical activity in 2/2 studies. Associations between perceived safety and physical activity was mixed as two studies reported null associations, while two others reported negative associations.

As with children, the systematic review performed by Ding et al. (2011) summarized the associations between objective and perceived environmental variables with objective and subjective measures of physical activity. Within this review it was observed that when measured objectively, most (9/10) environmental variables had null associations with objectively measured physical activity. Proximity/access/density of parks, proximity/access/density of recreational facilities, residential density, and street connectivity all had consistent positive associations with subjective physical activity. However, most (7/9) environmental variables had more null associations with subjective reports of physical activity. When objective and subjective measures of physical activity were combined, only land-use mix had a consistent positive association (> 50% of associations)(Ding et al., 2011).

In terms of the perceived environment, Ding et al. (2011) reported that all perceived environmental variables (5/5) primarily had null associations with objectively measured physical activity. Though several perceived environmental variables (e.g., proximity/access/density of parks, proximity/access/density of recreational facilities, land-use mix/destinations, street connectivity, walking/biking trails, traffic safety, crime-related safety, and general safety) had consistent positive associations with subjectively reported physical activity, there were more null associations observed.

In the McGrath et al. (2015) meta-analysis where age was included as a moderator, positive associations between features that supported walking only (e.g., intersection density, road density, street width, traffic lights, walkability), as well as walking and playing (e.g., park percentage/area, parks and playgrounds within 400m) with physical activity among 15-year old's. The effect sizes were larger than those observed for features that either promoted walking only or playing only (e.g., parks, playgrounds, and recreational facilities within 800m, 1.6km and 2 km). Further, it appeared that these features demonstrated a larger positive effect among adolescents (e.g., 15-year-olds) compared to children (i.e., 9-year-olds). The authors suggest that the larger effect sizes observed among adolescents could be due to greater independent mobility.

Therefore, they can utilize the walkable features of their environment to travel to recreational spaces that are present within their local neighbourhood.

In the umbrella review performed by (Carlin et al., 2017) it appeared that among the five systematic reviews that focused on adolescents, most of the findings pertaining to the association between environmental variables and overall physical activity were mixed. Only access/availability of PA infrastructure/equipment was reported as having a positive association with overall physical activity. Two other variables (aesthetics, level of urbanization) were reported as having null associations. Overall, the strength of evidence supporting these associations was deemed limited (Carlin et al., 2017).

A recent review among studies performed in China, found features that supported walking (e.g., time and distance to park, sidewalks, roads and aesthetics) had favourable associations with adolescent physical activity whereas findings regarding recreational facilities had both positive and negative associations (An et al., 2019). Inconsistencies regarding recreational facilities were also reported in another recent review with no geographic boundaries (Hu et al., 2021), though there were only three studies that measured this association. The mixed associations between availability of recreational facilities and adolescent physical activity could be due to their attractiveness, the type and condition of features they possess, or perceptions of safety (Van Hecke et al., 2018). Such features may not be appropriately assessed with objective measures (e.g., geographic information systems, accelerometers, global positioning systems) therefore, direct observations and subjective (e.g., interviews, questionnaires) measures should be included (Van Hecke et al., 2018).

Based on the review of literature performed for this dissertation, it appears that few environmental variables outside of recreational infrastructure and to a lesser extent neighbourhood safety, have been consistently associated with adolescent physical activity. Associations also tend to differ depending on whether objective or subjective measures were used. Given that most of the research examining these associations have been cross-sectional, more longitudinal study designs are needed.

Adults

Trost et al. (2002) performed a systematic review summarizing the correlates of physical activity among adults. Factors pertaining to the built environment included actual and perceived access to facilities, adequate lighting, cost of programs, enjoyable scenery, frequently observed others exercising, heavy traffic, high crime rates in the region, hilly terrain, neighbourhood safety, presence of sidewalks, satisfaction with facilities, unattended dogs, and urban location. However, other than urban location no other variables were studied five or more times. Though the evidence was considered weak, Trost et al. (2002) reported actual and perceived access to facilities, enjoyable scenery, observing others exercise, hilly terrain, neighbourhood safety, and satisfaction with facilities to be positively associated with physical activity. These associations were also supported in the review by Humpel et al. (2002), which focussed exclusively on environmental factors with adults' physical activity participation.

McCormack et al. (2004) performed a systematic review guided by the framework developed by Pikora et al. (2003) that groups associations based on four environmental domains (function, aesthetic, safety, destination). Evidence for the importance of behavioural specificity, as well as the need to measure both real and perceived environment was highlighted in this review (McCormack et al., 2004). For instance, aspects of objectively measured safety and aesthetic domains were associated with walking, but not TPA/MVPA. While aspects of perceived safety were associated with TPA/MVPA, but not walking (McCormack et al., 2004).

Generally, the four domains of the perceived environment were associated with TPA/MVPA, whereas only aspects of functionality and destination were association with TPA/MVPA when measured objectively.

A few years later Wendel-Vos et al. (2007) performed a systematic review that included 47 publications between 1989 and 2004. Within this review, a further breakdown of associations between characteristics of the environment with different modes of physical activity (general physical activity, MPA, VPA/Sports, MVPA, commuting, bicycling, walking, neighbourhood walking) among both men and women was provided. Though most associations were considered null, there was some features of the environment found to be associated with physical activity. For instance, positive associations between the availability of physical activity equipment with VPA/Sports, and connectivity of trails with commuting activities were observed. Further, positive associations were reported between convenience of recreational facilities with both VPA/Sports and MVPA; accessibility of recreational facilities, and availability of trails with MVPA; as well as the availability of sidewalks with walking. Lastly, aesthetics was reported to have a possible positive association with both walking and neighbourhood walking for men.

One issue with examining cross-sectional associations between the built environment and physical activity is that temporality cannot be determined. Therefore, it is possible that active individuals choose to live in neighbourhoods that possess specific features conducive to their physical activity, and vice versa for inactive individuals. This is known as residential self-selection. To better understand the causal associations between the built environment and physical activity, McCormack and Shiell (2011) performed a systematic review of only cross-sectional studies that accounted for residential self-selection (n=20) and quasi-experimental studies (n=13). Proximity to recreational and non-recreational land use was most frequently examined, however like most other features in the review, the associations were mixed. Though the evidence was limited, there was some support for positive associations between mixed land use, walkability, neighbourhood type, and population density with different modes of physical activity (e.g., transportation walking, combined walking/cycling). However, no consistent associations were observed for MVPA (McCormack & Shiell, 2011).

Contrary to much of the cross-sectional evidence, a review of longitudinal studies by Rhodes and Quinlan (2015) found accessible recreation, perceived safety (e.g., crime-related, lighting, loose dogs, traffic-related), or aesthetics (e.g., scenery, exhaust fumes) were not consistent predictors of physical activity change. Rather, motherhood and intention were the only reliable predictors of physical activity change. The authors suggested that a change-change scenario where a change in an environmental predictor is succeeded by a change in physical activity is needed to add a level of robustness to the evidence (Rhodes & Quinlan, 2015). Given most environments are relatively stable over time, drawing inferences from natural experiments where an actual change to the environment occurs is needed.

Reviews have also focussed on specific aspects of the neighborhood environment such as safety from crime (da Silva et al., 2016) and found largely null associations. In one review, most studies and statistical tests found null associations between safety from crime and physical activity. Similar proportions of null associations were found regardless of whether safety from crime was paired with leisure time physical activity or transportation physical activity. The authors suggest that these null associations may not implicate no relationship between safety from crime and physical activity, rather other ecological factors may exist and could function as moderators or mediators to these associations. However, 84 out of 87 studies were cross-sectional, therefore more longitudinal research and natural experiments were called for.

In the umbrella systematic review led by Carlin et al. (2017), most associations between the environmental variables under review had mixed associations with overall physical activity, as well as with other modes such as general walking and cycling, leisure/recreational physical activity, and active transport. Most associations with MVPA were reported as null. However, there were some associations that appeared to be positive (Carlin et al., 2017). For instance, walkability, quality of the environment (e.g., good neighbourhood perception; infrastructures, access to destinations, social environment, aesthetics), environmental barriers (e.g., light traffic, unattended dogs), and urban residency were all positively associated with overall physical activity. Street connectivity, availability/access/proximity of public transportation system, and diverse land use mix were positively associated with general walking and cycling. Finally, street connectivity and diverse land use mix was associated with active transport. These were similar to reports by a separate umbrella review, where Choi et al. (2017) found mostly inconclusive findings regarding facilities (e.g., access, convenience, satisfaction, cost), sidewalks and aesthetics, transportation (e.g., sprawl, population density, network connectivity, land-use mix, quality of the environment), safety (e.g., traffic, crime, unattended dogs, lighting) and the social environment (e.g., seeing others exercising). More recently, another systematic review found null trends between various aspects of the neighbourhood environment (e.g., cohesion, recreational facilities, parks, open space, and green space, most walkability and pedestrian friendly aspects, most crime and safety aspects) and physical activity. Inconclusive evidence for perceived personal safety and perceived walkability, number of physical activity resources, and a positive association for aesthetics among ‘disadvantaged’ adults were also reported (Craike et al., 2019).

In contrast to some of the inconsistencies reported by quantitative studies regarding destinations, access, and safety, a systematic review of qualitative studies found convincing evidence that these aspects of the neighbourhood environment are indeed important for adult physical activity (Grazia et al., 2018), lending partial support to framework developed by Pikora et al. (2003). For instance, safety from crime and traffic was consistently observed as being important aspects for physical activity for transportation and recreation (Grazia et al., 2018) which contrasts the quantitative evidence included in the review by da Silva et al. (2016). Further, having recreational facilities nearby and other amenities such as grocery stores and post offices were documented as being important for physical activity (Grazia et al., 2018). Just as there may be differences in observations by objective and subjective measures (Ding et al., 2011; Orstad et al., 2017), it appears there may also be differences between quantitative and qualitative methods.

As much of the literature has explored direct associations between environmental features and physical activity, Rhodes et al., (2018; 2020) looked at interactive (Rhodes et al., 2018) and mediated (Rhodes et al., 2020) associations between the built environment, intrapersonal processes, and physical activity to address the third principle of ecological models: cross-level interactions. However, Rhodes et al. (2018) found no evidence to support interactive effects between the built environment and social cognition with total physical activity or MVPA, and limited evidence for transport-related physical activity. Though some support was found for an interactive effect between accessibility/convenience and aesthetics with intentions and affective judgement, respectively, for leisure time physical activity (Rhodes et al., 2018). In a separate review, Rhodes et al. (2020) examined whether the built environment had a direct association with the physical activity or if its influence was mediated by intrapersonal processes. Their results indicated that once intrapersonal processes (e.g., self-efficacy, intention, behavioural control) were accounted for, there were no direct associations between built environment characteristics and total physical activity, MVPA, or transport-related physical activity. Direct associations were only observed for leisure-time physical activity, though the evidence was limited (Rhodes et al., 2020). These reviews highlight the importance of considering intrapersonal processes as moderators and mediators to better understand associations between the built environment and physical activity.

Together it appears that the earlier research found consistent associations between availability/proximity/access of recreational infrastructure and physical activity among adults. However, it appears the type of measurement used may attenuate these associations (McCormack et al., 2004). As the field progressed to incorporate more objective measures of both the environment and physical activity, these associations appeared to become less consistent (Carlin et al., 2017; McCormack & Shiell, 2011; Wendel-Vos et al., 2007). One reason for this could have been due to objective measures such as pedometers and accelerometers not having the capability to distinguish the type of physical activity being performed. As such, the concept of behavioural specificity (Giles-Corti et al., 2005) saw the field progress towards measuring more specific modes of physical activity such as walking for active transport, and recreational walking and cycling (Carlin et al., 2017; McCormack et al., 2004; McCormack & Shiell, 2011; Wendel-Vos et al., 2007). Regardless of attempts at matching environmental correlates with specific modes of behaviour, when broader systematic reviews were performed the evidence from the quantitative is still limited and mostly inconclusive (Carlin et al., 2017). Reviews of qualitative studies appear to report the importance of the neighbourhood environment for supporting physical activity (Grazia et al., 2018), though when measuring these associations objectively, it appears intrapersonal processes need to be considered (Rhodes et al., 2018; Rhodes et al., 2020).

Associations between the built environment and physical activity among adults have been examined extensively. However, no systematic review has focused exclusively on parents. Given that adults with children have been shown to engage in less physical activity than non-parents and possess the additional responsibility of caring for a child, it is reasonable to assume that the correlates of parents' physical activity may be different. One study by Carson et al. (2014) examined the associations between the objectively measured built environment with parents' report of physical activity, however, no statistically significant associations were observed. Others have found weak to moderate positive correlations between perceived safety and physical activity of parents of young children (Webber-Ritchey et al., 2018). While potentially distinct from parental physical activity, there has also been some research on the correlates of co-participation in physical activity, where both the parent and child are active together (Hnatiuk et al., 2020; Zhang et al., 2020). For instance, a quantitative study found no support for perceived physical activity facilities, overall-neighbourhood safety, or safety from crime with mother-child co-participation (Zhang et al., 2020). However, qualitative findings by Hnatiuk et al. (2020) suggest access to amenities, along with characteristics of amenities and the travel route, and walkability are important for co-participation in physical activity. The authors also reported about how certain aspects of the social environment (e.g., social network and sense of community) were mentioned by parents as being important for co-participation. Together, there appears to be more research needed in understanding neighbourhood correlates of both parents independent physical activity and co-participation in physical activity with their children, and perhaps intrapersonal processes should also be considered (Rhodes et al., 2020)

Summary

Across age groups it appears that there is some evidence to support associations between the built environment and physical activity. A common component of the built environment that has shown significant associations among children is access/proximity/availability of recreational infrastructure. Though limited in preschool children, there is evidence to suggest that having accessible play spaces may be an important feature for physical activity. In school-aged children, access to recreational facilities has shown positive associations with physical activity previously, though more recent research has shown null relationships. Similarly, for adolescents, access to recreational facilities have shown a positive relationship, however just as many null associations have been reported in recent years. In adults, the earlier research appeared to show consistent associations between recreational facilities and physical activity, however as measures of both the environment and physical activity have become more objective, these associations were less consistent. Although technological advancements have lead to increased availability of objective measures such as accelerometry, global positioning systems, and geographic information systems (McCrorie et al., 2014), it is still important to obtain information about the perceived environment and subjective measures of physical activity. Simply the presence of environmental features in a neighbourhood setting does not always imply its use. Therefore, the perceived environment may be a more accurate portrayal of the features that matter most to the individual. Similarly, most previous research using objective measures of physical activity have not had the capacity to capture the context of the behaviour. For instance, we may know that someone is achieving a certain intensity, at a specific location, however we may not be able to determine what it is about that location, or the type of behaviour that is being carried out (e.g., running vs playing basketball).

There have been multiple calls for behavioral specificity in the matching of conceptually appropriate environmental exposure with specific domains of physical activity (Atkin et al., 2016; Giles-Corti et al., 2005). This area has been more commonly explored in the adult literature, though calls have been made for this approach to be taken to the children and youth literature (Atkin et al., 2016). For early years children, a behaviour specific approach could be to examine the correlates of active play, compared to an overall measure of physical activity (e.g., TPA) or different intensities of physical activity (e.g., LPA, MVPA). For school-aged children and adolescents, an example of a behaviour specific approach could be to examine the correlates of active transportation both to and from school. Part of this problem has been somewhat alleviated though novel techniques using accelerometery, global positioning systems, geographic information systems, and self-reports though it may not be feasible with large sample sizes (Borghese & Janssen, 2018). Understanding the motivation behind choosing certain destinations, or the reason why characteristics of the neighbourhood environment influence physical activity may be best addressed through subjective-quantitative measures (e.g., questionnaires) and qualitative methodology (e.g., interviews).

Various limitations of the field have been identified over the years. For instance, the most cited limitation is most of the research has stemmed from cross-sectional studies. Though some longitudinal studies exist, they are relatively sparse in the literature pertaining to those under 18 years old (Smith et al., 2017). Further, despite the widespread use of ecological models, few studies have explored interactions within and across levels (Ding et al., 2012; Rhodes et al., 2018; Rhodes et al., 2020). Lastly, based on the reviewed literature there appears to be a paucity of literature focussing on the environmental correlates of parents' physical activity.

Summary of Literature Review

A large proportion of Canadians across all ages do not engage in enough physical activity for optimal health (Chaput et al., 2017; ParticipACTION, 2021; Statistics Canada, 2019) and could be at a higher risk for chronic diseases (I. M. Lee et al., 2012). Though there are several factors that determine whether someone will engage in physical activity (Sallis et al., 2006; Spence & Lee, 2003), findings strategies that has the potential to reach large proportions of people may yield the most benefit from a population health standpoint (Rose, 2001). Neighbourhoods have been identified as one setting where physical activity of all ages may take place (Sallis et al., 2006). However, based on the reviewed literature, evidence of favourable neighbourhood attributes in preschool-children is limited (Carlin et al., 2017). There is some evidence that the neighbourhood recreational infrastructure appears important for physical activity of school-aged children and adolescents though this evidence is somewhat inconsistent (Davison & Lawson, 2006; Ding et al., 2011; Hu et al., 2021). Among adults, there has been evidence for recreational infrastructure and walkability (Carlin et al., 2017), however, there is dearth of literature that has examined neighbourhood features that support parents' physical activity. There are some overall limitations in the current evidence base including, heterogeneity of methods (Ding et al., 2011; Orstad et al., 2017), lack of behavioural specificity (Atkin et al., 2016; Giles-Corti et al., 2005), and lack of longitudinal evidence (Bingham et al., 2016; Ding et al., 2011; Terrón-Pérez et al., 2021; Timperio et al., 2015; Van Hecke et al., 2018). This dissertation addresses these limitations over three studies in pursuit of identifying neighbourhood features that support physical activity for preschool children and their parents, school-aged children, and adolescents.

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Chapter 3: Perceived Relevance of Neighborhood Features for Encouraging Preschoolers' Active Play, Parents' Active Recreation, and Parent-Child Coactivity

Abstract

Purpose: To identify features parents perceived as being relevant for their child's active play, their own active recreation, and their coactivity.

Methods: Parents (n =145, M age =36.2 years) with preschoolers (M age =3.9 years) living in Edmonton, Canada were recruited from each of Edmonton's council wards. Parents reported demographic information and the importance of several neighbourhood features (destinations, design, social, safety, aesthetics) for their child's active play, their own active recreation, and their coactivity via 6-item Likert scales. After dichotomising response options, a series of proportional tests accounting for the clustered data (council ward) were performed to identify features considered relevant (important/most important) or not relevant (not at all important/unimportant/neutral/not applicable) by the majority of parents (>50%).

Results: The majority of parents reported that 23 of the 32 neighbourhood features were perceived as being relevant for all activity domains. These included destinations (parks, playgrounds, arenas, schools, sport fields, arenas/ice rinks, river valley/ravine), design features (quiet streets, trails, sidewalks), social features (friends/family, child's friends, other children playing outside, knowing neighbours, trusting neighbours), safety features (street lighting, crime, traffic, daylight, sidewalk maintenance, crosswalks), and aesthetic features (cleanliness, natural features).

Conclusion: Parents reported several neighbourhood features as being relevant for promoting their child's active play, their own active recreation, and co-activity. These findings may be helpful in guiding future research examining neighbourhood correlates of physical activity among preschoolers and their parents. Further, relevant government officials may find this information useful for creating neighbourhoods for active living in young families.

Keywords: Correlates, Early Years, Physical Activity, Environment

Public Significance Statements:

Several neighbourhood features were identified by parents as being relevant for their child's active play, their own active recreation, and coactivity. Nearly all social and safety aspects appeared to be particularly relevant for all three domains. These findings should be considered by relevant government officials who are trying to create active communities.

Introduction

Physical activity is important for optimal health, growth, and development during early childhood and throughout life (Piercy et al., 2018). However, creating strategies to promote healthy physical activity patterns can be difficult because it is a complex behaviour consisting of multiple domains (Sallis et al., 2006). For instance, adults' physical activity may include household activities, active recreation, active transportation, or occupational activities (Sallis et al., 2006), whereas children's physical activity may include organized sport, active play, and active transportation (Tremblay et al., 2016).

In children, active play typically involves longer and higher durations of physical activity compared to organized sport, especially when performed outside (Herrington & Brussoni, 2015). In adults, leisure time physical activity (active recreation) has shown the strongest associations with health (Li et al., 2013). Some parent-child dyads may have another domain reflecting the physical activities they perform together (coactivity), which may be beneficial for their relationships, along with enhanced mental and physical health (Thompson et al., 2010). As such, finding ways to promote preschoolers' active play, parent's active recreation, and parent-child coactivity is imperative.

Physical activity can also take place in multiple settings (Sallis et al., 2006). Among them, the neighbourhood is unique because it contains features that may support physical activity for multiple age groups. To date, the relationship between neighbourhood features with preschoolers' and parents' physical activity, especially coactivity, remains understudied and inconclusive (Bingham et al., 2016; Carlin et al., 2017). As such, the primary objective of this study was to identify neighbourhood features perceived as relevant for encouraging preschoolers' active play, parent's active recreation, and their coactivity. Given correlates are thought to be behaviour specific (Giles-Corti, Timperio, Bull & Pikora, 2005), a secondary objective was to determine whether features considered relevant differed between activity domains. Finally, previous research has indicated household income may be an important demographic characteristic to consider when examining neighbourhood correlates of children's physical activity (Westley et al., 2013). Therefore, the tertiary objective was to determine whether relevant features differed by household income.

Methods

Participants and procedures

Eligible participants were parent(s) or guardian(s) with a child aged 3-4 years that resided in Edmonton, Canada. During late spring and summer (May to September) of 2019, a convenience sample was recruited online, in person, and through an existing participant pool. Online recruitment consisted of uploading electronic posters with a link to the survey on social media and though online newsletters of relevant local organizations. In person recruitment took place at various locations throughout the city (e.g., parks, playgrounds, public open space, libraries). Participants who were approached in person were given the option to complete a paper version of the survey or have the electronic link sent to them via email. Participants who completed the paper version had their data entered manually into the electronic database. Finally, participants who previously participated in other research projects and indicated they would like to be contacted for future research were also contacted via email with a link to the survey. Quota sampling was used to recruit at least 10-12 parents from each of Edmonton's 12 council wards. This was confirmed by linking participant postal codes reported in the survey to their respective council ward. In total, 250 participants were recruited (online: n=129; face-to-face: n=120; existing database =1) to participate in this study. Ethics approval was obtained from the Human Research Ethics Board at the X. All participants provided written informed consent. Participants were asked to complete a neighbourhood survey online (n=185) or via paper copy (n = 65) that included several items regarding features of the neighbourhood environment (destinations, design, social, safety, aesthetics) as well as child and parent demographic information.

Measures

Neighbourhood Features. Parents completed a survey about various attributes in their neighbourhood. The neighbourhood was defined for participants as "the local area around your home, within a 10-15-minute walk in any direction" and participants were instructed to consider all seasons when answering the questions. There were 9 destination items, 6 design items, 6 social environment items, 6 safety items, and 5 aesthetic items (Table 2). Response options were on a 6-pt Likert scale where 1 = not at all important, 2 = unimportant, 3 = neutral, 4 = important, 5 = most important, and 6 = not applicable. Most neighbourhood features included in the survey were based on existing environmental questionnaires, audits, or items with previously established psychometric properties (Supplementary Table 1).

Physical Activity Domains. Participants were asked whether each feature was important for three physical activity domains: 1) parent's active recreation, 2) their child's active play, and 3) coactivity. Parent's active recreation was defined as "all the physical activities you do solely for recreation, sport, exercise or leisure." This definition has been used in the International Physical Activity Questionnaire (IPAQ) assessing recreation, sport, and leisure-time physical activity in adults (Craig et al., 2003). Children's active play was based on the characteristics described by Brockman et al. (2011) and was defined as "physical activities that are unstructured, self-directed, and enjoyable". It was also explained these activities could be performed both indoors and outdoors (Veitch et al., 2008). Coactivity was defined for participants as "physical activities performed together, including activities where you are both moving and being active." Participants were also provided with the following examples of coactivity: walking outside together, playing together in the neighbourhood (e.g., riding bikes, running), playing together at parks or playgrounds, or playing sports together (e.g., soccer)."

Statistical Analysis

All statistical analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC). Frequency counts and percentages were calculated to describe categorical variables. Means and standard deviations were calculated to describe continuous variables. Responses for each active recreation, active play, and coactivity were coded into two categories: irrelevant (not at all important/unimportant/neutral/not applicable) and relevant (important/most important). It should be noted that parents who completed the survey online did not have the option to select "not applicable" for features in the Active Play section due to an error. PROC SURVEYFREQ was used to account for the clustering of participants within each ward for all analyses addressing study research objectives. A Rao-Scott Chi-Square test was used to test differences in proportions from the expected frequencies (50%) as well as differences between high- and low-income groups (≤$100,000 / >$100,000). To determine whether there were differences between activity domains in the proportions of parents who identified features as relevant/not relevant, tests of discordant differences in proportions were performed. Finally, a sensitivity analysis was conducted to determine if findings changed when not applicable responses were coded as missing. Significance was determined a priori ($p < .05$).

Results

Of the 250 participants, 75 participants were excluded for not completing the survey. Another 26 participants were excluded because their children did not meet the age criteria (n=14), or they did not provide their child's date of birth (n = 12), which was used to calculate age. Finally, four participants were excluded for living outside of Edmonton. This resulted in 145 (58.00 %) participants who met the eligibility criteria. Demographic information is provided in Table 1. Parents' perceptions of neighbourhood features are presented in Table 2. Most features (23/32, 71.9%) were relevant for encouraging all three physical activity domains. Only one feature was unique for encouraging one physical activity domain, which was other people walking/exercising (Active Recreation: 60.00%). There were significant differences for 17 neighbourhood features in the proportion of parents who agreed features were relevant between activity domains (Supplementary Table 2). Differences were also observed between parents of higher household income (>$100,000) compared to lower household income (<$100,000) for seven neighbourhood features (Supplementary Tables 3-5).

Discussion

This study provides preliminary findings of the neighbourhood features parents perceived as relevant for their children's active play, parent's active recreation, and coactivity. Most features were considered relevant by the majority of parents for all three activity domains. There were several features where the proportion of parents who agreed on their relevance differed between activity domains, in line with the behavioural specificity concept (Giles-Corti, Timperio, Bull & Pikora, 2005). Finally, a few differences between income groups emerged.

Time constraints, commitment to their children, and other parental obligations have been expressed as barriers to physical activity by parents in previous literature (Bellows-Riecken &

Rhodes, 2008). Therefore, it is possible that most of parents' active recreation revolves around their child's active play or coactivity, which is why overlap occurred regarding relevant neighbourhood features among these domains in the current study. Nonetheless, it is encouraging parents identified several relevant neighbourhood attributes for their active recreation within a 10–15-minute walk from their home.

All neighbourhood safety features were considered relevant for all activity domains. Among adults, the findings in the literature vary regarding the relationship between neighbourhood safety and physical activity depending on whether quantitative or qualitative methods were used (Foster & Giles-Corti, 2008). Some inconsistencies have also been observed in preschoolers as some studies have found no relationship between neighbourhood safety and preschooler physical activity or coactivity (French et al., 2021; Zhang et al., 2020), whereas others have (Eichinger et al., 2017; Ezeugwu et al., 2021). However, in qualitative studies, concerns about crime, vagrants, and general safety have consistently been expressed by parents as important for their preschool child's physical activity and coactivity (Lindsay et al., 2006; Hnatiuk et al., 2020). Feelings of vulnerability or fear of crime may confound the relationship between neighbourhood safety and physical activity and should be included in future research in parent-preschooler dyads (Foster & Giles-Corti, 2008).

Most social features were considered relevant for all activity domains. For adults, it has been hypothesized that perceived social support and strong social networks may enable physical activity through walking groups or exercise contracts (McNeill et al., 2006). In parents of preschool children, a recent qualitative study revealed parents' social network grew from meeting other local families at parks where their children play and by joining community forums on social media (Hnatiuk et al., 2020). These relationships resulted in physical activities that could encompass active recreation, active play, and coactivity (Hnatiuk et al., 2020). In the current study, knowing and trusting neighbours was also considered relevant among all activity domains. This is consistent with previous research on active play among preschoolers (Parent et al., 2020) and adult physical activity (Evenson et al., 2003), though less is known about the influence on coactivity.

Several neighbourhood features were considered relevant for coactivity, which contrasts with previous literature (Zhang et al., 2020). However, the popularity of parks and playgrounds in the current study are supported by prior literature with older children (Dunton et al., 2012; Rhodes & Lim, 2018). Future research using global positioning systems (Dunton et al., 2012) and Bluetooth-enabled accelerometers (Jankowska et al., 2015) to contextualize coactivity combined with the assessment of parental- and home- characteristics (Zhang et al., 2020) will strengthen the evidence base on correlates of coactivity in parent-preschooler dyads.

Differences in proportions of parents who agreed on feature relevance for destination features may be due to characteristics of the destination itself and the surrounding area. For instance, in Hnatiuk et al., (2020), parents of preschoolers indicated age-appropriateness of equipment, shaded areas, quality of facilities, and the amount of open space as important characteristics for physical activity. Additional factors noted by parents in their study included the proximity and accessibility of destinations, as well as the safety of the route (Hnatiuk et al., 2020). It is possible these unmeasured factors were also considered by the parents in the current sample when thinking about relevant destinations for their activity domains. Our findings also suggest the social environment is universally relevant across domains. However, the proportion was less for coactivity in comparison to active recreation and active play for several features. This could be due to a stronger emphasis on parent-child social interaction during coactivity.

Although discrepancies were observed for sidewalks and cleanliness, they were still considered relevant by more than 90% of parents and could be important intervention targets for encouraging all three domains.

Though there were some differences, most neighbourhood features appeared universally relevant between income groups. This is supported by qualitative research in parents of young children living in both deprived and affluent neighbourhoods (Khanom et al., 2020). For instance, similarities were observed regarding the safety, maintenance, and design of facilities as well as safety for parks, walking routes, and cycling infrastructure, whereas differences emerged around quality and access to neighbourhood facilities (Khanom et al., 2020). Given most differences in the current study were regarding destinations, it is possible that these unmeasured characteristics of access, quality, and safety is what contributed to the discrepancies between income groups. Future research should consider these characteristics when examining the modifying effect of income or socioeconomic position on the relationship between neighbourhood features and physical activity in this population.

A main strength of this study was the recruitment strategy used to reach parents residing in each of Edmonton's 12 council wards. Further, the breadth of environmental features included (i.e., destinations, design, safety, social, aesthetics), as well as the three physical activity domains reported for parents and preschoolers fills a void in the literature. Despite these strengths, limitations should be acknowledged. First, data collection was performed in the summer, potentially biasing the results towards this season. A second limitation is the potential participation bias that may have occurred from online recruitment methods. It was impossible to obtain any information about eligible parents who saw recruitment posters and chose not to participate. Third, no meaningful comparisons could be made between survey non-completers and completers as demographic questions were near the end of the survey and not completed by the former. We recognize that missing data may have influenced the results. Fourth, there was no mechanism in place to prevent parents of the same household from participating. For example, parents could have participated in this study through separate social media accounts, or by being recruited online and in person. Finally, we were unable to estimate how online participants responded to neighbourhood features that were not present in their neighbourhood as they did not have the option to select “not applicable” for features in the Active Play section.

Conclusion

Parents perceived several relevant neighbourhood features for encouraging their child’s active play, their own active recreation, and coactivity. Only a few differences were observed between activity domains and income groups suggesting most features are universally important. For features that are not easily modifiable such as destinations, interventions may benefit from targeting increased accessibility via sidewalks and trails. Further, targeting modifiable social, safety, and aesthetic features may be important. Future research may benefit in sampling a larger representative sample from various geographic areas to examine whether differences exist in parent and child physical activity based on neighbourhood attributes. These findings may be helpful for government officials who are looking to create active living communities for young families.

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Table 3.1

Sociodemographic Characteristics of Participants

Characteristics	*M (SD)* or n	Range or %
Child age, years	3.9 (0.5)	3.0-4.9
Child sex		44.78
Male	66	45.52
Female	73	50.34
Missing Data	6	4.14
Child race/ethnicity		
White	82	56.55
Other	61	42.07
Missing data	2	1.38
Parent age, years	36.2 (4.5)	24.5-48.7
Missing data	5	3.45
Relationship to child		
Mother	124	85.52
Father	20	13.79
Guardian	1	0.69
Parental Education		
Less than high school	2	1.38
High school diploma	13	8.67
College or trade certificate	27	18.62
Bachelor's degree	53	36.55
University degree above bachelor's level	50	34.48
Household Income		
≤ $100,000	57	39.31
>$100,000	82	56.55
Missing data	6	4.14
Parent physical activity [a]		
Insufficiently active	22	15.17
Moderately active	19	13.10
Active	101	69.66
Missing data	3	2.07

Note. N = 145.

[a] Measured via the Godin-Shephard Leisure Time Physical Activity Questionnaire (Godin, 2011).

Table 3.2

Proportions of Parents who agreed Neighbourhood Features were Relevant for Physical Activity Domains

Feature	Parent Active Recreation		Child Active Play		Parent-Child Coactivity	
	n	%	n	%	N	%
Destinations						
Parks	142/145	97.9*	139/142	97.9*	141/145	97.2*
Dog parks	38/145	26.2*	35/143	24.5*	35/145	24.1*
Playgrounds	139/145	95.9*	143/144	99.3*	141/145	97.2*
Schools	116/144	80.6*	97/140	69.3*	88/144	61.1*
Sports fields	98/143	68.5*	98/144	68.1*	88/144	61.1*
Courts (e.g., basketball, tennis)	63/142	44.4	54/144	37.5*	60/144	41.7*-
Arenas/ice rinks	91/143	63.6*	94/144	65.3*	99/144	68.8*
Community league hall	85/144	59.0	73/144	50.7	70/144	48.6
River valley or ravine	96/145	66.2*	91/144	63.2*	110/145	75.9*
Design						
Main roads	70/143	49.0	63/144	43.8	62/144	43.7
Cul-de-sacs	59/142	41.6	69/143	48.3	68/144	47.2
Quiet streets	129/142	90.9*	124/143	86.7*	125/145	86.2*
Block length	55/139	39.6*	63/144	43.8*	61/144	42.4*
Trails	125/144	86.8*	116/143	81.1*	120/145	82.8*
Sidewalks	142/145	97.9*	130/143	90.9*	131/145	90.3*
Social						
Your friends/family	125/145	86.2*	128/144	88.9*	119/144	82.6*
Your child's friends	119/145	82.1*	126/144	87.5*	104/144	72.2*
Other people walking/exercising	87/145	60.0*	79/144	54.9	81/144	56.3
Other children playing outside	121/145	83.5*	130/144	90.3*	109/144	75.7*
Knowing who your neighbours are	119/145	82.1*	119144	82.6*	109/143	76.2*
Trusting people in your neighbourhood	139/145	95.9*	134/144	93.1*	125/143	87.4*
Safety						
Street lighting	133/145	91.7*	123/144	85.4*	125/145	86.2*
Low Crime	135/145	93.1*	132/143	92.3*	134/145	92.4*
Low Vehicle Traffic	124/145	85.5*	128/143	89.5*	134/145	92.4*
Daylight	124/145	85.5*	134/144	93.1*	129/145	89.0*
Sidewalk maintenance	132/145	91.0*	125/144	86.8*	135/144	93.8*
Pedestrian crosswalks	133/145	91.7*	123/144	85.4*	126/145	86.9*
Aesthetics						

Cleanliness (e.g., no animal waste, litter, glass)	143/144	99.3*	143/144	98.6*	139/145	95.9*
No graffiti	88/143	61.5*	83/143	58.0*	81/144	56.3
Attractive houses	70/144	48.6	52/144	36.1*	54/145	37.2*
Natural features (water, trees)	127/144	88.2*	118/144	81.9*	121/144	84.0*
Landscaped features (e.g., plants, flowers)	102/144	70.8*	90/143	62.9*	102/143	71.3*

Note. Values represent the proportion of parents who agreed the item was “important” or most “most important.

***** Significantly different from 50% ($p < .05$).

- Differences were no longer significant ($p > .05$) in sensitivity analyses where not applicable responses were coded as missing.

Chapter 4: Associations between parent's perceived neighbourhood environment and objectively measured walkability with their children's physical activity.

Authors: Stephen Hunter [a], John C Spence [a], Scott T Leatherdale [b], Valerie Carson [a] *

Author Affiliations:

[a] Faculty of Kinesiology, Sport, and Recreation. University of Alberta, Van Vliet Complex, Edmonton Canada.

[b] School of Public Health Sciences, University of Waterloo, Waterloo, Canada.

***Corresponding Author:**

Valerie Carson, PhD, 1-151, Faculty of Kinesiology, Sport, and Recreation, University of Alberta, Edmonton, AB, T6G 2H9, Phone: 780-492-1004, E-mail: vlcarson@ualberta.ca

This has been formatted to meet the requirements of the Journal of Physical Activity and Health.

Abstract

Background: Neighbourhoods are one setting to promote children's physical activity. This study examined associations between neighbourhood features and children's physical activity and whether season or socioeconomic status modified these associations.

Methods: Parents (n= 641) of children aged 6-10 years completed the Neighborhood Environment Walkability Scale – Abbreviated. Walkability was objectively measured at 400 m, 800m and 1200m around the centroid of participants' postal codes. Children's physical activity was measured via StepsCount (SC-T2) pedometers and parental report. Regression analyses were performed with interaction terms for season and socioeconomic status. Multiple imputation was used primarily to triangulate the results for children with missing steps data (n = 192).

Results: Higher perceived residential density and traffic hazards were significantly associated with lower parental-reported physical activity and steps per day, respectively. Higher perceived aesthetics was associated with higher parental-reported physical activity. In higher SES neighbourhoods, more perceived physical barriers was significantly associated with higher steps per day. During winter months, better perceived infrastructure and safety for walking was associated with higher parental-reported physical activity. No other significant associations emerged.

Conclusion: Residential density, traffic hazards, and aesthetics are important for children's physical activity. Few associations were modified by socioeconomic status or season.

Keywords: season, socioeconomic status, moderator, play, residential density

Introduction

Most school-aged children in developed countries do not achieve sufficient physical activity for optimal health benefits (Aubert et al., 2018; Bull et al., 2020). Additionally, physical activity patterns in childhood tend to track into adulthood (Telama et al., 2014), where physical inactivity is associated with a higher risk for chronic diseases (Lee et al., 2012). Therefore, finding sustainable ways to promote physical activity patterns among children is important. Ecological models suggest there are several factors both internal (e.g., demographic, psychological, and biological characteristics, environmental perceptions) and external (e.g., relationships with friends and family, home-, school-, and neighbourhood- characteristics, public policy) to individuals that may influence their physical activity (Spence & Lee, 2003; Sallis et al., 2006; Sallis & Owen, 2015).

Modifying or creating neighborhoods to promote physical activity has the potential to reach large proportions of children and is a sustainable strategy for physical activity promotion (Laine et al., 2014). However, before resources can be allocated to make activity friendly neighbourhoods, understanding which features are supportive of children's physical activity is important (Sallis et al., 2000). Few neighbourhood-level correlates are consistently associated with children's physical activity (Carlin et al., 2017), and these inconsistences may depend on the methods used to measure physical activity and the neighbourhood (Ding et al., 2011). As such, employing both subjective and objective measures of neighbourhood correlates and physical activity is recommended (Ding et al., 2011).

Interactions between and within levels of an ecological model may shape human behaviour (Sallis & Owen, 2015). However, this tenet of ecological models is understudied (Gubbels et al., 2014). Seasonality and socioeconomic status (SES) may modify the associations between features of the neighborhood environment and children's physical activity. For instance, children's physical activity is affected by season, particularly with lower physical activity in colder seasons (Carson & Spence, 2010). Therefore, it is possible some neighbourhood features may have stronger associations at certain times of year. Socioeconomic status has been suggested as a potential modifier of associations between the neighbourhood environment and physical activity (Welk, 1999). Previous research has found children's independent mobility and time spent outdoors may differ based on area-level SES (Veitch et al., 2008; Nyström et al., 2019). It has also been reported that higher SES areas have more public open spaces with more favourable attributes than lower SES areas (Crawford, 2008). Therefore, it appears that area-level SES could modify the extent to which the neighbourhood environment influences children's physical activity. Identifying whether different associations exist based on area-level SES is important for guiding neighbourhood physical activity initiatives.

This study aimed to address evidence gaps regarding the association between the neighbourhood environment and children's physical activity. The primary objective was to examine associations between the perceived and objectively measured neighborhood environment with children's parental-reported physical activity and pedometer-derived steps per day among families residing in and around Edmonton, Canada. The secondary objectives were to examine whether these associations were modified by season or area-level SES.

Methods

Study Design

This study uses a cross-sectional design and data from the Spatial Health Assessment of Physical Environments (SHAPEs) of Things to Come project. This project has been described in detail elsewhere (Stearns et al., 2016; Potter et al., 2017).

Participants and procedures

Recruitment for the SHAPEs of Things to Come project occurred from 2009 to 2011 in Edmonton, Alberta (Stearns et al., 2016; Potter et al., 2017). This data is unique in in that it provides the opportunity to examine the associations between device-based and subjective measures of physical activity and the neighbourhood environment. Families who participated in the initial SHAPEs project (2005 to 2007) and agreed to be contacted for future research (n=1377) were mailed an information letter, consent form, and parental questionnaire regarding participant characteristics, including children's physical activity. Those interested in participating were booked for a fitness testing session at the University of Alberta. At the session, parents (n = 668) were administered a second questionnaire on the neighbourhood environment, a pair of pedometers for both themselves and their child to wear, and a pedometer logbook. There were 25 families with two siblings in the study, and one family with three siblings in the study, so one sibling was randomly selected to be included in the analysis from each family, leaving a sample of 641 participants. This study was approved by the Human Research Ethics Board at the University of Alberta (Ethics # Pro00003747) and all parents provided written informed consent.

Exposures

Perceived neighbourhood environment. Parents reported on several aspects of their neighbourhood environment (i.e., residential density, land use mix-diversity, land use mix-access, walking and cycling infrastructure, street connectivity, traffic hazards, crime safety, aesthetics, physical barriers, parking, cul-de-sacs, and hilliness) via the Neighbourhood Environment Walkability Scale – Abbreviated (Cerin et al., 2006). Test-retest reliability for individual items have previously found to range from ICC= 0.13 to 0.9, with the majority of items ranging between ICC = .50 to .91 (https://drjimsallis.org/measure_news.html).

Objectively measured neighbourhood walkability. Participant postal codes were assessed in the neighbourhood questionnaire. Consistent with Thornton et al. (2011), geographic information systems (GIS) was used to create 400m and 800m and 1200m street network sausage buffers (Forsyth et al., 2012) around the centroid of the postal code. Neighbourhood walkability was based on intersection density, residential density, and land use mix. Intersection density was calculated as the number of true intersections divided by the buffer area. Residential density was calculated as the number of dwelling units (based on the 2006 Census) per buffer area. Land-use mix was estimated based on the number of facilities (institutional, maintenance, dining, leisure) divided by buffer area. Walkability was calculated by summing the z-scores for intersection density, residential density, and land use mix. As recommended by Frank et al. (2010), intersection density was weighted (multiplied by two). Higher intersection density, residential density, and land use mix scores contribute to a higher walkability score, and a higher walkability score indicates better walkability. Participants were excluded from walkability models if they resided outside of the city of Edmonton, did not provide a postal code, or lived in an area where geographic information was unavailable (400m = 244, 800m = 215, 1200 m = n=214).

Outcomes

Children's steps per day. Children's steps per day was measured via StepsCount (SC-T2) pedometers. An identical pedometer (Walk4Life 2505) has proven accurate in measuring steps among children aged 6 to 10 years compared to direct observation (self-paced walking: intraclass correlation coefficient = 0.985; treadmill walking: intraclass correlation coefficient = 0.832, 95%

CI: 0.760 to 0.884) (Beets et al., 2005). Participants were asked to wear the pedometers for four consecutive days (three weekdays, one weekend day), and record the number of steps at the end of each day in their logbook. Pedometers were to be removed when swimming, bathing, and sleeping.

Parental-reported physical activity. Parents reported children's physical activity using modified items from the Children's Leisure Activities Study Survey (Telford et al., 2004) in the parental questionnaire. These items asked parents to report on several physical activities (i.e., swimming, soccer, ballet/dance, gymnastics, skating, hockey, bike riding, gym activities, active play, other) their child usually does during the week. Parents reported the frequency of each activity during the week (Monday – Friday) and on weekends (Saturday and Sunday), as well as the average duration for times during the week and on weekends. The average duration of each activity was multiplied by its frequency. All activity modes were then summed to get an estimate of weekly physical activity, which were then converted to minutes/day for analyses. Parental-reported overall total physical activity derived from frequency of activities on the original Children's Leisure Activities Study Survey has previously demonstrated a test-retest reliability of ICC = 0.83 for children aged 5-6 years, and an ICC = 0.69 for children aged 10-12 years (Telford et al., 2004). Parental-reported overall total physical activity derived from duration of activities has previously demonstrated test-retest reliabilities of an ICC=0.76 for children aged 5-6 years, and an ICC = 0.74 for children aged 10-12 years (Telford et al., 2004). Criterion validity between parental-reported total physical activity duration against accelerometry was low (Spearman Correlation $r = .09$) with discrepancies of approximately ± 200 min/day (Telford et al., 2004). Despite the low criterion validity, this questionnaire has been recommended for use over other physical activity questionnaires for this age group (Chinapaw et al., 2010). Reliability and validity have not been previously assessed for each type of physical activity, therefore total physical activity was used in the present study as recommended (Telford et al., 2004).

Potential effect modifiers

Seasonality and area level-SES were considered as potential effect modifiers. Prior SHAPES studies have found season to be significantly associated with children's physical activity (Carson et al., 2010; Stearns et al., 2016). In the current study, seasonality was assessed via the date the child wore the pedometer (Spring, Summer, Fall, Winter). Edmonton and the surrounding areas are prone to extreme temperatures in the winter months (December to February); therefore, season was binary coded as Spring/Summer/Fall and Winter (reference group). Families' postal codes were used to obtain area-level socioeconomic status. Specifically, GeoPinPoint™ Suite software (DMTI Spatial Inc: GeoPinPointTM Suite Version 6.4, Markham, Ontario) was used to match postal codes with dissemination areas. Net educational difference scores for each dissemination area were then obtained from the 2006 Canadian Census. This variable was binary coded based on the mean value in line with previous research (Stearns et al., 2016).

Covariates

Child age, sex, health status, and annual household income were reported in the parental questionnaire. Health status was binary coded ("yes", "yes, sometimes" / "no") based on the item "Does your child have any problems that would hinder them from doing physical activities?" Household income was assessed ('< $20,000', $20-39,999', '$40-59,999', '$60-79.999', '$80 – 99.999', and '>$100,000') and entered in the model as a continuous variable.

Statistical analysis

Descriptive statistics were performed to describe the sample. We followed the guidance and recommendations for outliers and skewness outlined by Tabachnick & Fidell (2007). All dichotomous variables were checked for 90-10 splits to examine potential outliers. Children's physical activity data were standardized and scanned for outliers whose z-scores exceeded ± 3.29 SD. Three children had z-scores above 3.29 SD for step data. No alterations were made to children's step data as the values of the potential outliers were high (18478.5, 18068.7, 27009.3) but still plausible and it was deemed acceptable to have a few outliers given the sample size. Nine children had daily parental- reported physical activity z-scores > 3.29 SD. A square root transformation was applied due to positive skewness and the number of outliers was reduced to five (n=2 < -3.29 SD, n=3 >3.29 SD). For exposure variables, there were several univariate outliers for income (n= 10), residential density (n = 10), infrastructure for safety and walking and cycling (n = 7), crime (n = 4), hilliness (n = 8), physical barriers (n = 22), and objectively measured walkability (400m: n = 2; 800m: n = 2; 1200m: n = 2), though the number of observations and their corresponding values were deemed appropriate given the sample size and plausible ranges. Multivariate outliers among exposure variables and covariates were assessed prior to analyses by examining Cook's d values > 4/n. This procedure was performed individually for steps per day and parental-reported physical activity by including all covariates and exposure variables as independent variables, and an auto-generated observation number as the dependent variable in a regression model. No clear patterns emerged to describe these multivariate outliers and they were therefore kept in subsequent analyses.

For the primary objective, each exposure variable was entered in a separate multiple regression model that was adjusted for all covariates. To examine potential effect modification, each interaction term was added in each regression model separately along with season or area-level SES. Associations with significant interactions ($p < 0.05$) were re-run as stratified analyses based on the groupings of the modifying variable. To triangulate the results, multiple imputation with 100 imputations were performed using the MI procedure (Graham et al., 2007). Continuous variables were imputed using linear regression, ordinal binary variables were imputed using logistic regression, and nominal binary variables were imputed using discriminant regression. All variables included in the analyses, including interaction terms and auxiliary variables (parent steps, child's aerobic fitness, and child's World Health Organization's BMI z-score), were also included in the imputation phase (Pedersen et al., 2017).

Results

Descriptive statistics are presented in Table 1. The sample comprised of children aged 7.8 years (SD = 0.6) with just over half being females (52.3 %). Just over half of the sample had a household income over $100,000 (58.4%), and few participants had a health problem that would limit their physical activity (13.6%). Of the 641 participants, 449 had pedometer data for four days and took an average of 8642.10 steps/day (SD = 2888.9), while 625 participants had parental-reported physical activity data and engaged in a median of 94.3 mins/day of physical activity (interquartile range = 68.9). In terms of environmental characteristics, the median residential density was 197.0 (quartile range = 33). On average, parents reported low perceptions of crime (M = 1.3), adequate parking (indicated by a median lack of parking score of 1.0 out of 4), few hills (M = 1.0), and low physical barriers (M = 1.0). Parents also reported, on average, high land-use mix diversity ($\bar{x}$ = 3.2) and access (M = 3.3), and aesthetics ($\bar{x}$ = 3.3). Finally, just over half of participants resided in areas with a net educational difference lower than 11.8 (54.9%) and fewer were recruited in the winter (n=79).

The associations between neighbourhood environment features and children's physical activity are displayed in Table 2. In models with complete data, higher residential density was significantly associated with less steps/day (B = -12.40, 95% CI: -20.8 to -4.0). While a 1-unit increase in residential density may not be a meaningful change, for interpretation purposes a post-hoc analysis revealed that 1 SD higher residential density (31. 7) was associated with 393.03 (95% CI: -659.6 to -126.4) less steps. A higher perception of traffic hazards was associated with less square root transformed parental-reported physical activity in models with complete (B = -0.42, 95%CI: -0.8 to -0.0) and imputed (B = -0.43, 95%CI: -0.8 to -0.0) data. In contrast, a higher perception of neighbourhood aesthetics was associated with more square root transformed parental-reported physical activity in models with complete (B = 0.39, 95%CI: 0.0 to 0.8) and imputed data (B = 0.41, 95%CI: 0.0 to 0.8). No other significant main effects were observed for models with complete and imputed data.

A few associations were modified by either socioeconomic status or season (Table 3). In models with complete data, a higher perception of barriers was significantly associated with more steps/day (B = 756.89, 95%CI: 84.8 to 1429.0) in the higher SES group. No significant association was observed in the lower SES group, though the direction of the coefficient was in the opposite direction. Neighbourhood socioeconomic status also modified the association between perceived barriers and street connectivity with square root transformed parental-reported physical activity. Though, no significant associations were observed in stratified analyses, the direction of coefficients for perceived barriers was different for high and low SES groups and opposite of what was observed compared to steps/day. Finally, season modified the association between infrastructure and safety for walking and cycling and square root transformed parent reported physical activity. Specifically, during the winter months there was a significant positive association (B = 1.90, 95%CI: 0.4 to 3.4). Whereas in the other months, the direction of this association was negative, though nonsignificant (B = -0.01, 95%CI: -0.5 to 0.4).

Discussion

This study examined associations of the perceived and objectively measured neighborhood environment features with children's steps per day and parental-reported physical activity. In general, few individual neighbourhood features were associated with physical activity. Nonetheless, lower residential density and traffic hazards and higher aesthetics appeared to be supportive of children's physical activity. Most associations were largely unaffected by season or SES, but a few associations were modified by these variables.

The association observed between higher residential density and less steps per day differs from previous studies demonstrating a non-significant association with children's device-based physical activity (Aarts et al., 2012; De Meester et al., 2014). However, lower residential density neighbourhoods may be characterized by homes with more yard space for children to be active (Kowaleski-Jones et al., 2017). This is important given children aged 5-8 years may participate in physical activity in their yard or apartment complex more frequently than other neighbourhood destinations (Holt, Spence, Segn, & Cutuminsu, 2008; Corder et al., 2011). If this were true for the current sample, it would make sense from an ecological perspective that the influence of neighbourhood features would be buffered by the home environment (Spence & Lee, 2003). Though our findings regarding traffic hazards and aesthetics are intuitive, prior studies have reported null or mixed associations (Timperio et al., 2015). To better understand the association between the neighbourhood environment and children's physical activity, moderation analyses that include characteristics of the home environment (e.g., size of yard) are needed (Spence and Lee, 2003).

Our findings that aspects of the perceived environment were modified by SES has been previously reported (Hunter et al., 2020; Uys et al., 2016). The neighbourhood environment has been suggested to offer free opportunities for physical activity participation (McKenzie et al., 2013), however, lower perceptions of safety, comfort, and pleasure have been reported in lower SES neighbourhoods and may weaken this association (Franzini et al., 2010). The results from the present study cannot confirm this. However, previous qualitative research performed in a low-income neighbourhood of Edmonton found safety to be a barrier for children and youth physical activity (Holt, Cunningham, Sehn, Spence, Newton, Ball, & Lerner, 2009). In the current study, the direction of associations between the perceived environment and physical activity were different between higher and lower SES groups, which has been previously reported (Hunter et al., 2020; Uys et al., 2016). It is difficult to understand why the positive association between physical barriers and children's steps per day in the higher SES group was significant. Though it is possible children in the high SES group had greater means to overcome these barriers, such as larger backyards, nearby safe playgrounds, organized sport opportunities, or parental support to drive to other places without physical barriers to play.

Our finding that infrastructure and safety for walking and cycling was important for children's parental-reported physical activity during the winter months aligns with concerns expressed by other Edmontonians in a previous qualitative study (Montemurro et al., 2011). Specifically, adults expressed the lack of sidewalk accessibility due to snow and ice was a hazard during the winter months (Montemurro et al., 2011). Although the current study did not measure sidewalk condition, infrastructure and safety for walking and cycling was composed of individual items that assessed separated sidewalks, street lighting at night, having crosswalks and pedestrian signals, and being easily seen by people in their homes. Having sidewalks separated from traffic during the snowy and icy conditions in winter months may serve as an important buffer from traffic. Though, it will also be important that such features are well maintained as their use may be dictated on whether they are clear of snow and ice. Further, during winter months in Edmonton and surrounding areas, children have approximately 1-2 hours of daylight after school before the sun sets. Therefore, it is understandable why being visible by others, having pedestrian signals and street lighting are important for supporting children's physical activity.

Municipalities that are looking to support children's physical activity may benefit from requiring public open spaces such as playgrounds and parks to be included or retrofitted in areas of high residential density. This would ensure children living in higher residential density neighbourhoods have a safe space to play. Further, to support physical activity year-round increasing pedestrian crosswalks, street lighting, and separated sidewalks in residential areas as well as keeping these features clear from snow and ice during the winter months will be important. Future research may benefit from using direct observations such as the Microscale Audit of Pedestrian Streetscapes (Millstein et al., 2013) during the winter months to obtain a better understanding of how the walking and cycling infrastructure relates to children's physical activity. Additionally, using more nuanced natural environment characteristics (e.g., temperature, precipitation, wind speed, amount of daylight) as potential effect modifiers may be beneficial for understanding the relationship between the built environment and physical activity more acutely (Turrisi et al., 2021). To gain a better understanding of the neighbourhoods influence on children's physical activity, natural experiments or longitudinal designs that allow for the measurement of physical activity before and after a neighbourhood change has occurred may be required (Craig et al., 2012; Rhodes & Quinlan, 2015).

Study Limitations and Strengths

Strengths of this study include the validated measures of objective and perceived neighbourhood environment as well as children's parent-reported physical activity and pedometer derived children's steps per day. Further, it sought to explore the modifying effect of socioeconomic status and season to gain a more nuanced perspective of how neighbourhood features relate to children's physical activity. Despite these strengths, some limitations should be acknowledged. First, our measure of children's steps per day is general and context-free. While the parental report of children's physical activity was composed of several different individual types of physical activities these individual items were also context free and have not been validated for individual use. This lack of specificity could have limited our ability to detect a significant association between the neighbourhood environment and physical activity (Giles-Corti et al., 2005). For instance, others have observed several significant associations between similar perceived environment features measured by the Neighbourhood Environment Walkability Scales – Youth (NEWS-Y) with context specific behaviours (e.g., active in the park, walking to school, physical activity on nearby streets and on sidewalks) but no associations with subjective or device-based measures of physical activity (Rosenberg et al., 2009; D'Haese et al., 2015). Future research may benefit from including the combination of timestamp device-based measures of physical activity with GPS devices to better understand the exact locations and type of children's physical activity (Borghese & Janssen, 2018; Jankowska et al., 2015). Another limitation was that this study was cross-sectional in nature, therefore we cannot make causal claims about any of the observed associations.

Conclusion

Residential density, aesthetics, and traffic hazards may be important for children's physical activity. Consequently, in neighbourhoods with higher residential density, providing or renovating public open spaces, so children have adequate space to be active may be something to consider. Further, both new and old neighbourhoods may be able to incorporate aesthetics (e.g., trees along the streets, natural sights, interesting things to look at, attractive buildings), and traffic calming measures (e.g., lower speed limits). Though most associations were not modified by season, in regions facing extreme weather conditions (e.g., snow and ice during the winter months) having infrastructure that supports walking and cycling appears important. Future research and neighbourhood initiatives should consider how SES impacts the association between the neighbourhood features and children's physical activity as it may vary between higher and lower socioeconomic areas.

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Table 4.1

Sample Characteristics for Non-Imputed and Imputed Data

	Non-Imputed Data		Imputed Data
	n	M (SD) or n (%)	M (SD) or n (%)
Child Age (years)	639	7.8 (0.6)	7.8 (0.6)
Child Sex	641		
Male		306 (47.74 %)	306 (47.74 %)
Female		335 (52.26 %)	335 (52.26 %)
Health Problem	622		
Yes		537 (86.33 %)	554 (86.42 %)
No		85 (13.67 %)	87 (13.58 %)
Household income	589		
<$20,000		10 (1.70 %)	12 (1.87 %)
$20,000 to 39,999		10 (1.70 %)	12 (1.87 %)
$40,000 to 59,999		39 (6.62 %)	44 (6.86 %)
$60,000 to 79,999		66 (11.21 %)	73 (11.39 %)
$80,000 to 99,999		120 (20.37 %)	130 (20.28 %)
>$100,000		344 (58.40 %)	370 (57.72 %)
Steps/day	449	8642.1 (2888.9)	8650.5 (3024.6)
Parent reported physical activity min/day (square root)	625	9.7 (3.5)	9.7 (3.5)
Perceived Environment			
Residential Density [a]	621	197 (33.0)	
Land-use mix-diversity	629	3.2 (1.0)	3.2 (1.0)
Land-use mix access [a]	628	3.3 (1.3)	3.3 (1.3)
Street connectivity [a]	628	3.0 (1.0)	3.0 (1.0)
Infrastructure and Safety for Walking [a]	628	3.0 (0.5)	3.0 (0.5)
Aesthetics [a]	628	3.3 (1.0)	3.3 (1.0)
Traffic Hazards	628	2.5 (0.6)	2.5 (0.6)
Crime [a]	628	1.3 (0.7)	1.3 (0.7)
Lack of parking [a]	625	1.0 (1.0)	1.0 (1.0)
Lack of cul-de-sacs	628	2.3 (1.1)	2.3 (1.1)
Hilliness [a]	627	1.0 (0.0)	1.0 (0.0)
Physical Barriers [a]	627	1.0 (0.0)	1.0 (0.0)
Objective Environment			
Walkability 400m	397	0 (2.5)	-
Walkability 800m	426	0 (2.6)	-
Walkability 1200m	449	0 (2.7)	-
Area SES	639		
Low (< 11.77)		350 (54.77 %)	351 (54.76 %)
High (≥ 11.77)		289 (45.23 %)	290 (45.24 %)
Season	639		
Spring/Summer/Fall		560 (87.64%)	562 (87.63%)

Winter	79 (12.36 %)	79 (12.37 %)

Note. N = 641, PA = physical activity. SES = socioeconomic status. [a] Median (quartile range)

Table 4.2

Multiple Linear Regressions Modelling Associations between Neighbourhood Environment Features and Children's Steps per Day

	Non-Imputed Steps	Imputed Steps	Non-Imputed Min/day	Imputed Min/day
	B (95% CI)	B (95% CI)	B [95% CI]	B [95% CI]
Perceived Environment				
Residential Density	-12.40 [-20.8, -4.0] *	-7.90 [-16.6, 0.8]	-0.01 [-0.0, 0.0]	-0.01 [-0.0, 0.0]
Land use mix-diversity	-264.13 [-594.2, 66.0]	-247.81 [-596.7, 101.1]	-0.03 [-0.3, 0.3]	0.13 [-0.2, 0.4]
Land-use mix-access	-78.13 [-418.6, 262.3]	46.83 [-293.5, 387.2]	-0.10 [-0.4, 0.2]	-0.19 [-0.5, 0.1]
Street Connectivity	1.84 [-358.5, 362.2]	58.45 [-298.8, 415.7]	-0.01 [-0.3, 0.3] [a]	-0.10 [-0.4, 0.2] [a]
Infrastructure and Safety for Walking	-238.27 [-692.9, 216.3]	-160.63 [-624.4, 303.1]	0.13 [-0.3, 0.6]	0.11 [-0.3, 0.5] [b]
Aesthetics	113.65 [-300.2, 527.5]	312.61 [-121.8, 747.0]	0.39 [0.0, 0.8] *	0.41 [0.0, 0.8] *
Traffic Hazards	120.51 [-323.2, 564.2]	-54.00 [-500.6, 392.6]	-0.42 [-0.8, -0.0] *	-0.43 [-0.8, 0.0] *
Crime	265.24 [-237.6, 768.1]	94.40 [-391.7, 580.5]	-0.43[-0.9, -0.0]	-0.37 [-0.8, 0.1]
Lack of Parking	-107.66 [-455.4, 240.0]	-63.69 [-417.8, 290.4]	-0.23 [-0.5, 0.1]	-0.23 [-0.5, 0.1]
Lack of Cul-de-sacs	128.92 [-116.4, 374.2]	40.10 [-205.3, 285.4]	-0.08 [-0.3, 0.2]	0.02 [-0.2, 0.2]
Perceived Hilliness	63.34 [-408.2, 534.9]	75.47 [-417.7, 568.6]	0.26 [-0.2, 0.7]	0.22 [-0.2, 0.6]
Physical Barriers	150.58 [-254.25, 555.4] [a]	-54.41 [-477.9, 369.0]	0.15 [-0.2, 0.5] [a]	0.11 [-0.2, 0.5]
Objective Environment				
Walkability 400 m	-16.52 [-152.8, 121.8]	-	0.02 [-0.1, 0.1]	-
Walkability 800 m	51.84 [-74.0, 177.6]	-	0.02 [-0.1, 0.1]	-
Walkability 1200 m	-18.38 [-138.9, 102.2]	-	-0.02 [-0.1, 0.1]	-

Note. All analyses were adjusted for child age, sex, health status, and household income. Socioeconomic status and season were tested as potential effect modifiers with the inclusion of an interaction term. B = unstandardized beta coefficient. CI = confidence intervals. [a] significant SES interaction term ($p < .05$), [b] significant season interaction term ($p < .05$). * $p < .05$.

Table 4.3

Stratified Multiple Linear Regressions Modelling Neighbourhood Socioeconomic Status and Season as Effect Modifiers

	Non-Imputed		Imputed	
	B [95% CI]		B [95% CI]	
SES	Lower SES	Higher SES	Lower SES	Higher SES
Barriers (steps/d)	-254.21 [-753.7, 245.3]	756.89 [84.8, 1429.0] *	NS	NS
Barriers (min/d)	0.40 [-0.0, 0.8]	-0.32 [-0.9,0.2]		
Street Connectivity (min/d]	-0.24 [-0.7, 0.2]	0.48 [0.1, 1.0]	-0.37 [-0.8, -0.0]	0.36 [-0.2, 0.9]
Season			Winter	Spring/Summer/Fall
Infrastructure and Safety for Walking (min/d]	NS	NS	1.90 [0.4, 3.4] *	-0.01 [-0.5, 0.4]

Note. All analyses were adjusted for child age, sex, health status, and household income. Values for min/day are square root transformed. B = unstandardized beta coefficient. CI = confidence intervals.

* $p < .05$. [a] Significant socioeconomic status interaction term ($p < .05$). [b] Significant season interaction term ($p < .05$).

Chapter 5: Longitudinal associations between the school built environment and adolescents' physical activity: Evidence from the COMPASS study.

Stephen Hunter [a], Kate Battista [b], Scott T Leatherdale [b], John C Spence [a], Valerie Carson [a]

[a] Faculty of Kinesiology, Sport, and Recreation, 1-151 University Hall 8840 - 114 St NW University of Alberta, Edmonton, Canada, T6G 2H9

[b] School of Public Health Sciences, 200 University Ave West, TJB 2317, University of Waterloo, Waterloo, Canada, N2L 3G1

Email addresses:

Stephen Hunter: stephen1@ualberta.ca
Kate Battista: kbattista@uwaterloo.ca
Scott T Leatherdale: sleatherdale@uwaterloo.ca
John C Spence: jc.spence@ualberta.ca
Valerie Carson (corresponding author): vlcarson@ualberta.ca

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Abstract

Purpose: Examine adolescent moderate- to vigorous-intensity physical activity (MVPA) and active school travel over a four-year period; Examine associations between the surrounding school built environment and adolescent MVPA and active school travel, and whether adolescent MVPA and active school travel are moderated by the built environment over time.

Methods: Data from the COMPASS project (2013/14 to 2016/17) were used. Participants were adolescents aged 13-18 (n = 20,221) from 91 schools. MVPA and active school travel were self-reported via questionnaire. The built environment (park-, recreation-, retail- densities, Walk Score) was objectively measured. Multilevel modeling was conducted.

Results: Adolescent square root transformed MVPA (SQRT-MVPA) and the likelihood of active school travel decreased over time. Several positive associations were observed between the surrounding school built environment and SQRT-MVPA and active school travel when time was held constant. Adolescents attending schools in very walkable areas had an increased likelihood of active school travel over time. Higher park-, retail-, and recreation- densities appeared to help maintain the likelihood of active travel to school over time, though the same pattern was not apparent for active travel from school or SQRT-MVPA.

Conclusion: SQRT-MVPA and active school travel declined over time. However, the downward trend for the likelihood of active school travel appeared to be opposite for students attending schools in very walkable areas. Schools and municipalities should work together in creating built environments around schools that are more walkable and have greater park and recreation densities. Schools in unfavourable built environments may need additional physical activity programming.

Keywords: children, active transportation, exercise, correlates, physical environment

Highlights

- Moderate to vigorous physical activity and active school travel declined over time
- Most built environment features did not prevent declines in physical activity
- Greater walkability was associated with higher likelihood of active school travel

1. Introduction

Adolescence is a period of particular concern for physical activity promotion as it is characterized by a continued decline in overall physical activity (van Sluijs et al., 2021). In fact, recent global estimates suggest approximately 80% of adolescents are not meeting physical activity recommendations of at least 60 minutes of moderate-to vigorous- intensity physical activity (MVPA) per day (Bull et al., 2020; Guthold et al., 2020). Given that physical activity is associated with several health benefits (Poitras et al., 2016) and activity patterns tend to track over time (Telama, 2009; Telama et al., 2014), finding ways to promote physical activity during adolescence is important. One type of physical activity that has been suggested as a potential target to increase overall physical activity levels is active transport (Kek et al., 2019). However, recent global estimates suggest that less than half of adolescents walk or cycle to school (van Sluijs et al., 2021).

Ecological models suggest correlates of physical activity extend beyond the individual (Sallis et al., 2006; Spence & Lee, 2003). For adolescents, this may include family and peers(Martins et al., 2015) as well as social and built environments (van Sluijs et al., 2021). In fact, built environment initiatives have been suggested to be a cost-effective population approach for physical activity promotion (Laine et al., 2014). Therefore, identifying features of the built environment that are important for promoting MVPA and active transportation in this age group is necessary.

Previous research that has examined the associations between the built environment and physical activity and active transport among adolescents has primarily been cross-sectional (Carlin et al., 2017; Ding et al., 2011; Pont et al., 2009; Rothman et al., 2018). As such, calls have been made for more longitudinal research designs to add robust evidence to the literature in this area (van Sluijs et al., 2021). Therefore, the objectives of this study were to 1) examine changes in adolescent moderate- to vigorous–intensity physical activity (MVPA) and active school travel over a four-year period, 2) examine the associations between the built environment surrounding the school and adolescents' MVPA and active school travel, and 3) examine whether the built environment moderates adolescent MVPA and active travel over time.

2. Methods

2.1. Procedures

Data from the Cannabis, Obesity, Mental health, Physical activity, Alcohol use, Sedentary behaviour, and Smoking (COMPASS) project was used (Leatherdale et al., 2014). COMPASS is an ongoing multi-province school-based longitudinal cohort study in Canada designed to capture health behaviours and outcomes from students in grades 9-12. Each year, students from participating schools complete the COMPASS questionnaire (Cq) regarding several health behaviours and outcomes. Further, school administrators complete a survey on their school's programs and policies regarding these behaviours and outcomes. An audit is also performed on the school's food and physical activity environment. Lastly, geographic data is collected at 500m, 1000m, and 1500m buffers based on the centroid of the school's postal code (Leatherdale et al., 2014). The University of Waterloo Office of Research Ethics, the University of Alberta Institutional Review Board, and participating school board and schools approved all procedures.

2.2. Participants

COMPASS uses convenience sampling due to its active-information passive consent protocol. This means that all students who were enrolled in participating schools were deemed eligible to participate in the study (Leatherdale et al., 2014). The COMPASS team provides information letters to the school to be communicated to parents about the study. Parents can then contact the COMPASS team if they wish to have their child withdrawn. COMPASS uses an anonymous linking process to follow students over time (https://uwaterloo.ca/compass-system/student-data-linkage-over-multiple-years). Participants in the current study represent a subsample of students who were in grade 9 in 2013-14 (Time 1) and who completed the COMPASS questionnaire in 2013-14 (Time 1), 2014-15 (Time 2), 2015-16 (Time 3), and/or 2016-17 (Time 4) and attended a school that had environmental data collected at baseline (2013-14). This resulted in 8950 students with data at one time point, 4454 students with data at two time points, 4535 students with data at three time points, and 2272 students with data at four time points. These years were chosen because they had the largest linked sample sizes in these provinces as well as the most available covariate data. This resulted in an eligible sample of 20,221 students from 91 schools.

2.3. School built environment

School built environment data were measured within 500 m, 1000 m, and 1500 m circular buffers around each school. Data were obtained from CanMap Enhanced Points of Interest from the Desktop Mapping Technologies Inc. (DMTI). Retail density consisted of several different stores (e.g., department, grocery, variety general merchandise) within each buffer. Recreation density consisted of dance studios, dance schools, dance halls, bowling centres, physical fitness facilities, public golf courses, private sports and recreation clubs within each buffer. Baseline (2013) data for retail and recreation densities were used in the current study. Parks and sports fields consisted of the number of parks and sports fields present within each buffer was collected in 2012. Walk Scores for each school were calculated in August 2021 based on school addresses. Walk Score is a publicly available website that provides a walkability metric based on walking routes and distance to amenities within a 30-minute walk from an address, along with population density, and other road metrics (https://www.walkscore.com/methodology.shtml). Due to the lag between the data collection period for student responses (2013-17) and when Walk Scores were collected (2021), Walk Scores were coded into 4 groups based on the Walk Score website (https://www.walkscore.com/how-it-works/), "car dependent" 1 (Walk Score: ≤24, almost all errands require a car), "car dependent" 2 (Walk Score:25-49, most errands require a car), "somewhat walkable" (Walk Score:50-69, some errands require a car), and "very walkable" (WalkScore:70-80, most errands can be accomplished by foot). No schools had a high enough Walk Score (90 - 100) to be coded a "walker's paradise". This coding scheme was used as it is less sensitive to any changes to the built environment that may have occurred between 2013 and 2021.

2.4. Outcomes

Moderate- to vigorous- intensity physical activity. Each year participants were asked to report how many minutes of physical activity (both moderate and hard [vigorous]) they did on each of the previous seven days. This included any physical activity during physical education, lunch, after school, in the evenings, and in their spare time. Responses were recorded in hours and 15-minute intervals. Weekly MVPA was calculated by converting the hours to minutes and summing the responses from both questions. To calculate the amount of MVPA per day, the weekly MVPA variable was divided by seven. These items have demonstrated moderate test-retest reliability (ICC = 0.75); and slight criterion validity for MVPA (ICC = 0.25) against accelerometers (Leatherdale et al., 2014).

Active Transportation. Each year, participants were asked to report on how they usually travel to and from school. For each question, students were given seven response options and were instructed to choose the one they spend most time doing. The response options were: By car (as a passenger); by car (as a driver); by school bus; by public bus, subway, or streetcar; by walking; by bicycling; or other. As done previously, response options were used to create two categories: Passive: (by car as a passenger, by car as driver, by school bus/public bus/subway/streetcar) and active (by walking, by bicycling), while participants who identified "other" or who had missing data were excluded from the analysis (Lau et al., 2017). Separate variables were calculated for mode of travel to school and from school.

2.5. Covariates

Student sex, race/ethnicity, typical week of physical activity, and spending money were considered student-level covariates. These were measured via single items on the COMPASS student questionnaire. Students had six response options for race/ethnicity (White, Black, Asian, Latin, Aboriginal (First Nations, Metis, Inuit), Other) and could select more than one category. Based on frequency distributions, race/ethnicity was dichotomized (White/Other). Typical week of physical activity was assessed via one question with three response options (yes/no, more active/ no, less active) and was dichotomized (yes/no). Students had eight response options for spending money ($0, $1-$5, $6-$10, $11-$20, $21-40, $41-$100, $100+, I don't know). This was re-coded into seven categories and treated as a continuous variable, where those who responded "I don't know" or did not respond were coded as missing. Time (coded as baseline (2013-14), year 2 (2014-15), year 3 (2015-16), year 4 (2016-17) was also considered a covariate.

Potential school-level covariates were area-level median household income, school location, and season of data collection. Area-level median household income was derived by matching the first three digits of school postal codes with census profiles (http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/download-telecharger/comp/page_dl-tc.cfm?Lang=E). Location was categorized into 4 groups based on the population and population density: Large urban population centre ≥100,000 and ≥400/km^2; Medium population centre (30,000 to 99,999 and ≥400/km^2); Small population centre (1000 to 29,999 and ≥400/km^2), and rural (≤ 999). Based on frequency distributions, location was dichotomized (large/medium population centre and small population centre/rural). Season was based on the time of year that students completed the survey and categorized as Winter (December 21/22 – March 20), and Non-Winter (March 21 – June 20/21: September 22/23 – December 21/22) according to National Research Council of Canada classifications (https://nrc.canada.ca/en/certifications-evaluations-standards/canadas-official-time/3-when-do-seasons-start).

2.6. Statistical Analysis

Descriptive statistics for student variables were performed using PROC SURVEY MEANS and PROC SURVEYFREQ with CLUSTER statements due to the hierarchical nature of the data. PROC FREQ and PROC MEANS were used for school-level baseline descriptive characteristics. For continuous variables, histograms were used to detect potential univariate outliers. Residuals from PROC MIXED were used to assess model assumptions of normality, homogeneity, and linearity (Tabachnick & Fidell, 2019). However, when residuals were requested in a three-level model, the model failed to converge due to insufficient memory. As such, a two-level model that accounted for only the clustering of time within students was run to check residual plots. Student MVPA was positively skewed and was square root transformed after observing improvements in residual scatter plots (Tabachnick & Fidell, 2019). Based on the distributions, community environment data at the 500m buffer were categorized into presence/absence. Additionally, at 1000m and 1500m buffers, environmental variables were trichotomized at frequencies corresponding to ≤ 25%, 26-74%, ≥75% (Tabachnick & Fidell, 2019). Multilevel models were used to account for the hierarchical nature of the data (time nested within students, students nested within schools). For continuous outcomes, linear mixed effects models with a random intercept were run using PROC MIXED to determine how much variance in the outcomes were explained at the school- level in an unconditional model. Intraclass correlation coefficients revealed approximately 2% (ICC = 1.89 %) of the variance was explained at the school level, suggesting that the school environment is modestly associated with student square root transformed MVPA (SQRT-MVPA). For binary outcomes, generalized linear mixed effects models were initially run using PROC GLIMMIX to calculate the intraclass correlation coefficients for binary outcomes, however these models failed to converge. Therefore, generalized estimating equations using PROC GENMOD were instead run with a repeated statement to allow for hierarchical clustering without the need for an explicit calculation of random effects. In these models, the school variable was identified as the subject, and the student variable was identified as the subcluster. A model with only covariates was run first. Significant ($p < .05$) covariates were retained in the subsequent models. To examine the changes in MVPA and the likelihood of active school travel over time (objective 1) a model with significant covariates was performed. To examine the association between the built environment and MVPA and active school travel (objective 2), separate regression models were run for each environmental exposure with significant covariates. To determine whether trends in adolescent MVPA and active school travel were moderated by the built environment (objective 3), an interaction term (exposure*time) was included in a second set of separate regression models. Statistical significance was defined as $p < 0.05$ for all analyses.

3. Results

Participant and school characteristics are presented in Table 1 and Table 2, respectively. There were 11,813 students from 87 schools, 11,562 students from 87 schools, 10,250 students from 81 schools, and 6926 students from 70 schools in years 1, 2, 3, and 4, respectively.

The changes in adolescent square root transformed moderate- to vigorous–intensity physical activity (SQRT-MVPA) and active school travel over a four-year period are presented in Table 3. In general, adolescent SQRT-MVPA and the likelihood of active school travel declined over the four-year period. Specifically, for each year that passed, adolescents engaged in less MVPA (B = -0.50, -0.54, -0.46), and were less likely to actively travel to (OR = 0.94, 95%CI: 0.90, 0.97) or from (OR = 0.88, 95%CI: 0.85, 0.92) school.

The associations between the built environment and square root transformed MVPA, when time is held constant are presented in Table 3. At the 1000 m and 1500 m buffer, a medium density of recreational facilities was significantly associated with more SQRT-MVPA (1000m: B= 0.31, 95% CI: 0.05, 0.56; 1500m: B=0.32, 95% CI: 0.06, 0.59) compared to a low density of recreational facilities. Additionally, higher density of parks at the 1500 m buffer was significantly associated with more SQRT-MVPA (medium: B = 0.33, 95%CI: 0.06, 0.59; high: B = 0.35, 95% CI: 0.06, 0.63) compared to a low density.

In the models examining the moderating effect of the built environment, The Walk Score*time interaction, and the park*time interactions at 500m and 1000m buffer were significant (Table 3). These moderating effects are shown in Figure 1. Larger declines SQRT-

MVPA were observed among students attending schools in areas where almost all errands require a car (car dependent 1), or where some errands require a car (somewhat walkable). Although students attending schools with higher park densities (500m, 1000m) had more SQRT-MVPA at baseline they also experienced larger declines in SQRT-MVPA over time.

Associations between built environment characteristics and active travel to school are presented in Table 3. Holding time constant, a recreation facility within 500 m of the school was associated with a higher likelihood (OR = 1.50, 95% CI: 1.09, 2.09) of active travel to school compared to not having a recreation facility within 500 m from the school.

In the models examining the moderating effect of the built environment, significant interactions were observed for Walk Score group*time, park density at 1000m*time, retail density at 1000m*time and 1500m*time, and recreation density a 1500 m*time (Table 3). These moderating effects are shown in Figure 2. For walkability, students attending schools in very walkable areas had the lowest odds of active travel to school at baseline, however the likelihood of these students engaging in active travel to school increased over time, whereas the likelihood of active travel to school decreased over time among other students. Regarding the other environmental exposures, it appeared that students attending schools in very walkable areas or attending schools that had higher park densities at 1000m and 1500m had an increased or stable likelihood of engaging in active travel to school over time, while all other groups saw a decreased likelihood of active travel over time.

Associations between built environment characteristics and active travel from school are also presented in Table 3. Holding time constant, students attending schools with a medium retail density at 1000 m had a higher likelihood (OR = 1.54, 95% CI: 1.04, 2.30) of active travel from school compared to students attending schools with a low retail density.

In the models examining the moderating effect of the built environment, significant interactions were observed for Walk Score group*time, stores at 500 m*time, and parks at 1000m*time (Table 3). These moderating effects are shown in Figure 3. For walkability, students attending schools in very walkable areas were the least likely at baseline to engage in active travel to school, however the likelihood of these students engaging in active travel from school increased over time. Students attending schools in car dependent areas saw a relatively stable decline over time in the likelihood of engaging in active travel to school, whereas students in somewhat walkable areas saw the largest decline in the likelihood of engaging in active travel to school over time. Regarding retail density at 500m, it appeared that students attending school with >1 store at baseline had a higher likelihood of active travel from school. That being said, the likelihood of engaging in active travel from school over time declined among all students, with the decline being larger among students attending schools with no stores. Finally, students attending schools with medium and high park density (1000m) were more likely to engage in active travel from school at baseline. However, a decline in the likelihood of active travel from school was observed among all students regardless of park density at 1000m, with the decline occurring among students attending schools with a medium park density.

4. Discussion

The objectives of this study were to examine the changes in adolescent MVPA and active school travel, examine associations between the built environment surrounding the school and adolescents' MVPA and active school travel, and determine whether the built environment moderates these behaviours over time. Our findings suggest that in general, adolescent SQRT-MVPA and the likelihood of active school travel decrease over time. Further, some positive associations existed between built environment features and both SQRT-MVPA and active transportation, with time held constant. Higher recreation, park, and retail densities appeared to maintain the likelihood of active travel to school, however, they did not prevent the decline in likelihood of active travel from school that occurred over time. Though students attending schools in very walkable areas were less likely to engage in active school travel at baseline, they were the only group that experienced an increased likelihood of active travel both to and from school over time.

Our finding that adolescent SQRT-MVPA declined over the four-year period is consistent with previous research indicating a continued decline in physical activity throughout adolescence (Dumith et al., 2011; Kemp et al., 2019). Though, a recent analysis of two longitudinal cohort studies in Canada found that several MVPA trajectories exist among adolescents, with some adolescent MVPA remaining stable, while others either decreasing or increasing (Riglea et al., 2021). As such, more nuanced research looking into the different trajectories of MVPA in this age group may be helpful for identifying factors that contribute to stable, increasing, or decreasing trends. Our finding that active school travel declined during adolescence is both supported and contrasted in the Canadian literature. For instance, in a longitudinal sample of children and adolescents from various Canadian provinces a decline in active school travel was observed (Pabayo et al., 2011). Whereas an increase in active school travel over time among adolescents was observed among a sample of adolescents from New Brunswick, an eastern Canadian province (Larouche et al., 2019). Given the evidence of differing trajectories for MVPA during adolescence (Pabayo et al., 2011), it is also possible there are different trajectories of active school travel that occur during adolescence. Previous research using 2012/13 and 2013/14 data from the COMPASS study found little change in travel mode to or from school over a one-year period (Lau et al., 2017), though a longer duration may be required.

The finding that parks and recreational facilities were positively associated with SQRT-MVPA, with time held constant, is supported by some previous studies. For instance, in a previous systematic review, null or positive associations were found between higher neighbourhood densities of parks and recreational facilities with subjective adolescent physical activity (Ding et al., 2011). However, the current study differs from their review in that the focus was on the built environment surrounding the school rather than the home neighbourhood environment. Though it is possible there is an overlap between the buffers used in the current study and adolescent's home neighbourhood environment, this cannot be confirmed. To overcome this limitation, previous research has used global positioning systems, geographic information systems, and accelerometers to pinpoint locations where physical activity is occurring. For instance, others have classified adolescent time and physical activity into five locations (at home, near home, at school, near school, other)(Carlson et al., 2016). This approach could help explain why students attending schools with higher park densities had larger decreases in SQRT-MVPA over time by identifying locations where decreases in MVPA occurred.

Our findings showed associations between built environment features and active school travel differed at varying buffer sizes. For instance, retail density was significant at the 1500 m buffer, but not 1000 m or 500 m. Differences in associations based on buffer size and shape have been previously reported and highlight the need for multiple buffer sizes to be considered in future studies(Kerr et al., 2006). The positive associations between retail density at 1500 m and active travel to and from school is partially supported by previous research. For example, a recent study in Spain found land-use mix (a composite variable that includes aspects of the retail environment) within a 1350 m buffer around the school to be positively and negatively associated with the frequency of active school travel among urban and rural adolescents, respectively (James et al., 2014). In the current study, only students in very walkable areas had an increased likelihood of active travel to and from school over time, despite having a lower likelihood at baseline. It is unclear why students attending schools in very walkable areas had a lower odds of active school travel at baseline, though it could be due to parental safety concerns (Javier et al., 2020). For instance, in the current study it is possible that parental concerns were high at baseline due to their child's age (i.e., 13 years old) and fact that they were starting a new school but relaxed over time as they child grew older.

To better understand the associations between the built environment surrounding the school and adolescent active school travel, an assessment of adolescent's distance to school as a potential effect modifier may be needed (Panter et al., 2008). Previous studies have identified threshold distances (1.35 km [Spain](Rodríguez-López et al., 2017), 2 km [Belgium](Van Dyck, Bourdeaudhuij, et al., 2010), 2.25 km [New Zealand](Mandic et al., 2020), 2.41km [Ireland](Nelson et al., 2008), 3 km [England](Chillón et al., 2015), Cycling: 4 km [New Zealand](Mandic et al., 2020), Ireland](Nelson et al., 2008), 8 km [Belgium](Van Dyck, Cardon, et al., 2010) for when the proportion of students engaging in active school travel modes start to decrease. It is therefore possible that the features measured within the buffer distances (<1.5 km) used in the current study would have limited impact on students who lived father away. This may also explain why students attending schools with lower Walk Score categories had a decreased odds of active school travel over time as lower point values would have been assigned to school neighbourhoods with amenities that are farther away (https://www.walkscore.com/methodology.shtml).

Future research examining the associations between built environment characteristics and adolescent MVPA and active school travel will likely benefit from the combined used of devices such as accelerometers, global positioning systems, and geographic information systems in addition to self-report measures. Such technology could measure the active school travel route, as well as the type, intensity, location, and co-participation of physical activity with friends or family to be identified(Borghese & Janssen, 2018; Carlson et al., 2016; Dunton et al., 2012; Jankowska et al., 2015). In a longitudinal design, these measures would be helpful to determine where and why changes in physical activity are occurring. It would not have been feasible to incorporate these objective measures across the entire COMPASS sample given it is a large multi-location school-based study that is designed to collect information on multiple health outcomes and health behaviours. Though, this approach could be considered in a subsample of COMPASS or in future research. Where adding device-based measures is not feasible, including self-reports of distance or time between home and school may be beneficial (Nelson et al., 2008; Woods & Nelson, 2014).

Given the findings from the current study, interventions aiming to increase physical activity through active school travel among adolescents in less walkable areas is warranted. Such interventions should give special consideration to adolescents who live farther away. For instance, schools could work with their municipalities to create remote drop offs where students who live farther away could be driven or bussed to/from a designated location away from the school (Bejarano et al., 2021). Previous research has shown that a mix of motorized and active transport active school travel has yielded more physical activity than motorized transport alone and could be a feasible alternative for students living beyond threshold distances (Kek et al., 2019). Further assessment of other personal, social, and environmental attributes and how they relate to adolescent MVPA and active school travel may also be required (Mandic et al., 2020; Mandic et al., 2015; Sallis et al., 2006).

The main strengths of this study include the large sample size, and longitudinal design. However, several limitations should be acknowledged. For instance, MVPA and active transportation were self-reported, which may lead to inaccurate estimates of actual MVPA and or active school travel. Because all students responded to the same items year after year, it is reasonable to expect that these biases would be the same over time. Second, this study only examined objectively measured built environment features < 1.5 km from the school and did not consider adolescent perceptions of the schools' surrounding built environment. Given that perceptions of the environment may be different than objective assessments (Rodgers, 1982), future research may benefit from combining both objective and subjective assessments of the environment to better understand their impact on adolescent physical activity (Ding et al., 2011). Further, the student questionnaire did not assess the distance that students live from school. Given distance to destination has been identified as a main moderator of active travel in youth (Panter et al., 2008), and consistent correlate of active school travel (Wong et al., 2011) , future research will benefit from this inclusion. Finally, while this study adjusted for individual and school-level characteristics, there is a possibility of residual confounding due to unmeasured variables.

5. Conclusion

These findings suggest that some features of the school's surrounding built environment are positively associated with adolescent SQRT-MVPA and active school travel when adjusting for time. However, SQRT-MVPA and the likelihood of active school travel still decreased over time for most students. Though higher park, retail, and recreation densities appeared to help maintain the likelihood of active travel to school, the same effect was not apparent for active travel from school. Only adolescents attending schools in very walkable areas had an increased likelihood of active travel to and from school over time. Given few school built environments in the current study were categorized as "very walkable" and none were categorized as a "walker's paradise," there is an apparent need to improve the walkability of school neighbourhoods by targeting increased access to amenities, population density, and other road characteristics (e.g., intersection density, block length) used to create Walk Scores. One way to do this could be to zone or re-zone land parcels for mixed use (e.g., retail outlets on street level with residential units above) in vacant or pre-existing areas around schools. Such initiatives may support active school travel among adolescents. Assessing the impact of municipal changes through natural experiment designs would strengthen the literature providing a better understanding of how a change in the environment may impact adolescent physical activity (Craig et al., 2012; Rhodes & Quinlan, 2015). Interventions and school programming may also be needed to increase adolescent physical activity in areas where school neighbourhood environments are characterized as being less walkable, or have lower park, recreation, and retail densities.

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Authors' contributions

STL contributed to the funding acquisition, project administration, investigation and editing of the manuscript. SH conceived of the study, and contributed to the project administration, performed the statistical analyses, and drafted the manuscript. KB contributed to the project administration, assisted with the statistical analyses, and editing to the manuscript. VC helped draft the manuscript and contributed to the project administration. JCS revised and edited the manuscript for intellectual content. All authors have read and approved the final version of the manuscript and agree with the order of presentation of the authors.

Competing interests

The authors declare that they have no competing interests.

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Table 1

Characteristics of included participants from the COMPASS study at time 1 (2013/14), time 2 (2014-15), time 3 (2015-16), and time 4 (2016-17)

Characteristic	Time 1	Time 2	Time 3	Time 4
Students	N = 11813	N = 11562	N = 10250	N = 6926
Schools	N = 87	N = 87	N = 81	N = 70
Age [a]	13.6 (13.3, 13.9)	14.6 (14.3, 14.9)	15.6 (15.3, 16.0)	16.6 (16.3, 17.0)
Missing [b]	35 (0.3%)	23 (0.2 %)	24 (0.2 %)	20 (0.3 %)
Sex				
Female	5710 (48.3 %)	5611 (48.5 %)	4936 (48.2 %)	3355 (48.4 %)
Missing [b]	87 (0.7 %)	64 (0.6 %)	114 (1.1 %)	112 (1.6 %)
Ethnicity				
White	8810 (74.6 %)	8536 (73.8 %)	7269 (70.9 %)	4811 (69.5 %)
Other	2909 (24.6 %)	2976 (25.7 %)	2932 (28.6 %)	2084 (30.1 %)
Missing [b]	94 (0.8 %)	50 (0.4 %)	49 (0.5 %)	31 (0.4 %)
Spending money				
$0	2437 (20.6 %)	1999 (17.3 %)	1401 (13.7%)	774 (11.2 %)
$1 - $5	1199 (10.1 %)	877 (7.6 %)	470 (4.6 %)	209 (3.0 %)
$6 -$10	1323 (11.2 %)	997 (8.6 %)	561 (5.5 %)	252 (3.6 %)
$11-$20	2192 (18.6 %)	1864 (16.1 %)	1180 (11.5 %)	605 (8.7 %)
$21-$40	1468 (12.4 %)	1499 (13.0 %)	1261 (12.3 %)	691 (10.0 %)
$41-$100	932 (7.9 %)	1375 (11.9 %)	1637 (16.0 %)	1230 (17.8 %)
$100+	541 (4.6 %)	1452 (12.6 %)	2568 (15.1 %)	2416 (34.9 %)
Missing [b]	1721 (14.6 %)	1469 (12.7 %)	1172 (11.4 %)	749 (10.8 %)
Typical Week				
Yes	7613 (64.4 %)	7606 (65.8 %)	6814 (66.5 %)	4486 (64.8 %)
Missing [b]	261 (2.2 %)	190 (1.6 %)	114 (1.1 %)	145 (2.1 %)
MVPA [a]	116.2 (67.9, 177.2)	106.3 (58.3, 170.4)	103.4 (57.9, 167.4)	95.9 (49.8, 161.2)
Missing [b]	328 (2.8%)	359 (3.1 %)	286 (2.8%)	203 (2.9 %)
Form of Transport				
ATTS	1540 (13.0%)	1554 (13.4 %)	1297 (12.7 %)	761 (11.0 %)
Missing	484 (4.1 %)	449 (3.9 %)	487 (4.8 %)	337 (4.9 %)
ATFS	2224 (18.8 %)	2188 (18.9%)	1777 (17.3 %)	931 (13.4 %)
Missing [b]	1273 (10.8%)	1275 (11.1%)	1313 (12.8 %)	945 (13.6%)

Note. [a] Skewed continuous variables are expressed as Median (interquartile range). Categorical variables are expressed as frequencies (%). [b] Participants with missing data at all time points were not included in further analyses.

Abbreviation: ATTS = active travel to school; ATFS = active travel from school

Table 2

Characteristics of included schools from the COMPASS study at time 1 (2013/14), time 2 (2014-15), time 3 (2015-16), and time 4 (2016-17)

Environmental Variable		Time 1 n = 87	Time 2 n = 87	Time 3 n = 81	Time 4 n = 70
Location					
Large Urban/Medium		45 (51.7%)	44 (50.6%)	43 (53.1%)	36 (51.4%)
Small/Rural		42 (48.3%)	43 (49.4%)	38 (46.9%)	34 (48.6%)
Median School-Level Income		72845.97 (17052.53)	73486.98 (16939.33)	73568.94 (17771.74)	71863.39 (16261.78)
Season					
Winter		24 (27.6 %)	23 (26.4 %)	15 (18.5%)	11 (15.7%)
Built Environment					
Walk Score					
Car dependent 1		34 (39.1%)	35 (40.2%)	31 (38.3%)	28 (40.0%)
Car dependent 2		33 (37.9%)	32 (36.8%)	30 (37.0%)	26 (37.1%)
Somewhat walkable		16 (18.4%)	16 (18.4%)	15 (18.5%)	13 (18.6%)
Very walkable		4 (4.6%)	4 (4.6%)	5 (6.2%)	3 (4.3%)
500 m Buffer					
Stores	None	20 (23.0%)	19 (21.8%)	18 (22.2%)	14 (20.0%)
	≥1	67 (77.0%)	68 (78.2%)	63 (77.8%)	56 (80.0%)
Recreation	None	54 (62.1%)	55 (63.2%)	51 (63.0%)	44 (62.9%)
	≥1	33 (37.9%)	32 (39.8%)	30 (37.0%)	26 (37.1%)
Parks	None	54 (62.1%)	53 (60.9%)	49 (60.5%)	45 (64.3%)
	≥1	33 (37.9%)	34 (39.1%)	32 (39.5%)	25 (37.7%)
1000 m Buffer [b]					
Stores	Low	25 (28.7%)	26 (29.9%)	22 (27.2%)	21 (30.0%)
	Medium	40 (46.0%)	40 (46.0%)	39 (48.2%)	34 (48.6%)
	High	22 (25.3%)	21 (24.1%)	20 (24.7%)	15 (21.4%)
Recreation	Low	35 (40.2%)	35 (40.2%)	31 (38.3%)	27 (38.6%)
	Medium	30 (34.5%)	29 (33.3%)	28 (34.6%)	24 (34.3%)

	High	22 (25.3%)	23 (26.4%)	22 (27.2%)	19 (27.1%)
Parks	Low	24 (27.6%)	23 (26.4%)	20 (24.7%)	15 (21.4%)
	Medium	33 (34.9%)	34 (39.1%)	42 (51.2%)	31 (44.3%)
	High	30 (34.5%)	30 (34.5%)	19 (23.5%)	24 (24.3%)
1500 m Buffer [b]					
Stores	Low	22 (25.3%)	23 (26.4%)	20 (24.7%)	18 (25.7 %)
	Medium	43 (49.4%)	44 (50.6%)	42 (51.9%)	38 (54.3 %)
	High	22 (25.3%)	20 (23.0%)	19 (23.5%)	14 (20.0%)
Recreation	Low	28 (32.2%)	29 (33.3%)	24 (29.6%)	23 (32.9%)
	Medium	34 (39.1%)	34 (39.1%)	34 (42.0%)	30 (42.9%)
	High	25 (28.7%)	24 (27.6%)	23 (28.4%)	17 (34.3%)
Parks	Low	30 (34.5%)	30 (34.5%)	27 (33.3%)	21 (30.0%)
	Medium	32 (36.8%)	33 (37.9%)	31 (38.3%)	30 (42.9%)
	High	25 (28.7%)	24 (27.6%)	23 (28.4%)	19 (27.1%)

Note. [b] Variable is trichotomized based on quartiles ≤25%, 26 -74%, ≥75%. Car dependent 1 = Almost all errands require a car, Car dependent 2 = Most errands require a car, Somewhat walkable = Some errands can be accomplished on foot, Very walkable = Most errands can be accomplished on foot.

Table 3

Longitudinal Associations between the Built Environment and Student MVPA and Active School Travel

Parameter		SQRT MVPA B (95% CI)	p-value for interactions	ATTS OR (95% CI)	p-value for interactions	ATFS OR (95% CI)	p-value for interactions
Time		**-0.50 (-0.54, -0.46)**		**0.94 (0.90, 0.97)**		**0.88 (0.85, 0.92)**	
Built Environment							
Walk Score							
Car dependent 1		Ref	**0.0146**	Ref	**0.0007**	Ref	**<.0001**
Car dependent 2		-0.11 (-0.37, 0.14)		1.37 (0.91, 2.07)		1.43 (0.98, 2.10)	
Somewhat walkable		-0.02 (-0.33, 0.30)		1.46 (0.99, 2.15)		**1.67 (1.14, 2.46)**	
Very walkable		0.30 (-0.21, 0.80)		0.98 (0.38, 2.51)		0.98 (0.39, 2.47)	
500 m Buffer							
Stores	None	Ref	0.6947	Ref	0.1707	Ref	**0.0356**
	≥1	-0.17 (0.44, 0.10)		1.50 (0.95, 2.37)		1.47 (0.94, 2.29)	
Recreation	None	Ref	0.06	Ref	0.2677	Ref	0.3051
	≥1	-0.04 (-0.28, 0.19)		**1.50 (1.08, 2.08)**		1.34 (0.99, 1.83)	
Parks	None	Ref	**0.0118**	Ref	0.0808	Ref	0.0766
	≥1	**0.26 (0.05, 0.49)**		1.17 (0.84, 1.63)		1.11 (0.81, 1.52)	
1000 m Buffer							
Stores	Low	Ref	0.6305	Ref	**0.0201**	Ref	0.0619
	Medium	0.09 (-0.17, 0.36)		1.28 (0.88, 1.87)		1.31 (0.90, 1.90)	
	High	0.10 (-0.21, 0.41)		1.56 (1.00, 2.43)		1.49 (0.98, 2.29)	
Recreation	Low	Ref	0.3988	Ref	0.0844	Ref	0.3121
	Medium	**0.31 (0.05, 0.56)**		1.16 (0.80, 1.67)		1.10 (0.78, 1.56)	
	High	0.16 (-0.12, 0.44)		1.24 (0.79, 1.94)		1.14 (0.74, 1.75)	
Parks	Low	Ref	**0.0462**	Ref	**0.0025**	Ref	**0.0245**
	Medium	0.27 (-0.02, 0.55)		1.27 (0.83, 1.95)		1.30 (0.85, 1.99)	

	High	**0.30 (0.01, 0.59)**		1.48 (0.97, 2.28)		1.43 (0.94, 2.16)	
1500 m Buffer							
Stores	Low	Ref	0.4419	Ref	**0.001**	Ref	0.0518
	Medium	0.25 (-0.03, 0.52)		**1.59 (1.09, 2.32)**		**1.54 (1.04, 2.30)**	
	High	0.14 (-0.17, 0.46)		1.43 (0.89, 2.31)		1.37 (0.86, 2.20)	
Recreation	Low	Ref	0.3057	Ref	**0.0253**	Ref	0.133
	Medium	**0.32 (0.06, 0.59)**		1.30 (0.89, 1.90)		1.16 (0.79, 1.71)	
	High	0.10 (-0.18, 0.38)		1.17 (0.75, 1.82)		1.11 (0.72, 1.71)	
Parks	Low	Ref	0.1775	Ref	0.0641	Ref	0.1223
	Medium	**0.33 (0.06, 0.59)**		1.23 (0.83, 1.84)		1.09 (0.74, 1.59)	
	High	**0.35 (0.06, 0.63)**		1.26 (0.82, 1.96)		1.21 (0.79, 1.85)	

Note. MVPA was square root transformed Participants with missing data across all time points were excluded the analysis. MVPA models are adjusted for time, student sex, typical week of physical activity, spending money, location, and season. Active school travel models adjusted for time, student sex, ethnicity, weekly spending money, and season. [a] Significant interaction with time. Bolded values are significant ($p < .05$).

Abbreviations: ATFS = active travel from school; ATTS = active travel to school; SQRT MVPA = square root transformed moderate-to vigorous- intensity physical activity; OR = odds ratios; 95% CI = 95% confidence intervals.

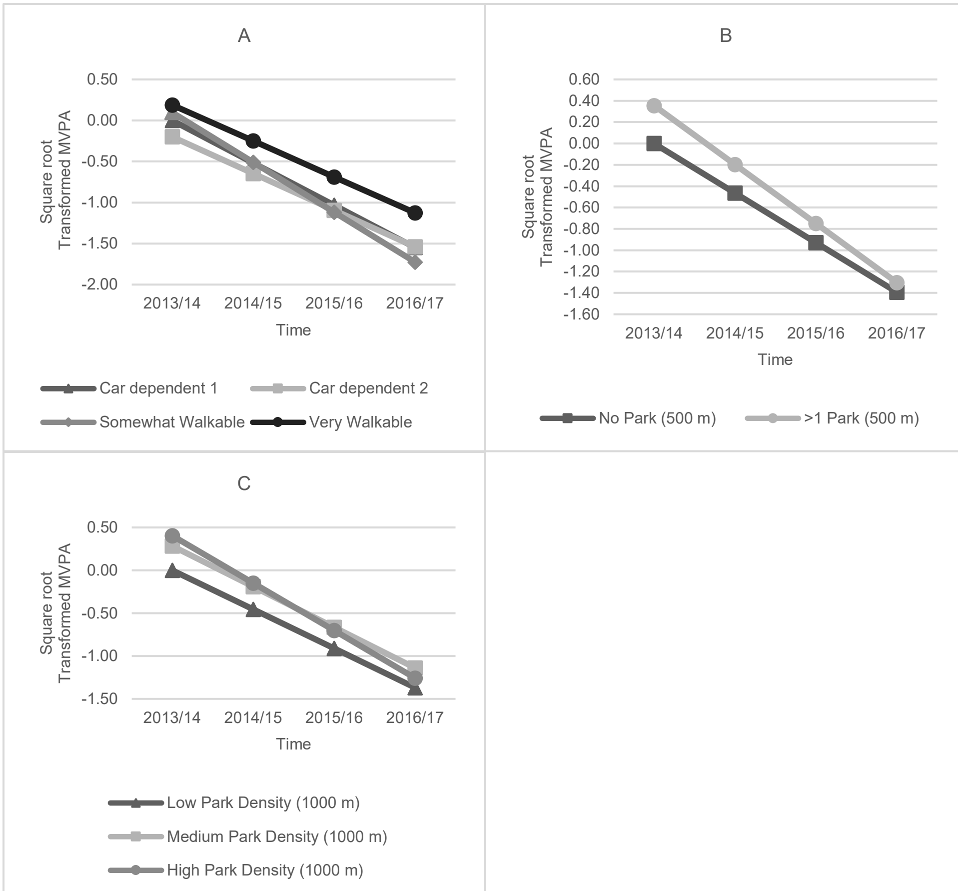

Fig. 1. Moderated effect of Built Environment on Square Root Transformed MVPA over time. Beta coefficients for square root transformed MVPA over time are shown by A) Walk Score B) Park density at 500 m buffer and C) Park density at 1000 m buffer.

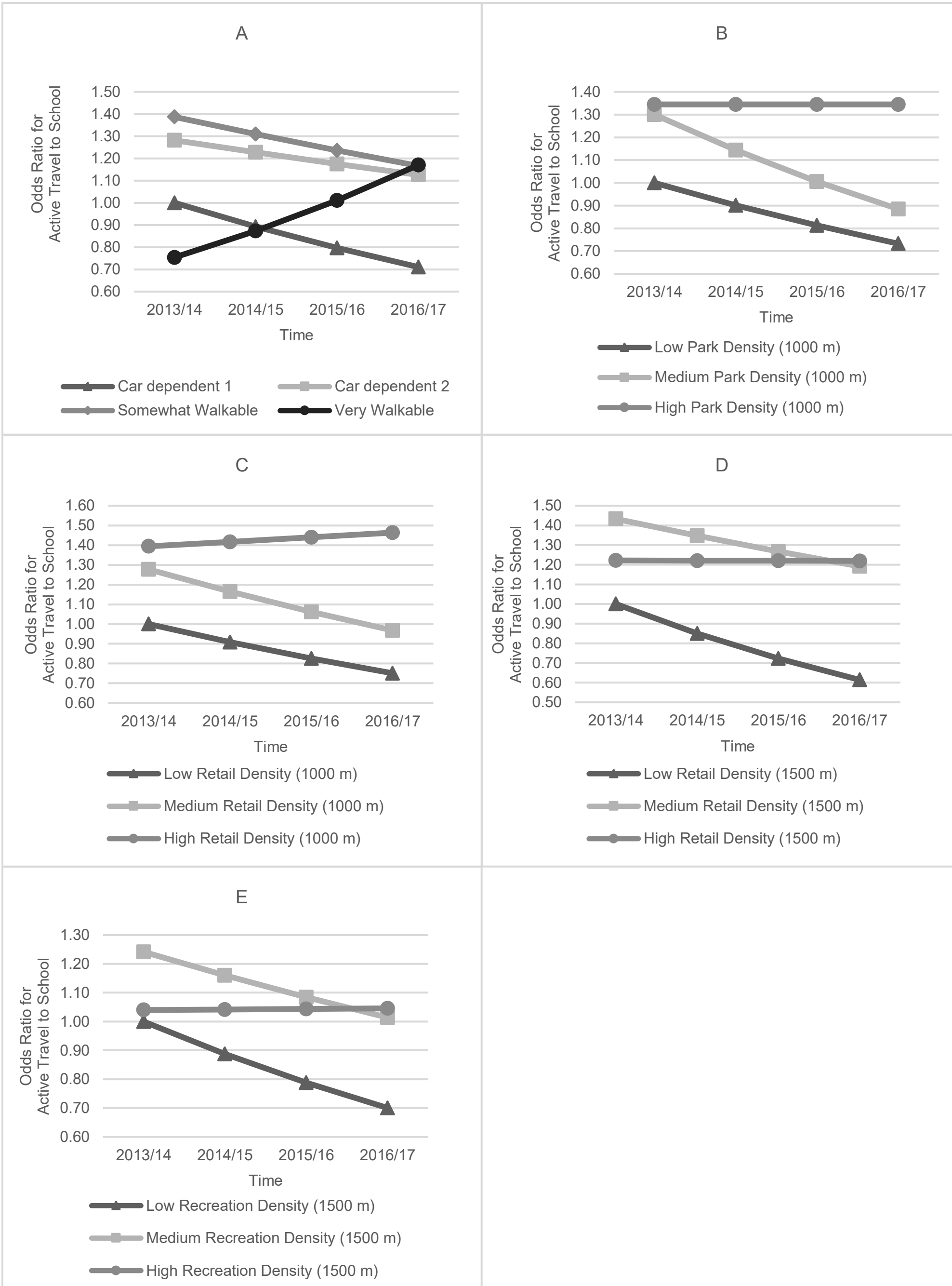

Fig. 2. Moderated effect of Built Environment on Active Travel to School over time. Odds Ratios for Active Travel to School are shown by A) Walk Score B) Park density at 500 m buffer and C) Retail density at 1000 m buffer D) Retail density at 1500 m buffer E) Recreation density at 1500 m buffer.

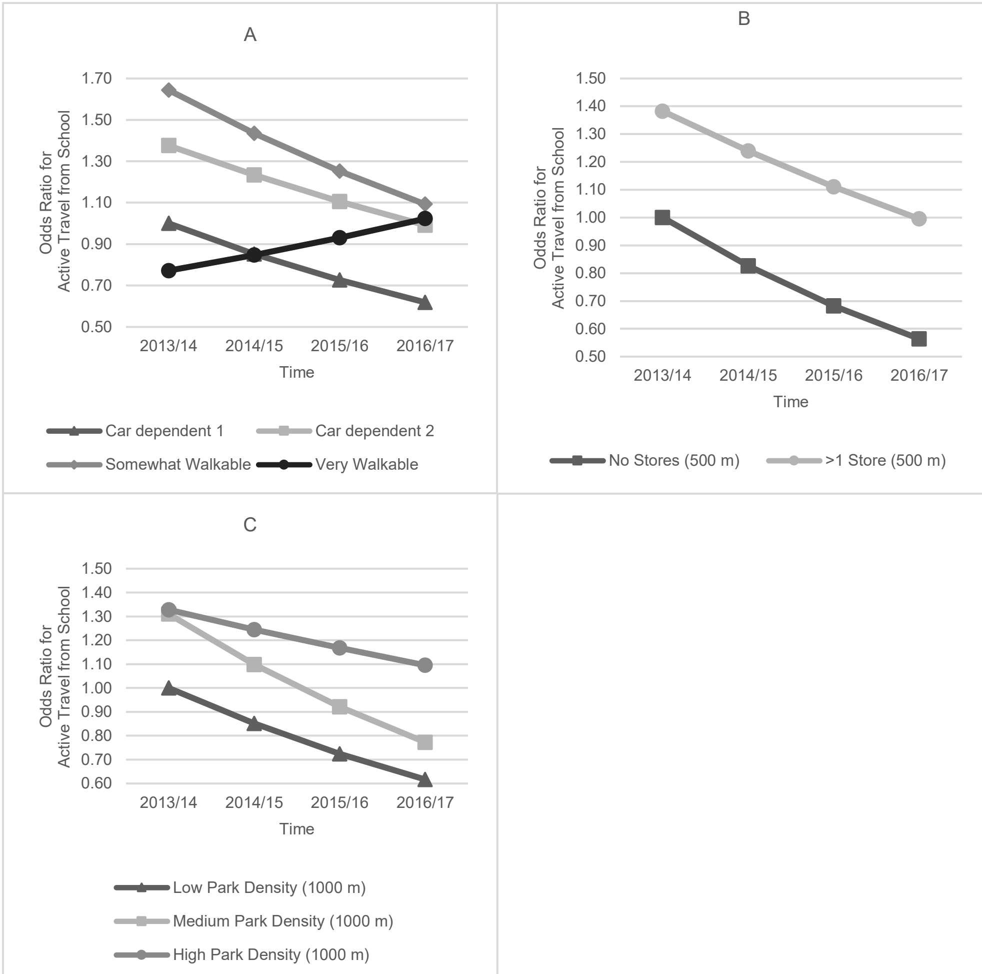

Fig. 3. Moderated effect of Built Environment on Active Travel from School over Time Odds Ratios for Active Travel from School are shown by A) Walk Score B) Retail density at 500 m buffer and C) Park density at 1000 m buffer

Chapter 6: Discussion

The overall objective of this dissertation was to identify features of the environment that supported physical activity among preschool children (3 to 4 years), school-aged children (aged 6-10 years), adolescents (aged 13 to 18 years), and parents (adults with preschool children). Though behaviour was not measured in study 1, parents of preschool children identified several neighbourhood destinations, some neighbourhood design and aesthetic features, and most neighbourhood social and safety features as being important for their active recreation, their child's active play, and their coactivity (Hunter et al., 2022). In study 2, among school-aged children, only a few environmental features were found to be associated with pedometer derived steps per day or parent reported physical activity. Specifically, residential density, traffic hazards, walking and cycling infrastructure, and perceived barriers appeared to be important for children's physical activity. In study 3, stores, recreational facilities, parks, and walkability were found to be important predictors of physical activity among adolescents. Therefore, across studies, findings aligned with ecological models that postulate there are modifiable contextual factors that may influence behaviour (Sallis & Owen, 2015; Spence & Lee, 2003). Although limited, some interactions between ecological levels were also observed. Specifically, some significant moderating effects of household income in study 1 (Hunter et al., 2022) and socioeconomic position and season in study 2 were found.

A novel aspect of this dissertation work is the ability to draw conclusions on features of the environment that may be important for physical activity across multiple age groups. Some common findings did emerge across studies. First, features that promote walking appeared important for all the age groups studied in this dissertation. Second, it appears that parks may support physical activity for multiple age groups, including preschool children and their parents as well as adolescents. It is important to note that although parks were measured in study 2 (school-aged children), they were included in a composite score along with 22 other features. Therefore, conclusions from this work can not be made regarding parks and physical activity for this age group. Third, traffic safety and aesthetics could be important for physical activity of preschool children and their parents as well as children aged 6-10 years. The common finding regarding features that promote walking will be discussed in further detail in this section, given this feature appeared important across all age groups that were included in this dissertation.

The findings from study 1 regarding the importance of features supportive of walking are supported by qualitative evidence (Hnatiuk et al., 2020) and a few associations in quantitative studies (Aarts et al., 2012; Lovasi et al., 2011). However, most quantitative associations between features that promote walking and physical activity of preschool children (Aarts et al., 2010; Carson et al., 2014; Colley et al., 2019; Ezeugwu et al., 2021; Lovasi et al., 2011; Xu et al., 2017) or their parents (Carson et al., 2014) have been non-significant. Other proximal factors of the social ecological model, such as parental perceptions of safety, parental perceptions of child competence, parental value of physical activity (for themselves or their child), and the barrier of time, were also identified as important in Study 1 and among qualitative research (Hnatiuk et al., 2020; Hunter et al., 2022; Mitchell et al., 2012). Therefore, considering these proximal factors when examining the association between walkable neighbourhood features and physical activity of preschool children and their parents may help address the inconsistent findings observed in the current evidence base.

In study 2 of this dissertation, significant associations between the perceived infrastructure for safety and walking and parental reported physical activity were observed, though this was only evident during the winter. It is possible that the infrastructure for safety and walking are more important for physical activity in the winter months, given the snow and ice in Alberta, Canada, which make it more challenging to use other neighbourhood features, such as playgrounds and parks. In their systematic review, Ding et al., (2011), reported null or positive associations between pedestrian safety structures and walking or cycling facilities with physical activity in children aged 3-12 years (Ding et al., 2011). However, the included studies did not examine the modifying effect of season (de Vries et al., 2007; Evenson et al., 2006; Evenson et al., 2007; Fyhri & Hjorthol, 2009; Johansson, 2006; Kerr et al., 2008; Mollie Grow et al., 2008; Oreskovic et al., 2009; Rodriguez & Vogt, 2009; Rosenberg et al., 2009; Saksvig et al., 2007; Zhu et al., 2008; Zhu & Lee, 2009).Therefore, the fact that study 2 examined the moderating effects of season represents a novel contribution to the evidence base.

As children get older and are granted more independent mobility (Riazi et al., 2022), the neighbourhood environment may be more meaningful for physical activity (McGrath et al., 2015). For instance, in a meta-analysis performed by McGrath et al., (2015), larger effect sizes were observed between features that promoted walking and MVPA in adolescents compared to school-aged children. Further, a recent Canadian study using nationally representative samples across childhood (e.g., preschool children, school-aged children, adolescents) did not find significant associations between walkability and accelerometer-derived physical activity of preschool children or school-aged children. However, significant associations with walkability and school-aged children's parent reported unorganized physical activity (negative), adolescent accelerometer-derived physical activity (MVPA: positive; LPA: negative), and adolescent self-reported transportation physical activity (positive) were observed (Colley et al., 2019). While greater independent mobility may be one reason for why the neighbourhood walking environment becomes more important for adolescents, it could also be that the neighbourhood walking environment is more important for transport-related physical activity rather than their general physical activity (Colley et al., 2019; D'Haese et al., 2015; Giles-Corti et al., 2005; Williams et al., 2018). This partially aligns with study 3 of this dissertation, where adolescents attending schools in neighbourhoods considered very walkable had an increased likelihood of engaging in active school travel over time. Though this is also contrasted as it was observed that adolescents attending schools in neighbourhoods that were car dependent or somewhat walkable had pronounced decreases in MVPA, whereas MVPA remained highest across the four-year period among adolescents attending schools in neighbourhoods that were very walkable. Thereby suggesting that the walkability of the school neighbourhood could be important for both adolescent MVPA and active school travel over time. When possible, it will be beneficial to use a natural experiment design to examine the impact that changes to the school neighbourhood environment have on adolescent MVPA and active school travel (Benton et al., 2016).

Future research directions

The findings from this dissertation combined with previous literature also highlight several important directions for future research. The main purpose of this dissertation was to examine associations between the neighbourhood environment and identify whether there were any features that emerged as important for multiple age groups. Although it appeared features that support walking was important across studies, the ability to draw firm conclusions is limited due to the inconsistent methodology across studies. For instance, study 1 measured perceptions only without measuring actual behaviour, while study 3 used objective measures of the environment and relied on adolescent self-report for behaviour. This could lead to differential associations being significant, as evidenced by study 2, where there was no overlap in significant associations between objective and subjective measures. Previous research has suggested that perceived and objective measures of the neighbourhood environment may be measuring two different constructs (Orstad et al., 2017). In fact, among some adults there is evidence to suggest a 'mismatch' may exist in which perceptions of neighbourhood walkability may be opposite of objective measures (Gebel et al., 2009). The same may be true for measuring perceptions of the parent versus the child (Rosenberg et al., 2009). As such capturing children's perceptions of their neighbourhood environment when trying to examine associations with physical activity may yield additional insight (Holt et al., 2009; Holt et al., 2008; Rosenberg et al., 2009; Veitch et al., 2007). Therefore, it appears capturing both perceived (i.e., parental and child) and objective measures of the neighbourhood are needed in future research to gain a more comprehensive understanding of the associations between neighbourhood walkability and physical activity (Ding et al., 2011; Orstad et al., 2017).

This dissertation focused primarily on the direct association between neighbourhood features and physical activity. Although there were some intrapersonal and intrapersonal characteristics that were adjusted for, they were mainly demographic in nature (e.g., age, ethnicity, income). Our understanding of how the neighbourhood environment and in particular walkable features of the neighbourhood environment, impact physical activity could have been enhanced by measuring other proximal intrapersonal and interpersonal factors of the social ecological model (McLeroy & et al., 1988). For instance, intrapersonal characteristics such as self-efficacy was identified in recent reviews as being positively associated with physical activity in school-aged children (Cortis et al., 2017; Hill et al., 2020) and adolescents (Cortis et al., 2017; Hill et al., 2020; João et al., 2021) and could moderate the associations between the neighbourhood environment and physical activity (D'Haese et al., 2016; Deforche et al., 2010). Though the extent to which intrapersonal characteristics, such as self-efficacy, moderate environment-physical activity associations may differ based on type of physical activity as well as the neighbourhood attribute examined ((D'Haese et al., 2016; Deforche et al., 2010; Rhodes et al., 2018). Further, the predictive capacity would likely be enhanced if the self-efficacy being measured were behaviour and context specific (e.g., self-efficacy for walking in the neighbourhood) (D'Haese et al., 2016; Giles-Corti et al., 2005). It has also been previously hypothesized that "psychological factors mediate most of the relationship between extra-individual factors and physical activity" (Spence & Lee, 2003, p 16). Recently, self-efficacy/perceived behavioural control was found to mediate the relationship between aspects of the built environment (e.g., land-use, connectivity, walkability) and physical activity, though this evidence is mostly based on adult samples (Rhodes et al., 2020). In terms of interpersonal factors, parental rules and restrictions around indoor and outdoor play (Sallis et al., 1993), the amount of independent mobility parents allow their child to have (Larouche et al., 2020), decisions over where, when, and with who their children play (Loptson et al., 2012) along with parental perceptions of vulnerability to crime or unsafe aspects of their neighbourhood (Foster & Giles-Corti, 2008) could mediate or moderate the relationship between features of the neighbourhood environment and children's (preschool children, school-aged children), adolescents', and parents' physical activity. Together, it seems apparent that our understanding of the association between the neighbourhood environment and physical activity would be enhanced by including proximal intrapersonal and interpersonal factors and testing for mediation and moderation in future research (Spence & Lee, 2003).

Future research may also benefit from measuring aspects of other settings where children and their parents are active (Gubbels et al., 2014; Rosenberg et al., 2009; Spence & Lee, 2003). For instance, it has been reported that preschool children and school-aged children spend most of their time playing closer to home (Cerin et al., 2016; Corder et al., 2011; Holt et al., 2008). Among adolescents, Carlson et al. (2016) found approximately one-third of adolescents' time spent in MVPA was spent at or near their home. Therefore, physical characteristics of the home environment (e.g., size of yard, equipment, indoor space) may be important factors to consider in future research as they moderate (e.g., those who have a small yard may be more likely to play out in the neighbourhood) the impact of neighbourhood features (Spence & Lee, 2003). Stratifying the responses in study 1 by characteristics of the home environment could have yielded insightful results pertaining to whether certain neighbourhood features are more important among families with more or less supportive home environments. In studies 2 and 3 the association between the neighbourhood and surrounding school environment with children's physical activity and adolescent MVPA may have been different based on whether their home had features that support physical activity. For active school travel in study 3, home characteristics of potential interest could have been whether they possessed a bike, skateboard, scooter, or other equipment that would facilitate active travel, along with if they had vehicle that could be used (either to drive themselves or to be driven) to get to school. Including an assessment of the characteristics of these other settings in future research may help better understand the impact the neighbourhood environment has on physical activity.

Though there were several significant associations observed among this dissertation, further specifying the behaviour, its context, and better matching the environmental correlates could have yielded stronger associations (Giles-Corti et al., 2005; Timperio et al., 2015). Nonetheless, attempts were made to uncover the differential associations between the environment and different types of physical activity (behaviour specificity). For instance, in study 1, parents were asked to report features relevant for their active recreation, their child's active play, and coactivity, though few differences in relevant features by activity type were observed. In study 3, the relationship between the built environment and self-reported overall moderate to vigorous intensity physical activity and active school travel were examined. However, across all studies, there was a lack of context (e.g., where physical activity took place). For instance, in study 1 it could have specified that parents should report on the physical activity types that take place in and around their local neighbourhood (Giles-Corti et al., 2005). Similarly, the context of where the steps were taken was missing from study 2, and in the self-reports of MVPA in study 3. By not examining the context of these behaviours it is anticipated that the strength of associations could have been underestimated and any true associations could have gone undetected (Giles-Corti et al., 2005; Timperio et al., 2015).

For future research, the issue of behaviour and context specificity may be partially alleviated by combining accelerometers and global positioning systems, geographic information systems, and subjective measures. For instance, Borghese and Janssen (2018) used accelerometry and GPS in addition to geographic information systems and subjective measures to classify physical activity into several types (active travel, curriculum-based physical activity, outdoor active play, organized sport). Others have used these devices to pinpoint locations where children and their parents are active (Dunton et al., 2012), and how much time is spent being active in differing locations (Carlson et al., 2016; Cerin et al., 2016; Klinker et al., 2014). However, there are still some behaviours that may not be accurately captured by these devices such as swimming, and some forms of resistance training (e.g., upper body exercises) that may still need to be collected via subjective measures. The strength of measuring physical activity with accelerometers and global positioning systems is it can obtain an unbiased and accurate measure of the location where physical activity is performed (Jankowska et al., 2015). However, the characteristics of these locations and the motivation behind choosing said locations will also need to be assessed (Jankowska et al., 2015). Therefore, it may be best for future research to combine these devices with subjective assessments of characteristics of locations that participants perceive contributes to their activity selection and destination (Jankowska et al., 2015).

It should be noted that although having participants wearing multiple devices as well as completing subjective assessments is ideal, it may limit the number of participants included in the study due to the time and resources needed and the amount of data processing that is required (Borghese & Janssen, 2018). When possible, larger studies, such as studies 2 and 3 could have a feasible subsample of participants wear multiple devices and complete subjective assessments. When this is not an option, larger studies should consider the incorporating the concepts of behaviour and context specificity when developing survey items. This may require the research team to focus on only one specific type of behaviour, as it has been suggested that reporting on several behaviours is more difficult than reporting on several correlates (Giles-Corti, 2005). Focussing on multiple contexts of a specific behaviour could eliminate or at least reduce the chance of spatial misclassification due to spatial polygamy (the concept that people engage in physical activity in more than one area) (Matthews, 2011) and residential trap (the concept that people do not engage physical activity outside their residential neighbourhood) (Cummins, 2007) that may be present when using static neighbourhood boundaries (perceived or objective). To overcome this, measuring activity spaces (locations where people are active and the route(s) to get there) via self-report or GPS devices have been suggested (Duncan & Kawachi, 2018).

In terms of study design, this dissertation utilized both cross-sectional and longitudinal analyses. While the longitudinal analyses are stronger than cross-sectional analyses and add to the current literature, future research would benefit from capitalizing on natural experiments where municipalities make changes to the environment. Natural experiments would allow for the measurement of behaviour (e.g., resident active travel) before and after a change in the environment occurred (e.g., installation of neighbourhood sidewalks). To capitalize on these changes made by municipalities, researchers will need to collaborate with key stakeholders (e.g., government officials, developers) to ensure adequate time and resources (McLaren et al.,2019). For example, School Streets is a recent initiative by the City of Vancouver and the Vancouver School Board that involved having a car-free zone (i.e., blocked off street) around school drop-off and pick-up times. Municipal representatives identified streets that were suitable (e.g., no driveways, residents had alternative routes), school staff volunteered to run daily operations, and resident feedback was obtained (City of Vancouver, n.d.). Though it is unclear if a research team was involved or whether the results will be published in the scientific community, this would have been an opportunity to use a natural experiment design. Another approach that may be beneficial and is community driven is a participatory research design. In this approach, researchers work with community members and key stakeholders to design the research methods. This was recently done in the City of Edmonton (Nykiforuk et al., 2012) and a rural northern Alberta community (Nykiforuk et al., 2018), in which researchers, residents, and community partners worked together to develop community walking maps. Such an approach could enhance the uptake of the evidence generated and be used to inform future developments and research (Raine et al., 2010; Raine et al., 2012).

Given this dissertation focussed only on select age groups throughout childhood and parents of preschool children, it may be valuable for these findings to be considered in light of the evidence from other age groups such as older adults and people with mobility impairments. It may also be important for future research to consider whether differential associations exist based on other sociodemographic intersections aligning with the social determinants of health (e.g., gender, race, education, disability) in Canada (Raphael et al., 2020). Such examination may be performed through targeted recruitment approaches as well as through effect modification in statistical analyses.

Practical Implications

Canadian cities have experienced more growth in the suburbs compared to their inner-city cores (Gordon et al., 2018). From a physical activity perspective, suburban neighbourhoods are typically characterized by less walking and cycling infrastructure, less public transportation, and more personal vehicles (Gordon et al., 2018; McCormack et al., 2019; Vitale et al., 2019). If suburban growth continues, it will be important to consider aspects that make these types of neighbourhoods supportive of physical activity. The findings from this dissertation suggest that focussing on aspects that make neighbourhoods more walkable (e.g., sidewalks and sidewalk maintenance, pedestrian crosswalks, traffic calming measures) may be important for preschool aged children and their parents, along with school-aged children. While this dissertation did not measure the home neighbourhood environment for adolescents, it appears that having schools with walkable surroundings are important for facilitating active school travel. Walk Scores are composed of various features (routes, distance to amenities, density of amenities, other road metrics) so it is unclear which features are most important for intervention and can be targeted by urban planners for community development. Further, there are likely different considerations that need to be taken when developing new neighbourhoods compared to renovating pre-existing ones. Nonetheless, finding ways to increase schools' proximity to residential areas, nearby amenities, and multiple walking routes appear to benefit active school travel in this age group.

For schools located in neighbourhoods where change is unlikely or unfeasible, programs that support active school travel may be needed.

Several features were identified as important for the physical activity of preschool children and their parents in study 1. However, it may be beneficial for municipalities with budgetary constraints to target those that appear most feasible (e.g., remove litter, animal waste, glass vs sidewalk installation). Based on the findings from study 2, it will be important for municipalities looking to densify their neighbourhoods to retain or provide public open spaces such as parks or playgrounds for children to remain active. Further, in places where winters are long and characterized by snow and ice, ensuring the walking and cycling infrastructure is well-maintained could be beneficial for year-round physical activity. Finally, based on the findings from study 3, increasing the walkability (i.e., WalkScores) of school neighbourhoods could be achieved through mixed land use developments characterized by retail outlets on the street level with residential units above. While not explicitly studied in this dissertation, such developments would result in increased amenities and population density; two factors that comprise the WalkScore. Previous research has suggested external funding is integral for built environment changes (Wilson & Mitra, 2020). Therefore, planners and developers may use this evidence to support their funding applications to government agencies (e.g., municipal, provincial, federal).

These findings are also promising given most features that support walking measured in this dissertation (except for amenities used in the Walk Score metric) have not been impacted by the provincial/territorial and municipal attempts control the spread of COVID-19. While closures to playgrounds, recreation centers, schools, and organized sports may affect children's physical activity having neighbourhoods that support walking and cycling may act as line of defense to preserve physical activity levels across ages groups and maybe even promote increased family physical activity during the pandemic (Riazi et al., 2021). In fact, a recent Canadian study found parents of children aged 5-15 years reported cycling and walking/hiking as a family were the two most common outdoor hobbies during the first (April 2020) and second (October 2020) waves of pandemic (Moore et al., 2021). As such, calls have been made for spaces that support these activities be preserved to promote healthy behaviours during the pandemic (Moore et al., 2021). In fact, some suggest the constraints enforced by the COVID-19 pandemic has highlighted the need for cities to rethink their urban design in the post-pandemic world (Moreno et al., 2021). One concept that appears to have gained some traction is the “15-Minute-City”, where basic amenities are accessible to residents within 15-minutes by walking or cycling (Moreno et al., 2021).

Conclusion

Based on the findings from this dissertation, features of the home and school neighbourhood environment appear to be important for physical activity among preschool children and their parents, along with school-aged children and adolescents. While few associations were moderated by socioeconomic position or season, these should be continued to be explored as primary objectives in future research as they may add clarity to observed associations. Although the neighbourhood environment was measured differently in each of the dissertation studies, it appears some neighbourhood features that supported walking and cycling were important for physical activity across age groups. This research could have been strengthened if consistent measures of the environment and behaviour across age groups were used. Further, addressing more proximal intrapersonal (e.g., self-efficacy) or interpersonal (e.g., parental characteristics) factors along with characteristics of the home environment (e.g., equipment, yard space) may have had potential mediating or moderating effects. Finally, combining subjective measures with devices such as accelerometers and global positioning systems, along with geographic information systems and direct observation may have provided further insight into the types, intensity, locations, and nature (alone vs with others) along with the reasons for choosing those locations. Such methods would address issues of behaviour and context specificity, as well as spatial misclassification. Nonetheless, the findings from this dissertation may be used to inform the development of new residential communities, upgrade existing communities that lack supportive physical activity characteristics (e.g., walking and cycling infrastructure), as well as inform active school travel initiatives. Though these findings are based on data collected pre- COVID-19 pandemic, the results pertaining to walking and cycling infrastructure appear to still be relevant. More research is needed to examine how these, along with other associations (e.g., destinations, social environment) change over time as the COVID-19 pandemic ensues and in the post-pandemic world.

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Appendix

Table 6.1

Supplementary Table 1

Features Included in the Current Study

Feature	Source
Destinations	
Parks	NEWS, NEWS-Y, MAPS-Global, PIN3, ANC
Dog parks	Added by authors
Playgrounds	NEWS-Y, PANES, PIN3, ANC
Schools	NEWS, NEWS-Y, MAPS-Global, ANC
Sports fields	NEWS-Y, ANC
Courts (e.g., basketball, tennis)	NEWS-Y, ANC
Arenas/ice rinks	Added by authors
Community league hall	MAPS MAPS-Global
River valley or ravine	Adapted from NEWS-Y
Design	
Main roads	NEWS-Y
Cul-de-sacs	NEWS, NEWS-Y MAPS, ANC
Quiet streets	NEWS, Mujahid et al., 2007
Block length	NEWS, NEWS-Y
Trails	NEWS, MAPS-Global, PANES, PIN3, ANC
Sidewalks	NEWS, NEWS-Y, MAPS, PANES, PIN3, ANC
Social	
Your friends/family	NEWS, Veitch et al., 2014
Your child's friends	Veitch et al., 2014
Other people walking/exercising	PANES, PIN3, Mujahid et al., 2007
Other children playing outside	Veitch et al., 2014
Knowing who your neighbours are	NEWS, Veitch et al., 2014
Trusting people in your neighbourhood	Mujahid et al., 2007
Safety	
Street lighting	NEWS, NEWS-Y, MAPS, MAPS-Global
Low Crime	NEWS, NEWS-Y, PANES, Mujahid et al., 2007
Low Vehicle Traffic	NEWS, NEWS-Y
Daylight	Adapted from NEWS, NEWS-Y, PANES
Sidewalk maintenance	NEWS, PANES MAPS
Pedestrian crosswalks	NEWS, NEWS-Y, ANC
Aesthetics	

Cleanliness (e.g., no animal waste, litter, glass)	NEWS, MAPS, MAPS-Global, PIN3, ANC, Mujahid et al., 2007
No graffiti	MAPS, MAPS-Global, PIN3, ANC
Attractive houses	NEWS, NEWS-Y
Natural features (e.g., water, trees)	NEWS, NEWS-Y, MAPS, MAPS-Global
Landscaped features (e.g., plants, flowers)	NEWS, NEWS-Y MAPS-Global

Note. NEWS = Neighborhood Environment Walkability Scales (ICC subscales range 0.58 to 0.80). NEWS-Y = Neighborhood Environment Walkability Scales – Youth (ICC subscales range: 0.56-0.87). PIN3 = PIN3 Neighbourhood Audit Instrument (Cronbach's Alpha subscales range: 0.43-0.73), MAPS = Micro Audit of Pedestrian Streetscapes (MAPS Original: Subscale ICC's range 0.753-0.847, MAPS-Global: median ICC= 0.92, range 0.50-1.00); PANES= Physical Activity Neighbourhood Environment Survey (Subscale ICCs range 0.52-0.88); ANC = Active Neighbourhood Checklist (Cohen's k statistic: Mean = 0.68, range = 0.21-1.00). Veitch et al., 2014 (Cronbach's alpha for Social Network = 0.78 (reported in Hunter et al., 2020)), Mujahid et al., 2007 (Cronbach's alpha subscale range = 0.73-0.83).

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Table 6.2

Supplementary Table 2

Differences in the Proportion of Parents who agreed Neighbourhood Features were relevant between Physical Activity Domains

Feature	Parent Active Recreation		Child Active Play		Parent-Child Coactivity	
	n	%	n	%	n	%
Destinations						
Parks	142/145	97.93	139/142	97.89	141/145	97.24
Dog parks	38/145	26.21	35/143	24.48	35/145	24.14
Playgrounds [a]	139/145	95.86	143/144	99.31	141/145	97.24
Schools [b, c]	116/144	80.56	97/140	69.29	88/144	61.11
Sports fields	98/143	68.53	98/144	68.06	88/144	61.11
Courts	63/142	44.37	54/144	37.50	60/144	41.67
Arenas/ice rinks	91/143	63.64	94/144	65.28	99/144	68.75
Community league hall [a, b]	85/144	59.03	73/144	50.69	70/144	48.61
River valley or ravine [b+, c,]	96/145	66.21	91/144	63.19	110/145	75.86
Design						
Main roads	70/143	48.95	63/144	43.75	62/144	43.66
Cul-de-sacs	59/142	41.55	69/143	48.25	68/144	47.22
Quiet streets	129/142	90.85	124/143	86.71	125/145	86.21
Block length	55/139	39.57	63/144	43.75	61/144	42.36
Trails	125/144	86.81	116/143	81.12	120/145	82.76
Sidewalks [a, b]	142/145	97.93	130/143	90.91	131/145	90.34
Social						
Your friends/family	125/145	86.21	128/144	88.89	119/144	82.64
Your child's friends [b, c]	119/145	82.07	126/144	87.50	104/144	72.22
Other people walking/exercising	87/145	60.00	79/144	54.86	81/144	56.25
Other children playing outside [b, c]	121/145	83.45	130/144	90.28	109/144	75.69
Knowing who your neighbours are [b, c]	119/145	82.07	119144	82.64	109/143	76.22
Trusting people in your neighbourhood [b, c-]	139/145	95.86	134/144	93.06	125/143	87.41
Safety						
Street lighting [a]	133/145	91.72	123/144	85.42	125/145	86.21
Low Crime	135/145	93.10	132/143	92.31	134/145	92.41
Low Vehicle Traffic [b]	124/145	85.52	128/143	89.51	134/145	92.41
Daylight [a]	124/145	85.52	134/144	93.06	129/145	88.97
Sidewalk maintenance [c]	132/145	91.03	125/144	86.81	135/144	93.75

Pedestrian crosswalks [a]	133/145	91.72	123/144	85.42	126/145	86.90
Aesthetics						
Cleanliness [b, c]	143/144	99.31	143/144	98.61	139/145	95.86
No graffiti	88/143	61.54	83/143	58.04	81/144	56.25
Attractive houses [a, b]	70/144	48.61	52/144	36.11	54/145	37.24
Natural features [b]	127/144	88.19	118/144	81.94	121/144	84.03
Landscaped features	102/144	70.83	90/143	62.94	102/143	71.33

Note. Values represent the proportion of parents who agreed the item was “important” or most “most important”.

[a] Significant difference in the proportion between Active Recreation and Active Play ($p < .05$).

[b] Significant difference in the proportion between Active Recreation and Coactivity ($p < .05$).

[c] Significant difference in the proportion between Active Play and Coactivity ($p < .05$).

- Differences were no longer significant ($p > .05$) in sensitivity analyses where not applicable responses were coded as missing.

+ Differences became significant ($p < .05$) in sensitivity analyses where not applicable responses were coded as missing.

Table 6.3

Supplementary Table 3

Differences in the Proportion of Parents who perceived Neighbourhood Features as Being Relevant for Parent's Active Recreation by Household Income.

Feature	Low Income (n = 57)		High Income (n = 82)		Rao-Scott X^2
Household Income	n	%	n	%	
Destinations					
Parks	56	98.25	80	97.56	0.06
Dog parks	19	33.33	18	21.95	5.28*
Playgrounds	55	96.49	79	96.34	0.00
Schools	43	76.79	68	82.93	0.41
Sports fields	40	71.43	55	67.90	0.16
Courts (e.g., basketball, tennis)	28	49.12	33	41.77	0.56
Arenas/ice rinks	34	59.65	55	68.75	0.88
Community league hall	38	66.67	45	55.56	2.10
River valley or ravine	35	61.40	59	71.95	3.96*
Design					
Main roads	29	51.79	38	46.91	0.41
Cul-de-sacs	19	33.93	39	48.15	1.29
Quiet streets	52	92.86	73	90.12	0.32
Block length	20	37.04	33	41.77	0.82
Trails	45	80.36	76	92.68	10.27*
Sidewalks	55	96.49	81	98.78	0.67
Social					
Your friends/family	49	85.96	71	86.59	0.02
Your child's friends-	51	89.47	63	76.83	4.64*
Other people walking/exercising	39	68.42	46	56.10	0.89
Other children playing outside	52	91.23	65	79.27	6.32*
Knowing who your neighbours are	48	84.21	66	80.49	0.55
Trusting people in your neighbourhood	56	98.25	78	95.12	1.03
Safety					
Street lighting	55	96.49	72	87.80	4.49*
Low Crime	53	92.98	76	92.68	0.01
Low Vehicle Traffic	47	82.46	72	87.80	0.78
Daylight	50	87.72	69	84.15	0.50
Sidewalk maintenance	54	94.74	73	89.02	1.88
Pedestrian crosswalks	52	91.23	75	91.46	0.00
Aesthetics					
Cleanliness (e.g., no animal waste, litter, glass)	57	100	80	98.77	
No graffiti	36	64.29	48	59.26	0.37
Attractive houses	29	50.88	37	45.68	0.20

Natural features (water, trees)	50	87.72	72	88.89	0.06
Landscaped features (e.g., plants, flowers)	41	71.93	56	69.14	0.06

Note. N = 139. Values represent the proportion of parents who agreed the item was "important" or most "most important". Empty cells indicate a Chi-square analysis could not be performed due to one cell having a 0-cell count.

***** A significant difference (p < .05) between lower and higher household income groups in the proportion of parents who agreed the item was "important" or "most important".

- Differences were no longer significant (p > .05) in sensitivity analyses where not applicable responses were coded as missing.

Table 6.4

Chapter 3: Supplementary Table 4

Differences in the Proportion of Parents who perceived Neighbourhood Features as Being Relevant for Child's Active Play by Household Income.

Feature	Low Income (n = 57)		High Income (n = 82)		Rao-Scott X^2
Household Income	n	%	n	%	
Destinations					
Parks	55	98.21	78	97.50	0.08
Dog parks	18	32.14	15	18.52	12.74*
Playgrounds	56	98.25	81	100.00	
Schools	37	67.27	57	72.15	0.39
Sports fields	42	73.68	52	64.20	1.43
Courts (e.g., basketball, tennis)	23	40.35	29	35.80	0.31
Arenas/ice rinks	37	64.91	54	66.67	0.08
Community league hall	37	64.91	34	41.98	7.51*
River valley or ravine	37	64.91	52	64.20	0.01
Design					
Main roads	28	49.12	33	40.74	1.45
Cul-de-sacs	28	49.12	39	48.75	0.00
Quiet streets	47	82.46	71	88.75	1.07
Block length	26	45.61	34	41.98	0.24
Trails	44	78.57	69	85.19	1.42
Sidewalks	52	92.86	73	90.12	0.35
Social					
Your friends/family	48	84.21	76	93.83	2.53
Your child's friends	50	87.72	71	87.65	0.00
Other people walking/exercising	36	63.16	40	49.39	1.52
Other children playing outside	53	92.98	71	87.65	1.48
Knowing who your neighbours are	50	87.72	65	80.25	1.02
Trusting people in your neighbourhood	53	92.98	76	93.73	0.03
Safety					
Street lighting	52	91.23	65	80.25	2.19
Low Crime	52	91.23	74	92.50	0.06
Low Vehicle Traffic	52	91.23	70	87.80	0.89
Daylight	52	91.23	76	93.83	0.38
Sidewalk maintenance	52	91.23	68	83.95	1.78
Pedestrian crosswalks	50	87.72	68	83.95	0.86
Aesthetics					
Cleanliness (e.g., no animal waste, litter, glass)	56	98.25	81	100.00	
No graffiti	33	58.93	45	55.56	0.13
Attractive houses	21	36.84	28	34.57	0.07

Natural features (water, trees)	46	80.70	68	83.95	0.15
Landscaped features (e.g., plants, flowers)	35	62.50	51	62.96	0.00

Note. N = 139. Values represent the proportion of parents who agreed the item was "important" or most "most important". Empty cells indicate a Chi-square analysis could not be performed due to one cell having a 0-cell count.

***** A significant difference ($p < .05$) between lower and higher household income groups in the proportion of parents who agreed the item was "important" or "most important"

Table 6.5

Supplementary Table 5

Differences in the Proportion of Parents who perceived Neighbourhood Features as Being Relevant for Parent-Child Coactivity by Household Income.

Feature	Low Income (n = 57)		High Income (n = 82)		Rao-Scott X^2
Household Income	n	%	n	%	
Destinations					
Parks	55	96.49	80	97.56	0.15
Dog parks	17	29.82	17	20.73	5.10*
Playgrounds	56	98.25	79	96.34	0.85
Schools	37	64.91	47	58.02	1.16
Sports fields	36	64.29	48	58.54	0.39
Courts (e.g., basketball, tennis)	29	50.88	27	33.33	6.21*
Arenas/ice rinks	36	63.16	57	70.37	0.64
Community league hall-	34	59.65	34	41.98	6.76*
River valley or ravine	43	75.44	62	75.61	0.00
Design					
Main roads	23	41.07	37	46.25	0.29
Cul-de-sacs	28	49.12	38	46.91	0.03
Quiet streets	48	84.21	72	87.80	0.34
Block length	27	47.37	33	40.74	0.83
Trails	46	80.7	71	86.59	1.59
Sidewalks	51	89.47	75	91.46	0.11
Social					
Your friends/family	47	83.93	67	81.71	0.08
Your child's friends	45	80.36	54	65.85	2.89
Other people walking/exercising	38	67.86	40	48.78	2.96
Other children playing outside	45	80.36	59	71.95	0.64
Knowing who your neighbours are	45	81.82	60	73.17	1.68
Trusting people in your neighbourhood	50	89.29	71	87.65	0.09
Safety					
Street lighting	53	92.98	66	80.49	6.00*
Low Crime	52	91.23	76	92.68	0.10
Low Vehicle Traffic	51	89.47	77	93.60	1.19
Daylight	51	89.47	72	87.80	0.22
Sidewalk maintenance	55	96.49	74	91.36	1.94
Pedestrian crosswalks	53	92.98	68	82.93	2.25
Aesthetics					
Cleanliness (e.g., no animal waste, litter, glass)	56	98.25	78	95.12	1.19
No graffiti	32	57.14	45	54.88	0.05
Attractive houses	17	29.82	33	40.24	1.23

Natural features (water, trees)	48	84.21	69	85.19	0.01
Landscaped features (e.g., plants, flowers)	41	73.21	57	70.37	0.05

Note. N = 139. Values represent the proportion of parents who agreed the item was "important" or most "most important".

***** A significant difference ($p < .05$) between lower and higher household income groups in the proportion of parents who agreed the item was "important" or "most important".

- Differences were no longer significant ($p > .05$) in sensitivity analyses where not applicable responses were coded as missing.