A 4-SEASON LONGITUDINAL STUDY EXAMINING THE ASSOCIATION BETWEEN SEASONALITY, THE BUILT ENVIRONMENT AND SEDENTARY TIME IN 9-14 YEAR OLD CHILDREN LIVING IN A MID-WESTERN CANADIAN CITY.

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By

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ABSTRACT

Background: Canadian youth spend on average 8.6 waking hours of their day in a sedentary state, and consistently exceed recommended leisure hour screen-based sedentary limits of two hours per day. Sedentary behaviour (SB) is associated with an increased risk of overweight, obesity, cardiovascular disease and all-cause mortality. Understanding how the built environment and urban design may influence children's sedentary time (SED), in different social and physical contexts, addresses a significant gap in the scientific literature and contributes to promoting health in children.

Research Aim: This work seeks to examine how seasonal changes affect weekday school hour, leisure hour, total daily and location-specific SED in children and if this relationship is moderated by urban design. The relationship between SED and parental support or children's perception of this support and seasonality are also explored. Research Questions: (1) How do seasonal changes affect SED accumulation in children? (2) Are seasonal changes in SED moderated by neighbourhood built environment (BE)? and (3) Is parental support or children's perception of this support associated with activity behaviour outcomes in children?

Methodology: Families with children aged 9-14 years were recruited from the prairie city of Saskatoon, Canada. Location-specific, device-based SED was captured in children during three time frames over one year using GPS data loggers and accelerometers. Neighbourhood-level BE features were assessed using multiple audit tools and neighbourhood era design. Using a random intercept model, a multilevel modelling approach was taken to understand the relationship between seasons, demographic factors, BE and SED of children. Multilevel model outcomes were stratified by time- (total daily, leisure hour, school hour) and location-dependent SED (home, school, school park and park area).

Results: In multilevel models predicting SED outcomes, older children, those with obesity and children with decreased levels of moderate-to-vigorous physical activity consistently accumulated greater levels of SED. Over a child's entire day, and while at home or in school, children were significantly less sedentary in fall months but more sedentary in spring (vs winter) months. Neighbourhood-level pedestrian access and traffic safety in a child's home neighbourhood and safety from crime and traffic and universal accessibility in a child's school neighbourhood moderated the predicted effect of season on children's SED. Children who perceived screen time limitations by their parents accumulated significantly lower levels of SED and higher levels of MVPA year round. Similarly, children with parents who reported regulating screen time in their children accumulated significantly lower levels of SED and higher levels of MVPA year round.

Project Significance: This study provides greater and more nuanced detail about BE, season and sedentariness/activity in children living in a city with four distinct seasons. This new-found understanding of children's activity behaviours could shape infill and new urban development projects by providing necessary information to relevant public health policy architects, driving urban transformation and healthier cities year-round.

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DEDICATION

This thesis is dedicated to my beautiful family. I can never thank you enough for all the support and love you have given me throughout the years.

To my husband and best friend, Dan Johnson, for being everything I could ever wish for.

To my mother and father, Karin and Joe Lotoski, for instilling an endless love of learning and a spark of defiance for accepting what we are told. And to my sisters, Avila and Sabina, for joining me on this journey.

To my daughter, Farrah, a constant source of much-needed laughs.

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LIST OF ABBREVIATIONS

BE – Built environment

BMI – Body mass index

CSEP – Canadian Society for Exercise Physiology

GIS – Geographic information systems

GPS – Global positioning system

IMI – Irvine Minnesota Index

LPA – Light-Intensity Physical Activity

MLM – Multilevel Model

MPA - Moderate-Intensity Physical Activity

MVPA – Moderate-to-Vigorous Physical Activity

NALP – Neighbourhood Active Living Potential

NEWS – Neighbourhood Environment Walkability Scale

NEWS-Y – Neighbourhood Environment Walkability Scale - Youth

PA – Physical activity

SASK – Seasonality and Active Saskatoon Kids

SD – Standard deviation

SB – Sedentary behaviour

SED – Sedentary time

SEP – Socioeconomic position

SES – Socioeconomic status

VPA – Vigorous-Intensity Physical Activity

WHO - World Health Organization

GLOSSARY

Accelerometers: Piezoelectric devices worn by individuals, typically on the hip, arm or thigh, capable of detecting accelerations in one to three planes (1).

Actigraphy: A non-invasive device-based method of measuring activity behaviours in human populations. Accelerometry movement patterns are directly related to specific energy states, such as sleep, sedentary behaviour and physical activity, allowing activity behaviour surveillance of large populations over extended periods of time.

Body mass index (BMI): A measure of body mass (kg) relative to height (cm). In children and adults, BMI is expressed as standard deviations (SD) from the mean (based on an international reference sample population) and kg/m^2, respectively. In children, BMI is categorized into five primary categories: severe thinness (<-3 SD), thinness (<-2 SD>), normal weight (-2 SD ≤ x ≤ +1 SD), overweight (>+1SD, equivalent to BMI 25 kg/m^2 at 19 years) and obese (>+2SD, equivalent to BMI 30 kg/m^2 at 19 years) (2,3)

Built environment (BE): Anything that is built by humans, for humans, for the purpose of human activity (4).

Device-based physical behaviour: The use of electronic devices (*e.g.* accelerometers) to quantify physical movement through the measurement of body accelerations in up to three planes.

Global positioning systems (GPS): A satellite navigation system that provides users with global positioning paired with atomic clock timing information, allowing the creation of a temporal-spatial map of a GPS device (5).

Geographic information systems (GIS): “A system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data,” (6).

Irvine Minnesota Inventory (IMI): “An extensive audit tool aimed at measuring a broad range of BE features that may be linked to active living," (7). The IMI is comprised of 160, primarily binary, items assessing the absence or presences of specific BE features on a neighbourhood scale.

Light-intensity physical activity (LPA): Any waking behaviour of a person that does not result in sweat production or the shortness of breath. Light-intensity physical activity includes activities equivalent to 1.5≤MET<3 in adults, and 1.5≤MET<4 in children. Example: ‘incidental activities,’ including walking slowly and light household tasks (8).

Metabolic equivalent of task (MET): “One metabolic equivalent is defined as the amount of oxygen consumed while sitting at rest and is equal to 3.5 ml O_2 kg body weight^{-1} min^{-1}.” (9) Activities above the equivalent of sitting are expressed as a ratio of the activity metabolic rate over the metabolic rate of sitting or lying still.

Moderate-intensity physical activity (MPA): Any waking behaviour of a person while they are performing tasks intense enough to elevate the heart rate. Moderate-intensity physical activity behaviours include actions equivalent to $3 \leq MET < 6$ in adults and $4 \leq MET < 6$ in children (8,10,11). Example: walking briskly, skate boarding or playing games that require catching or throwing.

Neighbourhood Active Living Potential (NALP): A neighbourhood level audit tool aimed at measuring four themes of the built environment thought to be linked to active living.

Vigorous-intensity physical activity (VPA): Any waking behaviour of a person causing a substantial increase in heart rate and body temperature and a difficulty to speak without pausing for a breath. Vigorous-intensity physical activity behaviours include actions equivalent to $MET \geq 6$ in adults or $MET \geq 7$ in children (8,10,11). Example: running.

Physical activity (PA): "Any bodily movement produced by skeletal muscles that requires energy expenditure," (12). Physical activity includes physical actions equivalent to $MET \geq 1.5$ (11,13). Physical activity can be described as light, moderate or vigorous in nature, but often, and confusingly, only implies higher intensity movements limited to moderate-to-vigorous physical activity (14).

Physical behaviour: Any waking behaviour, inclusive of sedentary behaviour and light-, moderate- and vigorous-intensity physical activity.

Physical inactivity: "An insufficient physical activity level to meet present physical activity recommendations," (13). Physical inactivity often, confusingly, implies both light-intensity physical activity and sedentary behaviour.

Physical literacy: An individual's motivation, physical confidence, knowledge and understanding to value and take responsibility for engagement in and maintenance of physical activity throughout the life course (15–17).

Sedentary Behaviour (SB): Any waking behaviour of a person while they are in a sitting, reclined or lying position with very little movement of the whole body. Sedentary behaviours in children and adults with no physical limitation include actions with a $MET < 1.5$ (11,13,18,19). Examples: sitting in a chair, laying down while awake.

Sedentary Time (SED): "The time spent for any duration (e.g., per day, per week), in any context (e.g., at school/work), and at any intensity (e.g., standing in a line, working on an assembly line with no ambulation, working at a standing desk, sitting in a classroom) in stationary behavior," (13).

Socioeconomic status (SES): A composite measure capturing an individual or population's economic and social standing. SES often considers income, education and occupation (20).

Chapter 1 Introduction

1.1 General Introduction

The relationship between physical activity (PA) and our health has been a major focus of scientific research for approximately 80 years. In the early 2000s sedentary behaviour (SB) focused research emerged from activity-based research, adding to our understanding of the benefits of remaining active throughout life. Our understanding of the determinants of SB remains limited. SB can be defined as any waking (*i.e.* non-sleeping) behaviour of a person while they are in a standing, sitting or reclined position with very little movement of the whole body (13,19). SB and inactivity are not interchangeable states. Inactivity is defined as the lack of attaining an adequate amount of moderate-to-vigorous PA (MVPA) (8), which can encompass both light PA (LPA) and SB. The majority of activity-based research has primarily focused on MVPA and studies reporting SB often do so without rigour, pooling inactivity and true SB together (21).

The precarious combination of obesity, physical inactivity, and sedentary time (SED) is reaching global proportions (22,23), affecting both industrialized and developing nations (24). In response to this global issue, interventions targeting obesity, SB and physical inactivity have been widely implemented, but have demonstrated limited success (25). Such interventions often target individual psychosocial behaviours and are challenging to implement on a population scale, promoting continued exploration of the mechanisms underlying SB and effective population health interventions.

Governing bodies worldwide have responded to the high prevalence of time spent sedentary by setting recommendations to limit this behaviour. In 2011, the Canadian Society for Exercise Physiology (CSEP) released evidence-based PA and SB guidelines for all ages. More recently, CSEP revised these recommendations and developed the 24 Hour Movement Guidelines. These guidelines outline how to achieve a balanced day through four actions: sweat (MVPA), step (LPA), sleep, and sit (SB) (26). These recommendations have been adopted and adapted by other influential bodies, such as the Canadian Paediatric Society (27), the Australian Government Department of Health (28), and the American Academy of Pediatrics (29). Despite these efforts, recommendations to limit sedentariness remain largely unmet. Among 38 countries examined by Tremblay *et al.* (30), less than half of children and youth (20-39%) met proposed SB targets of ≤2 hours of screen time per day. Like many health recommendations, even those proposed by CSEP have failed to translate into quantifiable change. The CSEP recommends that children and youth limit leisure time screen-based SED to no more than 2 hours per day (31). Canadian children are becoming increasingly overweight and obese (32) and they consistently do not meet recommended guidelines to limit sedentariness (33). Only 49.3 and 36.0% of Canadian youth aged 5 to 17 years meet screen time limits and PA recommendations, respectively. Of these same youth, 79.3% failed to meet both screen time limits and PA recommendations simultaneously (33). Saskatoon youth spend on average 9 hours of their day in a sedentary state (34). Over their entire waking hours of a day, Saskatoon and Canadian youth spend more than 8 hours in a sedentary state (35,36). These high levels of SED are established in childhood and continue to increase throughout adolescence (37,38), pushing our communities towards ever increasing sedentariness.

Within Canada, a 2018 Report Card gave Canadian youth a D+ grade in their daily sedentary routines (39). Two previous Canadian PA report cards published in 2014 and 2016, identified the need to better understand the determinants of SB (40,41). The majority of practice and policy recommendations have returned to the common focus of increasing PA *and not reducing SB*. Hamilton *et al.* (42) describes this trend as the promotion of "purposeful exercise," adopted by health practitioners and public health experts, which continue to focus only on increasing MVPA, and largely ignores the intrinsic relationship between all forms of PA and SB. Although there are few publications in existence that include all activity behaviours, isotemporal substitution models examining health outcomes in adult populations have demonstrated that the replacement of sedentary time (SED) with more healthful activities results in an improvement in all-cause mortality (43,44). While our knowledge base surrounding SB has recently expanded substantially, there is a continued need (and call) to better understand SB to improve our population's health (45).

1.2 Research Aim

This dissertation seeks to establish how patterns of weather that show observable changes from one season to the next, in a given year in Canada, effect SED in pre-adolescent and adolescent children and how the relationship between season and SED are moderated by the built environment (BE) and how children's and parent's perceptions relate to SED.

1.3 Specific Problem Statements & Research Questions

Reduced SED in children has been associated with decreased lifelong risk of multiple non-communicable diseases and all-risk mortality. However, the majority of Canadian children fail to meet recommended guidelines to limit SED. Attempts have been made in the past to positively shift our population's activity behaviours, but interventions focusing on either micro- or macro-level BE features or behavioural changes have been met with limited success (46,47). Over the past 20 years, the primary focus of physical behaviour research (i.e. any waking behaviour, inclusive of SB and light-, moderate- and vigorous-intensity physical activity) has largely focused on moderate-to-vigorous-intensity PA (MVPA). This has led to the realization that little is understood of what predicts SB, a state distinct from PA, both in its health outcomes and determinants. In response to this problem, this study seeks to better understand what predicts SED by asking three questions:

A. **Do seasonal changes and a child's demographic factors predict SED? Do the built environments in home and school neighbourhoods moderate the effects of season or demographic factors on SED?**

i. Do seasonal changes or a child's demographic factors predict SED outcomes of children if we consider a child's entire day, or only school and leisure hours of the day? Do the BEs in home and school neighbourhoods moderate these effects?

ii. Do seasonal changes or a child's demographic factors predict SED outcomes of children when they are at home or school or utilizing city parks? Do the BEs in home and school neighbourhoods moderate these effects?

B. **Do parenting support practices, attitudes and beliefs contribute to a child's SED outcomes?** Are children's and/or parent's perception of unfavourable weather over different seasons a predictor of increased accumulation of SED?

1.4 Hypotheses

A. Seasons with colder temperatures will increase children's SED; Furthermore, seasonal changes will impact the frequency and location where children are sedentary. However, these changes will be moderated by a child's age, gender, immigrant status, SES and by the type of neighbourhood (urban design and BE) that a child experiences daily. Children who are younger, male, not recent immigrants, of normal weight, and living or attending schools in more activity-friendly neighbourhoods will accumulate significantly less SED than their counterparts. Finally, the predictors of SED will differ given the time of day or activity location—i.e. a child's entire day, school hours, and non-school leisure hours and by their specific location (home, school, school parks, public city parks and other locations). A child's demographic factors will have a greater impact on SED when a child is in their home (vs school) environment.

B. Children who perceive low levels of support of outdoor play and whose parents report low levels of support of outdoor play will be significantly more sedentary and significantly less physically active than their counterparts.

Chapter 2 Literature Review

When a child's day is considered, three primary physical behaviours can be performed: PA, SB, and sleep. Physical behaviours performed within a 24 hour period (or time budget) assume a, "zero-sum relationship," (48). When one activity is gained, another must be lost. It was only until recently that attempts have been made to delineate the relationship between specific physical behaviours and health, while simultaneously considering other behaviours within the same time budget (49,50). This review attempts to capture the health risks related to SB and SED (i.e. the rationale for studying sedentariness in children) and the correlates of SB while making clear distinctions between findings that purposefully considered other physical behaviours.

2.1 Sedentary Behaviour

There is an emerging body of evidence suggesting that SB results in a unique physiological state distinct from a lack of moderate-to-vigorous PA (51). Greater than 2 hours of recreational screen time, SB, or SED per day is associated with an increased risk of overweight, obesity, metabolic syndrome, and cardiovascular disease, and a decreased risk of musculoskeletal health (bone quality), VO_2max (maximum rate of oxygen consumption during high intensity movement), cardiovascular fitness (heart rate in response to aerobic movement), aerobic fitness (ability to perform aerobic movement), and self-esteem in youth (52,53). In Canadian youth, SED is positively associated with waist circumference and body mass index (BMI) (54). In a child and adolescent population with equivalent MVPA time, a reduction in SED provided a protective effect against select cardiometabolic risk factors. Specifically, mean triglyceride and fasting insulin levels were improved by 27% and 71% in the most active group (vs the least active group tertile), respectively (55). Adults spending most of their day sitting in a sedentary state are at a greater risk of type 2 diabetes ($p<0.05$) (56) and cardiovascular (OR 1.54, 95% CI 1.25-1.91) and all-cause mortality (OR 1.54, 95% CI 1.09-2.17) in comparison to those spending almost no time sitting (57). Additionally, with every one-hour increase in time spent watching television there is an associated 1.11 (95% CI 1.03 to 1.20) and 1.18 (95% CI 1.03 to 1.35) fold increased risk of all-cause and cardiovascular disease mortality, respectively (58). Prolonged periods of both television viewing and homework or reading time are both independently associated with increased BMI in adolescents (59). This growing body of evidence has resulted in a call to deepen our understanding of the role of SED in shaping our health, and conversely what extrinsic factors shape our SED patterns throughout our day (60).

The most commonly reported form of SB in children and adolescents is screen time (40,61), which includes television and video viewing, video gaming, and the use of computers (62), smartphones and tablets (8). The sole use of screen time as a surrogate for SB is a major limitation of existing research and should be only one of many forms of SB captured to help advance research in this field (40). Other SBs include travelling in automobiles and reading but are often excluded from SED for simplicity purposes or because of dataset limitations. The use of accelerometry has removed the subjective labelling of what activities should be included in SED analysis, but how we define device-based measures of SED using accelerometry data is less clear. Standardized methods derived from accelerometry data is only in its infancy (36,63–66). Accelerometry data cut-off points used in the literature are often derived from calibration studies providing counts per minute (cpm) equivalents to METs and have ranged from <100 to <1100 cpm depending on the device used (29), with <100 cpm being most commonly used by our research group and others (34,67).

Since the recent effort to distinguish SB and inactivity, researchers have made an effort to delineate the distinct role that sedentariness, inactivity and MVPA play in health. As reviewed by Thorpe *et al.* (68) disease incidence risk, including some cancers and diabetes, are attenuated when corrected for lack of PA (note: this systematic review did not clarify if PA criteria were inclusive of LPA). Based on limited research, SB may play a significant role in the manifestation of cardiovascular disease, mental disorders, and symptomatic gallstone disease.

Through the use of accelerometry (the measurement of bodily movement accelerations using a wearable device), activity-based research has been able to move into a new realm of examining daily movement beyond cumulative minutes and examine patterns in how we move. An individual may be meeting PA requirements, yet spend the remainder of their day in an inactive state. These “physically active couch potatoes”, are distinct from “active non-couch potatoes” who spend a higher proportion of the day in LPA, with the former having substantially lower total daily energy expenditures (51). Interrupted SED may have important health implications, as those who frequently ‘interrupt’ SED by engaging in some movement have significantly lower waist circumferences (54,67) and 2-hour plasma glucose levels (67).

The questions, what actually promotes, hinders, and determines sedentariness has become an increasingly prominent component of SB research. Systematic reviews have examined physical, psychosocial and biological factors (52,69–71), and while consensus appears to be emerging as to what we mean when we say SED (13) and what factors are correlated with it, this is not without controversy. Human energy expenditure regulation is complex, involving sympathetic and parasympathetic-hormonal axes centrally controlled by the brain (72). The peripheral signals centralised in energy expenditure homeostasis are affected by genetics, diet, the environment, epigenetics (73), and the gut microbiome (74), all of which can be moderated by the developmental stages of human growth (73). As discussed below, factors most consistently related to activity behaviour in children are a complex milieu of social constructs, environmental exposures within one's lived environment, and biological factors.

2.2 Correlates and Determinants of Sedentary Behaviour

Sedentary lifestyles beginning in childhood result in lifelong consequences, but childhood also provides a critical period where intervention may be most effective. A Portuguese cohort including 4575 participants aged 10-102 showed that this increase in sedentariness occurs until mid-to-late adolescence (38). Understanding the determinants of SB in pre-adolescence and adolescence is critical to preventing lifelong chronic disease as the precarious level of sedentariness seen in Canadians has reached global proportions (75). For this reason, the majority of the literature reviewed here and the entire analysis presented within this thesis will focus on the pre-adolescence and adolescence period of development. As the breadth of research findings on PA greatly outweighs publications exploring SED, and to address the compositional nature of physical behaviours, this thesis reviews a broad range of physiological energy states to present a more in-depth understanding of SED. This literature review will examine if the determinants and correlates of SED and PA have similar (or dissimilar) effects on each physiological state.

2.2.1 Age & Gender/Sex

Age is inversely associated with PA (69,76,77), with the greatest decline occurring between approximately 10-18 years of age (38,78). The overall decline of PA into adulthood is continuous, leading to an average accumulating decrease of 5.9% per year (69), but different forms of PA do not decline equally, nor are genders affected to the same degree. Vigorous-intensity PA (VPA) demonstrates a sharp decline following early childhood whereas moderate-intensity PA (MPA) declines at a more modest rate (78). In this same developmental period (6-12-year-olds) television screen time (79) and overall SED significantly increase (80,81). As children age into adolescence, they engage in less free play and dedicate more time to organized sports (78). In contrast to studies examining the relationship between age and PA, studies examining the relationship between age and SED are far more limited but the prevalence of SED has been shown to be higher in older children (82). As males age throughout adolescence, their SED continually increases until age 15-16 and then becomes stable. In contrast, adolescent females sedentariness peaks at age 16-17 and continually decreases until late adulthood (38).

Throughout childhood and adolescence, males are significantly more active than females (35,62,77). However, even though males accumulate less SED, their bouts of SED are longer and more continuous. Males are more sedentary on weekdays after 3:00 p.m. (54), and they accumulate more screen time in comparison to females (83,84). Yet, as females age, they increase their sedentariness at a greater rate than males (37). Sallis *et al.* (78) demonstrated that with increased age, males (vs females) show a greater decline in total energy expenditure, but both sexes show an equal decline in VPA. This decline in PA is independent of pubertal maturation in females, but not in males. Early maturation in males increases the risk of PA decline, whereas, in contrast, late maturation demonstrates a protective effect (85).

Sallis *et al.* (78) have suggested that similar maturation-related declines in PA seen in other animal species indicate the decline may be partially biological. In partial agreement, a systematic review by Dumith *et al.* (69) suggests that since the late 1980s the age-related decline in boy's PA has remained stable, whereas this decline in females has increased in magnitude. Although longitudinal studies defining the increase in SED with age of children exist, the evidence examining SED levels across the lifespan is limited (38). The observed marked decline in PA and increase in SED have prompted suggestions that future interventions targeting activity levels should focus on preventing SBs rather than taking a reactive approach to reversing established sedentariness in adolescence (86).

2.2.2 Immigration and Ethnicity

The understanding of the relationship between immigrant status or ethnicity and SB remains unclear. In the limited activity behaviour research that considers ethnicity or immigrant status in children, PA has been the primary outcome of focus. New immigrant children to

Canada are significantly less likely to participate in adequate levels of MVPA compared to their Canadian born peers (60 minutes of MVPA 4-6 times per week, OR: 0.66, 95% CI: 0.53–0.83). With longer residency time in Canada, this difference becomes less pronounced, and by 3 years non-significant. Of children residing in Canada those born in Africa (OR=0.77, 95% CI 0.65–0.92, 60 minutes 4-6 days/week) or South and Southeast Asia (OR=0.37, 95% CI 0.29–0.48, 60 minutes 7 days/week) are significantly less likely to accumulate adequate levels of MVPA in comparison to Canadian born youth (87). Both Canadian immigrant youth (88) and Latina-American mothers (89) express cold weather being a major barrier to pursuing physical activities outdoors (in comparison to their country of origin). Variation in children's PA has been theorized as being dependant on socially learned dispositions and cultural norms. Habitus, originally defined by Pierre Bourdieu in the early 1970s and expanded upon by Mauss in 1979, is the concept of an 'acquired ability' or habits that not only vary between individuals, but between societies, educations, and levels of prestige and in no way are limited by intelligence, knowledge, understanding or strategy (90). In the context of PA in a modern BE, Ergler *et al.* (91) further draw on the concept of habitus, including the environment and cultural capital, both of which are conceptualized in shaping activity levels (or subsequently inactivity levels) throughout one's childhood. It has yet to be explored if immigrant status shapes levels and forms of SED in Canadian children throughout different seasons.

2.2.3 Psychosocial Correlates of Sedentary Behaviour

The relationships between perception of the physical environment (BE and seasonal difference), social support of SB reduction in children, and SB outcomes in children are complex and not well understood. Both physical objects (*e.g.* play structures, paths, *etc.*) and larger scale environments, including one's climate or neighbourhood environment, can be viewed as sources of either potential affordance or hindrance (91). Affordance, a noun originally termed by psychologist James Jerome Gibson in 1966, defines a particular action in relation to a specific object, which is directly observable with minimal effort (92). For example, a child sees a rope with two handles on the end of the rope and understands that it is a jump rope used for skipping. Ergler *et al.* (91) further elaborate that affordance of an object or environment can exist (through potential) but requires actualization to translate a potential opportunity to reality. Affordance is further influenced by our culture, social class and economic resources, resulting in dispositions (or a lack of) towards engagement of outdoor activities. In a similar themed but contrasting approach, interventions to create sustained PA regimes among adults have primarily focused on tackling perceived barriers. Like affordance, beliefs related to barriers are multifaceted and as described by Bouma *et al.* (93) are comprised of attributions, self-efficacy and negative outcome expectations. It should be noted that in a meta-analysis of 61 studies examining changes in PA behaviour in adults with obesity, self-efficacy provided a significant, but notably small effect, on activity behaviours (Cohen's $d = 0.23$, 95% CIs 0.16-0.29, $p < 0.001$) (94). Additionally, Australian parents perceived that their children have low motivation to play outside in inclement weather conditions (95), but it is unclear to what degree to which a child's perceptions of 'poor' weather (and reasoning to avoid outdoors) are a product of their parent's views. To my knowledge, no publications have examined the relationship between child and/or parental perceptions of season-specific SB and SED outcomes in children (aged 8-11 years) in Canada or elsewhere.

2.2.4 Socioeconomic Status

The relationship between socioeconomic status (SES) and SED has been documented, but a clear relationship has yet to be established. In 11-12-year-old British children, affluence was negatively, and level of deprivation (using the Townsend Index) was positively associated with self-reported SB in a simple correlation analysis for both males and females. When applied to a multiple variable model, neighbourhood deprivation became non-significant, but only for males (81). In a second British study of 11-12-year-olds, self-reported TV viewing and computer or video gaming was significantly higher in children of lower SES than children of higher SES groups (using the Townsend Index). The result of this inequality translated to 2.29 and 4.09 additional hours of SED in lower SES children (62). Similarly, Icelandic children (aged 11-16 years) of higher SES were significantly less likely to be sedentary in their leisure time in comparison to children from families living with middle and lower SES (82).

Some studies have shown less pronounced relationships between SES and SED, while others have shown no significant relationship between the two. In a single study examining two cohorts of American children separately, the second cohort demonstrated a dose-like response to screen time exposure, with children in the lowest income group accumulating the greatest weekly screen time hours. In the first cohort, the study authors found that children in the second lowest income group ($25,000-35,999/year), but not the lowest income group, accumulated significantly more screen time than all other groups (96), which may be related to families being able to afford screen devices. In an Australian study, children's (10-12 years of age) device-based SED did not differ significantly between medium and high socioeconomic position (SEP) with maternal education as a surrogate marker of family SEP. In this same study self-reported TV/video viewing was significantly lower in children living within a higher SEP (97). Children of lower SES spent more time indoors as a result of a lack of neighbourhood safety and green space access (98). A significantly higher proportion of children of low SES have TV, DVD/VCR, or video game systems in their bedroom (99). The avoidance of outdoors and the presence of sedentary-promoting elements may provide greater opportunities for SB accumulation in children of lower SES.

2.2.5 The Social Environment

The social environment in which we live plays a major role in how active we live our lives. How social support shapes PA habits of children has been widely researched, but less is known of how social support effects SB habits of children. The odds of being an active child significantly increase with parental support (76,100). As described by Beets *et al.* (101), "…parents serve a "gate-keeper" role to PA, controlling access to community activity and sports programs and access to outdoor environments where activity can take place." However, in a qualitative study examining the Canadian Sedentary Behaviour Guidelines (for children aged 0-4 years), parents described the guidelines as unrealistic, listing (cold) weather, easy access to screen-time based SBs and the BE as major barriers in meeting these guidelines (102).

According to Beets *et al.* (101) support for PA can be divided into two different categories: tangible (instrumental and conditional support), and intangible (motivational and informational support). Instrumental support relies on providing the opportunity of PA through a physical means, such as transportation to a sports facility or purchasing sports equipment for a child. Conditional support involves the direct interaction between a child and parent, either through play itself, or through supervision. Motivational support involves encouragement or praise, and informational support provides children with the reasoning behind PA promotion. While these primary forms of support are pivotal in promoting PA (and potentially reducing sedentariness) in youth, they do not explore how parental attitudes, beliefs and modelling can moderate each of these forms of support.

Support can be presented in many forms, but not all forms are created and received equally (103). Mothers and fathers are likely to provide their children with different forms of support based on their child's gender and body composition, and likewise, youth are likely to perceive the types of support they receive from their parents differentially depending on their gender. Males perceive more paternal tangible support than females, yet both males and females perceive their mothers providing more intangible support (vs tangible) (104). In contrast, Davidson *et al.* (103) found that mothers are more likely to provide logistical (instrumental) PA support and fathers are more likely to model PA behaviours. It is unclear if different types (and sources) of support lead to differential activity level outcomes. In a cross-sectional study of 9-year-olds, children were more likely to be active regardless of which parent provided support (103). In contrast, children with active mothers were not more likely to be active in comparison to those with inactive mothers, but children with active fathers were significantly more likely to be active than those with inactive fathers (100).

Independent mobility is described as a child's ability to move freely within their neighbourhood or city without adult supervision. Parents and the broader social and physical environment support a child's independent mobility. Parental fears of strangers and perceptions of neighbourhood safety and friendliness significantly alter the level of independent mobility a child receives. Social norms unsupportive of independent mobility can negatively impact a child's ability to move independently in their free-living environment (105). Additionally, independent mobility in children is associated with 2-5 fewer minutes of SED per day (106,107). Varying forms of support, such as those described above, sources of support (maternal vs paternal), and how they affect SED behaviour in children have not been explored.

2.2.6 Seasonality

Season is the division of a chronological year into four equal parts based upon consistent changes in weather that result from the, "annual variation in the angle at which the Sun's rays reach Earth's surface and from the annual variation in the duration of sunlight on Earth's surface each day," (108). In studies exploring the relationship between seasonality and SB, almost all have taken place in regions of the world where average winter temperatures do not drop below -5°C or lack comprehensive comparisons between all four seasons. In all of the studies reviewed here, SB across seasons was examined in areas with moderate winter temperatures, yet significant differences between seasons were still detectable, with winters having the highest and summer or spring having the lowest level of sedentariness in children. In the youngest populations examined, both Scottish and Midwestern American preschoolers (aged 3-5) accumulated significantly more SED in spring (vs summer and fall months) (109) and less (light-vigorous) PA in fall months (vs winter months) (110). British 7-year-olds were more sedentary in winter and spring/fall than in summer months (111). Similarly, Danish (8-11-year-olds) (80), British (8-10-year-olds) (112), and Portuguese (10-13-year-olds) (113) children demonstrated the highest level of SED in winter months (vs summer and shoulder season months).

In agreement with quantitative studies, a qualitative study of Latina American mothers found that cold weather was a deterrent for choosing non-sedentary activities for their families, such as visiting parks (89). Contrasting patterns of lower activity in summer months has been found, but only in cohorts living in areas with exceptionally hot and humid summer climates (114). In contrast, a lack of association between sedentariness in children and seasonality has been found elsewhere. In two European studies, the effect of seasonality on self-reported SED was inconsistent in 11-21 year olds (115). A second study found that device measured SED was unchanged after statistical models were adjusted for season of data collection (116).

Specific daily weather conditions that make up seasonal climates have also been attributed to reductions in PA. British 8-11-year-olds participated in significantly more device-based MVPA on days with greater daylight hours independent of cloud cover, rainfall and wind speed. Yet, cloud cover, rainfall and wind speed were associated with significantly less MVPA in these same children (117). Cooler temperatures were associated with significantly greater levels of sedentariness in children (81), and for every 10°C increase in temperature, Canadian children increased their daily MVPA by 5.8% (118). Snowfall negatively impacts children's PA, but the accumulation of snow on the ground is positively associated with MVPA in children. In contrast to PA in children, increased rainfall, but not daily temperature, has been shown to significantly impact SED (119). In a study that included 34,201 participants aged 3 to 18 years from 10 countries using an international database of accelerometry data, temperatures between 0-20°C showed the strongest association with physical activity in comparison to all other weather conditions measured (day length, precipitation, visibility) (120).

The effect of seasonal weather may also be driven by social norms and culture, as a comparison between countries showed that day length had both a positive and negative effect on children's activity outcomes depending on their country of residence (120). Limited studies exist that have considered detailed weather variables beyond the broader context of season. Harrison et al. (120) have proposed that the effect of weather conditions on children's physical activity levels is likely additive amongst weather conditions, emphasizing the importance of seasonality on physical behaviour outcomes (vs individual weather conditions). Therefore, there is much to be gained in examining these weather-related variables and how they both individually and collectively relate to SED in children.

2.2.7 The Built Environment, Built Environment Features and Neighbourhood Design

The BE, in the broadest sense, comprises of anything that is built by humans, for humans, for the purpose of human activity (4). Buildings, spaces and objects make up our BE, but urban planning and policy define how we interact with BE features (121). Aspects of our neighbourhoods, such as the presence of parks, open spaces, and commercial destinations, can be predictive of our PA behaviours, but a systematic review revealed that construction of such infrastructures does not necessarily guarantee increases in PA (122), demonstrating the increased need to understand the determinants of PA and SED at a population level.

The BE can be measured through both objective and perceived measures. When objectively measured, BE features may be examined in singularity, cumulatively as attribute-specific dimensions (*e.g.* safety from traffic or crime), or with broader themes encompassing general design eras. The quantification of neighbourhood attributes through audit tools, such as the Irvine Minnesota Inventory (IMI) or the Neighbourhood Active Living Potential (NALP) tool (123), have contributed significantly to understanding what factors of the BE influence our activity patterns. Both the IMI and NALP utilize dimension scores to measures themes of attributes of neighbourhood-scale BEs (124,125). In a validation study exploring single items of the IMI, first-order infrastructure (*e.g.* street characteristics, traffic, *etc.*), but not second-order aesthetic elements, were associated with walking and PA (125). Mismatch between perceived and objective measures are common (126), and are associated with lower levels of PA (127,128).

Perceived and objective measures are associated differently with PA and SED for adults and children. Neighbourhoods with greater street connectivity and mixed (residential and commercial) land use are more walkable for adults, but tend to have higher levels of traffic, a deterrent for cycling and walking in children (129). In an Australian cohort of 10-13-year-olds, high (vs low) street connectivity was associated with children walking to and from school ≥6 times per week if their route had low traffic volumes (130). Nearby public open space features were negatively associated with parental report of TV viewing and computer/e-game time in very young children (4-5-year-olds). However, device-based SED was not associated with select features of the neighbourhood public open spaces measured (131). In contrast, in a cohort of 8-12 years old children, the presence of a nearby park and recreational area density was negatively associated with TV viewing in males (Pearson's $r = -0.29$, $p < 0.05$) (132). In a qualitative study with Latina American mothers, reliance on cars to carry out necessary daily activities was seen as a barrier to achieve sufficient PA and avoiding SB in them and their children (89). Similarly, in a focus group discussing SB in young children, parents expressed the necessity of using an automobile to reach destinations (65). Therefore, although particular BE attributes may impact SB at one stage of a child's life, caution must be used when extrapolating meaning from different age groups.

Although audit tools provide a useful means of assessing the local environment, the timing of measurement acquisition is critical, as features such as sidewalk accessibility and presence of paths may change dramatically with the presence of large amounts of ground cover in the form of snow or ice. To further complicate manners, these measurement tool assessments may be carried out in a different season then when the outcome is measured. It is unclear what effect season has on BE features and if season changes how individuals interact with these features. Direct measurement of BE features and physical activity and SED and relating these with seasons is rarely undertaken in research studies. Preliminary studies from our group have shown that in one winter to spring transitional season in 2010, the type of neighbourhood of residences in Saskatoon moderated the risk of sedentariness and PA in children even though they were all exposed to the same weather patterns. Within this same study, design era was used to understand if neighbourhood era-specific design features, such as the degree of road connectivity, were associated with children's activity behaviour outcomes. Children living in fractured-grid patterned neighbourhoods developed between 1930 and the mid-1960s accumulated the most SED and the least MVPA in comparison to grid- and curvilinear-patterned neighbourhoods developed before 1930 and after the mid-1960s, respectively (34). In the same Saskatoon cohort of 9-14-year-olds, children living in fracture grid-patterned neighbourhoods were significantly less likely to accumulate MVPA (OR=0.45; CI 0.22 to 0.93) (133). It remains unclear if these same SED patterns apply to children across different seasons.

Although outdoor areas, such as green spaces, still provide an opportunity for sedentariness as well as PA, children accumulate the most SED while indoors. On average, this translates to an additional 181.2 and 343.7 minutes of SED per day on weekdays and weekends, respectively (134). In 9-15-year-old children and teens in Saskatoon, those who spend no time outdoors accumulated an additional 70 more sedentary minutes per day in comparison to those who spend the most time outdoors, and SED decreases in a dose-like manner with increased time spent outdoors (135). Similarly, 11-year-olds in Toronto who spend the least amount of time participating in outdoor play accumulate the greatest amount of SED. In males, outdoor play was associated with a significant reduction in SED (64%) in comparison to indoor play time (71.3%) during afterschool hours (136). The amount of time a child spends outdoors and the decision to participate in outdoor activities, such as active travel, is influenced by a child's level of independent mobility and parental perceptions of the BE (137). Stone *et al.* (107) demonstrated that highly independently mobile children accumulate between 2.2-4.2% less SED in the two hours directly following end-of-school. Conversely, only 2 of the 5 studies reviewed by Schoeppe *et al.* (138) showed that active travel was associated with significantly lower levels of SED, with the remainder of studies reviewed showing no association. Further complicating matters, a child's independent mobility can be moderated by parental fear of danger (including fear of danger related to extreme weather) and a child's developmental stage (139,140). Additionally, males are afforded greater levels of independent mobility (nearly 70% vs 54% in females), which further increases with age (107). Collectively, our understanding of how children interact with their physical environment is only in its infancy and much remains to be learned.

Chapter 3 Theoretical Framework

3.1 Theories of Activity Behaviours Throughout the Life Course

Existing theories explaining how an individual's daily activity behaviours are shaped are plentiful but largely focused on PA and individual behaviours with limited simultaneous consideration of both the physical and social environment. While these theories position themselves under different theoretical lenses, they exhibit common and complementary standpoints. The theories explored below examine the broader social *or* physical environments experienced by an individual throughout the life course, which steer individuals towards specific activity outcomes. Many of these conceptual frameworks attempting to delineate the determinants of healthful PA contain themes that are readily translatable to examining energy expenditure balance, inclusive of SED. Theoretical constructs, models and frameworks used in the conceptualization of the framework developed for this thesis are discussed.

In the 2010 book, "Physical literacy: throughout the life course," Margaret Whitehead explores the philosophical underpinnings of physical literacy (15). "Physical literacy is the motivation, confidence, physical competence, knowledge and understanding to value and take responsibility for engagement in physical activities for life," (16). Physical literacy is thought to be a crucial component in promoting PA and is often implemented through physical education school curriculum and interventions targeted at increase PA levels in children (141). Whitehead (2010) argues that physical literacy is grounded in existentialism and phenomenology (15). Existentialism describes an individual's "essence" as being not an inflexible product of "human nature", but one that is dynamic, adaptable and adopted by an individual, and by no means a permanent fixture of that person's being. At the core of existentialist belief, individuals have "freedom over values that organize" their experiences and shape their behaviours. The level of freedom an individual has to seek or dismiss value in their lived experiences is controversial and has been debated since the birth of existentialism by its founders, Jean-Paul Sartre and Simone de Beauvior (142). Whitehead (2010) elaborates that values and perceptions of the world are both cyclical and evolving, with the perceiver constantly having to interpret their environment, and come to a decision, which will be influenced by past experiences and knowledge. In cases where new scenarios are encountered, the individual must adapt, but this response is a product of past experiences.

A second contributing philosophical underpinning of physical literacy described by Whitehead (2010) is the concept of phenomenology (15). Phenomenology examines the, "structures of consciousness as experienced from the first-person point of view," or more simply, one's lived experience. As the term, "lived experience," implies, it is a moment in time or phenomenon that is experienced, and not something that is actively performed, and past and present states of consciousness have influence on how an individual recalls that particular experience. Phenomenology attempts to understand and describe the first-person's point of view and experience of a phenomenon (143). As described by Whitehead (2010), "individuals do not come into the world 'ready made'," but are a result of an, "accumulation of all the situations in which we have been involved, whether by design or by chance." An individual's experiences and resulting perceptions will shape future phenomenon interpretation, resulting in continual alternations of who an individual is. Finally, Whitehead (2010) theorizes the influence of operative intentionally, embodied perceptions and response on physical literacy outcomes. Intentionality is an individual's persistent determination to interact and perceive the environment. Operative intentionality describes one's perception and response to the lived environment, but as it occurs through meaningful actions. The perceptions of an object, including its use and how one can interact with it, is often overlooked or taken for granted. These theories of existentialism, phenomenology, operative intentionally, embodied perceptions and response are aggregated to describe an individual's capability. Whitehead describes an individual's capability of being physically active as a trait all human beings possess, and this capability functions at a subconscious level. Embodied experiences play a significant role in one's perceptions of their lived environment (15). Whitehead's description of physical literacy through existentialism and phenomenology describes how individuals constantly interact and learn from both their physical and social environments, shaping their physical activity behaviours. Yet, it is unclear if these concepts share a similar relationship with SBs. In a study including 1208 parents of children aged 5-17 years, Rhodes et al. used the theory of planned behaviour to identify how much variation in children's activity outcomes were explained by parental perceptions and support of these behaviours. PA and SB outcomes in children were explained by divergent theoretical components of the theory of planned behaviour (144), suggesting that this may also occur amongst other theoretical frameworks.

The systems-of-sedentary behaviours (SOS)-framework was developed to address the transdisciplinary natures of SB research and the limitations of most SB frameworks being drawn exclusively from behavioural epidemiology and individual-level determinants and outcomes (145). Six clusters of determinants were identified using an interdisciplinary consensus to develop an “exhaustive” list of the determinants of SB: physical health and wellbeing, social and cultural context, the built and natural environment, psychology and behaviour, politics and economics, and institutional and home settings. While this framework is limited in its explanation of how clusters may interact with one another, it considers both the life course of an individual and the broader physical, social and political environments an individual experiences and contributes to, and how this shapes the SB of individuals and populations. Furthermore, it purposely avoids theoretical constraint and emphasizes removing attention from the individual and shifting it towards that of system design (145).

The ecological perceptual framework, described by Ergler (2013) includes the concepts of affordance, actualization and habitus, developed by James Gibson and Pierre Bourdieu. As Ergler (2013) explains, “objects…may afford possibilities of throwing, hiding behind, hanging or falling from, whereas surfaces may afford running, climbing, balancing or tripping. How, and to what extent, an action is carried out depends, however, on what the individual child perceives in the environment and how they evaluate its possibilities for action.” Furthermore, the environment in which a child lives and interacts with must offer something that a child can recognize as either an enabler or inhibitor of a specific action or behaviour. Ergler (2013) uses Harry Heft’s extension of Gibson’s theory, which provides a distinction between potential and actualization. For example, a child may recognize that objects or situations afford a potential opportunity for specific behaviours, but may only actualize a small proportion of these associated behaviours. Perceived barriers, however inherited by the child, such as fear of danger, inhibit the actualization of behaviours. Lastly, Ergler incorporates Bourdieu’s concepts of social, cultural and economic capital and habitus in shaping children’s propensity for outdoor play (91). Edgerton and Roberts (2014) summarize Bourdieu’s key concepts as, “*social capital*, which is comprised of ‘social obligations’ or ‘connections’; *cultural capital* or ‘cultural competences’, which can be embodied (internalized and intangible), objectified (cultural products), and institutionalized (officially accredited),”; and *habitus*, “the learned set of preferences or dispositions,” (146). These concepts are translated to Ergler’s (2013) explanation that, “affordances can only be perceived and actualised when [a child] is able to master the rules associated with certain affordances,” and children may, “perceive, utilise, transform and reject affordances according to their knowledge of these rules in the field of affordances, their capital endowments and the practical sense of how to ‘behave’.” A child’s inclination towards outdoor play is a result of, “actualised affordances in relation to the locality children are growing up in, their economic circumstances (*e.g.* the possibility of organised trips) and parents’ educational background as well as their beliefs in the value of outdoor activities in different seasons,” (91).

In Weinstein and DeHaan’s (2014) exploration of the mutuality of human motivation and relationships, the authors describe that, “support for healthy motivation (or lack thereof) by important relationship figures (*e.g.*, parents) as well as by individuals who have a specific social role…influences stable motivational orientations or dispositions over time, and shape one’s sense of well-being, psychological growth, and resilience over the long term,” (147). Parents, school teachers and other influential adults in a child’s life can provide social environments that are supportive or inhibitory in increasing a child’s active play. From a self-determination theory perspective, individuals are thought to be, “growth-oriented organisms who actively seek optimal challenges and new experiences to master and integrate.” The motivation to seek out new experiences is tied to one’s intrinsic motivation or one’s self-propulsion towards participating in activities out of “interest and enjoyment without the aid of external awards/constraints.” This engagement in an activity is maintained through, “interest, enjoyment and curiosity,” and, “derives from the inherent satisfaction of the basic needs for autonomy, competence, and relatedness,” and, “parents can socialize their children to be active agents in their learning, play, development, and functioning by providing supports for their autonomy, competence, and relatedness (*e.g.*, taking on board the child’s inner frame of reference, and providing clear rules, structure, and expectations within a caring and supportive environment).” In contrast, directive, cold, and controlling parental practices can serve to hinder a child’s natural propensity towards play and learning by frustrating their innate needs for autonomy, competence, and relatedness.” In addition to influential parents, autonomy-supportive school physical education teachers are theorized to provide students with increased physical literacy (147).

Ergler’s ecological framework describes how a child’s social, cultural and economic capital and habitus shape the affordance and actualization of actions as they relate to specific objects. Similarly, the concept of motivation, as described by Weinstein and DeHaan, underscore the importance of socially learned and supported actions. Yet, both of these frameworks have not explore the context of a child's highly complex physical environment on a neighbourhood scale, and how this may change with season.

In Bauman's (2012), "adapted ecological model of the determinants of physical activity," theoretical framework, the influence of both relatively static (biological: genetics and evolutionary psychology) and dynamic (psychological: cognition, beliefs, motivation) individual characteristics influence PA. Specifically, psychological factors, such as self-efficacy (i.e. one's confidence to perform a PA or action in a specific situation), are suggested to steer children towards specific activity outcomes (148). Bauman's consideration of genetic predispositions contrasts those of Whitehead's (2010) framework, which primarily assumes physical behaviour outcomes, as a product of physical literacy, are malleable.

The 'displacement hypothesis' states that as a person performs one level of activity behaviour, they cannot simultaneously perform another (48). Mutz *et al.* (48) first developed the displacement hypothesis to describe the theory that children had reallocated physical activity with sedentary television viewing. Mutz described our waking behaviours as having a, "symmetrical, zero sum relationship," where two behaviours could not be performed simultaneously; for example, PA and SB. Mutz's hypothesis included concepts derived from displacement theory and 24-hour time-budgeting but primarily focused on tasks a child performs throughout their day, rather than the focus being only on energy expenditure states.

3.2 A Theoretical Framework Exploring the Determinants of Children's Activity Behaviours

Common patterns in daily activity behaviours of children have been established, yet from much of our understanding, both temporal and spatial contextual information from these findings are often lacking. Throughout the introduction, correlates and determinants of SB were discussed. To merge these independent factors into a dynamic network of what influences children's activity outcomes, a theoretical framework was developed using concepts derived from Panter's (2008) environmental determinants of active travel in youth framework (139), Ergler's (2013) framework that combines an ecological perceptual psychology model paired with Bourdieu's theory of practice (91), Bauman's (2012) ecological framework (148) the Systems-of-Sedentary Behaviour (SOS)-Framework (145), Whitehead's theoretical description of physical literacy (15), and Mutz's, "displacement hypothesis," (48). In the proposed theoretical framework developed for this thesis, a child activity behaviours are explored in relation to their individual characteristics, the social environment in which the activity is experienced, whether the child is at home or in school, and the physical environment in which the child/activity located. Concepts directly explored in this study are displayed in purple (**Figure 3.1**). This framework is unique in that it focuses on a specific critical period of child and adolescent development, but simultaneously considers the life course of the child. Further, it includes influences of the social environment a child experience within multiple domains, including home and school environments, and how the child and their social environment can shape interactions with the broader physical environment. The physical environment uniquely includes both climate and weather and the built environment a child experiences on a daily basis within their home and school neighbourhoods. To date, no other framework has explored children's activity behaviour outcomes with the consideration of their neighbourhood scale built environment *and* climate simultaneously.

As shown in **Figure 3.1**, the top bar shows the life course of an individual, from infancy to late adulthood. The life course timeline bar proposes three themes: that the determinants of a person's activity behaviours are dynamic and will change with age, and that this framework (and accompanying research) focuses only on a short period in a person's life (children aged 9-14 years). Thirdly, activity behaviour outcomes can be affected by experiences of the past (*i.e.* younger years), and in turn, can influence activity behaviours in the future (older years). This idea is similar to that reflected in Whitehead's description of the theoretical roots of physical literacy but also takes into consideration the lack of personal autonomy children experience. Much of which a child values is the product of their social environment. The value they see in actions (whether SED or not) are largely influenced by what they have been told to value, and how value has been modelled in their lives.

Children's lived experiences are a product of what the gatekeepers of their lives (parents, schools/school teachers/school policy) allow them to be exposed to, and find value in.
In concert with existentialism and phenomenology, the proposed framework outlined in **Figure 3.1** brings with it the assumption that our physical behaviours, including sedentariness, are a product of the environment in which we experience throughout our life course. Yet, it also considers genetic predispositions, such as maturation onset and phenotypic energy expenditure difference of an individual, resulting in a spectrum of activity behaviour outcomes.

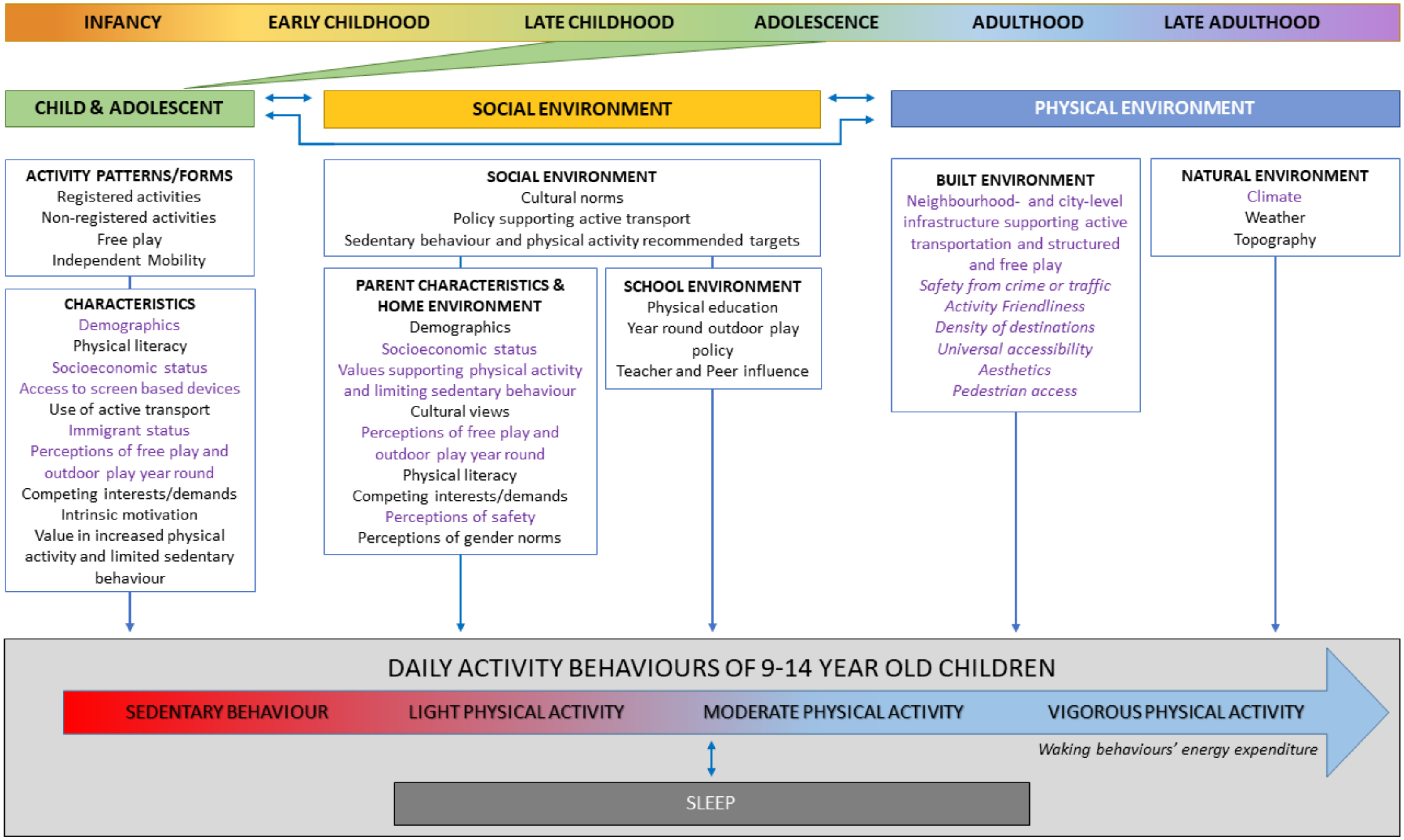


Figure 3.1 A theoretical framework exploring factors that influence a child's activity behaviours.

Variables listed in purple are explored in subsequent analyses.

A child's characteristics influence activity behaviour outcomes, but also demonstrate interdependence and influence one another (**Figure 3.1**). As children age, their SED increases in concert (82). Increased age is closely tied to changes in activity patterns (78), but how and when this happens varies by both gender and sex (37,54,149). The effect of biological age on activity behaviours is moderated by the gendered social environment a child experiences. These trajectories can be further altered by a child's weight status and their own social environment's perceptions of their weight status.

Parents and other adults in charge of caring for children influence children and their activity behaviours continuously throughout their childhood. The actions taken by these adults, whether directly involving the child or not, are seen, heard, and mimicked by children under their care, shaping their perception and access to movement (or confinement to SBs). Social interactions within parent-child dyads are encapsulated by culture (including that of immigrants originating and adopted cultures), social class and economic capital, which in turn can moderate a child's activity behaviours. School policies, including those that encompass mandatory physical education and outdoor play, especially in winter climate conditions expected in central Canada, are theorized to alter a child's activity behaviours. Social structures imposed on children shape their daily activity patterns by altering their interpretation/perception of the social and physical environments in which they interact. Children's dispositions are partially inherent, but largely a product of their social environment exposures (**Figure 3.1**). This concept of an individual's disposition is adapted from Ergler's (2013) ecological perceptual psychology framework.

It is theorized that if a child is oriented to only see cold weather as "bad" and afforded no outdoor opportunities in typical winter weather conditions, they will continue on a trajectory of prolonged time spent indoors and sedentary. Similarly, children never given the opportunity to experience seasonally normal winter weather conditions will be unable to actualize physical behaviours that reduce sedentariness (through year-round outdoor play). Children afforded greater levels of independent mobility and/or with a higher level of physical literacy can navigate both the natural and BE successfully. Children restricted in their movement by either their parents or school policy will have limited or altered interactions with their natural and BEs. This restriction of a child's exposure/interaction to the physical environment can be a product of social norms and parent or school/policy views on the physical environment, further influencing a child's perceptions and beliefs.

The physical environment can be interpreted by both parents and school policymakers through the assessment of its degree of safety (both from crime and traffic), affordance of opportunities/destinations, activity friendliness (infrastructure supporting safe and age-appropriate active transportation and PA), pedestrian access, universal accessibility for those with limited physical ability, and aesthetics. These perceptions of the BE, regardless of how accurately they match objective measures, can influence a child's activity outcomes. In this study, both a child's and parent's perception of outdoor play (and support of it) in year-round weather conditions are considered. Although it is not explored in this thesis, this influential relationship can be extended beyond the parent to other influential individual's in a child's life: other family members, peers, school teachers, *etc*. The social practices of support and motivation by parents and teachers within schools can alter children's activity outcomes, but if increased PA and reduced sedentariness are not valued by a child's social environment, an imbalance in energy expenditure will be encountered (**Figure 3.1**).

As shown in **Figure 3.1**, the bottom grey box outlines the primary outcome of interest of this study: a child's activity behaviours, as defined by energy expenditure. From left to right, SB, LPA, MPA and VPA are listed from the least to the highest level of energy a child can expend throughout the waking hours of their day. Within a child's day is also sleep, which has been sized appropriately to represent approximately one-third of a child's day. Sleep is not considered in this study, but can influence waking behaviours and therefore waking energy expenditure of individuals, and vice versa. While sleep and SB energy expenditure are roughly equivalent, they are distinct physiological states, and in contrast to SB, continuous high-quality sleep is considered beneficial to our health and is recommended by the CSEP (31). Furthermore, activity behaviours performed by children are discrete, measurable, and follow the assumptions of Mutz's displacement hypothesis (48). If a single physical action is being carried out, another cannot be performed at the same time. The addition or loss of one action will concurrently result in the loss or gain of another action.

It is theorized that the value in free-play oriented PA and independent mobility has been eclipsed by parental fear of the social and physical environment, increased value in the academic performance of children, and competing workplace demands of the parent. The result of parental fear is the shifting of children's PA from free play to that of one that is controlled, confined and under the watchful eyes of adult supervision. With competing (workplace) demands of parents and increased emphasis on children's academic performance, children are afforded ample opportunities to participate in SB, whether it be considered educational or for entertainment purposes only. It is also theorized that parents value indoor, and often sedentary, play of children because it reduces the risk of the social and legal repercussions associated with children participating in unsupervised outdoor independent mobility and free play. These play and mobility behaviours are influenced by both a child's and parent's demographic factors. Family income may also moderate activity pattern balance by either restricting access to PA programs, or providing opportunities for active transport (*e.g.* walking to/from school) when income is restricted (150). Economic capital and family social values provide children with opportunities to be more active (151) and less sedentary (82,134), through opportunities of registered play. Registered PA opportunities often require the need for a personal vehicle, are costly, and can be exclusive to those living with lower incomes. Conversely, economic capital can provide children with sedentary forms of transportation (personal vehicles) and easier access to costly screen devices and on-demand streaming media. Parental fear of child-abduction, constrained independent mobility and social views of femininity can oppress female gendered children in achieving active lifestyles (**Figure 3.1**).

When constructed, the BE is developed with the intention that objects afford specific uses. Hard surfaced pathways are intended to guide pedestrians and cyclists, roadways restrict the movement of cars through signage and barriers, planted trees provide shade, wind protection and aesthetic, yet the utility of BE features can ebb and flow with seasonal change. Outdoor pedestrian walkways along high-density commercial routes can be appealing in warm months, but provide little protection from cold wind in winter months. Sidewalks and pathways designed for pedestrians and cyclists have limited utility with excessive snow and ice cover or poor drainage of water. The physical features of the environment in which we interact, whether constructed or natural, are also a product of our perceptions, values and motivation to experience seasonally normal climate year-round. It is theorized that a child's social environment directly influences their interpretation and utilization of the built and natural physical environments. Parents can provide children with tangible support (providing warm weather clothes and opportunities for outdoor play in winter months), modelling (themselves participating in active outdoor play with or without their children), and motivation to reduce SB by placing value in outdoor active play year round. School policies promoting year-round outdoor play place value in children's PA. In this study, child SB interactions with the BE are examined at the neighbourhood scale, but the confinement of SBs are not restricted to the neighbourhood in which one lives or attends school, creating importance of neighbourhoods on a city-scale. Within all of these relationships, children's daily activity behaviours are formed (**Figure 3.1**).

3.3 A Theoretical Model Exploring Time- and Location-Dependent SED

To more deeply explore the theoretical foundation of the specific research questions and hypotheses outlined in **Chapter 1**, a theoretical model was created (**Figure 3.2**) for Research Question A (**Section 1.3**) and Hypothesis A (**Section 1.4**). It is proposed that a child's demographic factors and season are significant predictors of SED and that a child's home or school neighbourhood can moderate these effects. In the model explaining these hypotheses, both time- and location-dependent SED are considered.

In the model shown (**Figure 3.2**), climate and season are theorized to directly impact a child's daily physical behaviours. The effect of season on these behaviours is moderated by a child's demographic factors and the BE they experience either within their home or school neighbourhood. This model can be applied to children's daily physical behaviours, physical behaviours performed within a specific period of the day (school vs leisure hours) or physical behaviours performed within specific physical spaces (home, school, school park, or park areas). Between these time- and location-specific domains, the influence of season and a child's demographic factors will vary, as homes, schools and public parks offer different social and physical environments that can either support or hinder healthful physical behaviour balance.

3.4 A Theoretical Model Exploring the Influence of Perceptions of Year-Round Outdoor Play on Children's Activity Behaviours

A theoretical model was created (**Figure 3.3**) for Research Question B (**Section 1.3**) and Hypothesis B (**Section 1.4**). It is proposed that parents who do not support year-round outdoor play and instead support indoor SBs will have children who participate in prolonged SED. Moreover, children who perceive low levels of support of outdoor play, low parental regulation of SBs and winter as having fewer opportunities for outdoor play will participate in prolonged SED.

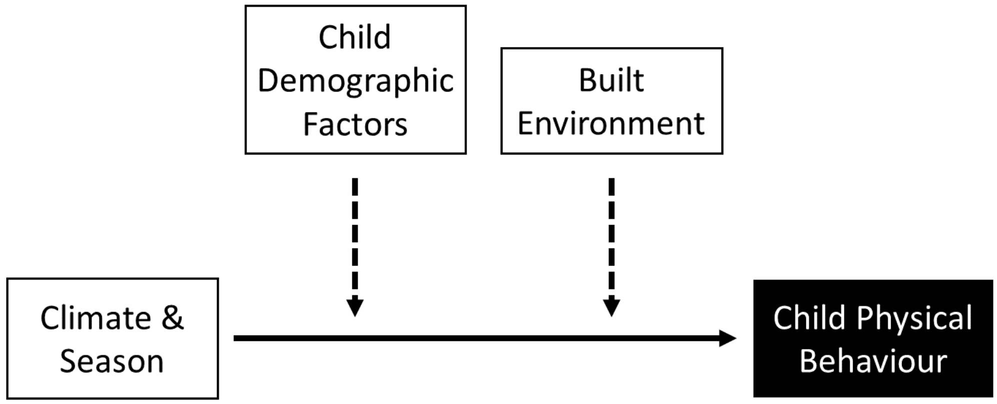


Figure 3.2 A model outlining the role of children's demographic factors, climate and season and the built environment in shaping sedentary behaviour outcomes of children.

Solid arrows indicate a causal relationship. Dashed arrows indicate effect modification.

The theoretical model explaining the described hypotheses are shown in **Figure 3.3**. In this model, the primary influence of a child's activity behaviours begins with the social environment they experience. Parent values, perceptions and their method of supporting their children in what they value are a product of the social environment they have experienced throughout their life. When parents and their children interact with the physical environment, parents can either support or discourage the interaction, thereby sharing their values and perceptions of the physical environment. To some extent, children adopt the values and perceptions of their parent(s) and recognize support or discouragement in specific physical environment conditions. Parent support encouraging year-round outdoor play and discouraging unlimited screen-time use is hypothesized to result in reduced sedentariness of their children. Additionally, children who perceive support to participate in year-round outdoor play and restrictions on screen time use will have lower levels of daily SED.

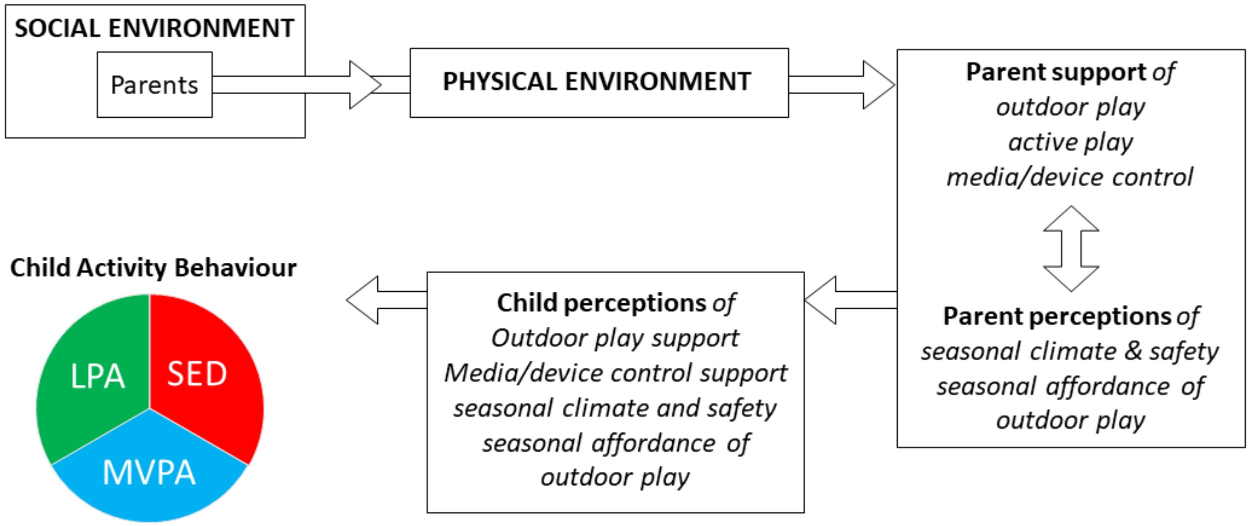


Figure 3.3 A model describing the social and environmental influences on children's activity behaviours through parent support and beliefs and a child's own perceptions of these supports and beliefs.

Chapter 4 Methodology

4.1. Research Context

Saskatoon is the largest city within the province of Saskatchewan, Canada with a growing population estimated at 246,376. Almost 19.8% of Saskatoon residents identify themselves as a visible minority, and 18.0% were born outside of Canada. Over 7% of these immigrants have been living in Canada for less than 6 years (152).

Saskatoon experiences a humid continental climate with four distinct seasons, average temperatures of 3.4°C in spring, 17.2°C in summer, 3.2°C in fall, and -14°C in winter, relatively low levels of precipitation, and predominantly NW winds of 15km/hr year round (153,154). With temperate summers and cold winters, the city remains under snow cover for an average of 6-7 months annually.

While 87.1% of Saskatoon residents live within the city's urban centre, the city of Saskatoon has the 2nd lowest population density, the 7th highest proportion of single dwelling units and the 4th highest cumulative metropolitan sprawl rank amongst Canada's 27 largest cities (155). Within the city are 4 distinct neighbourhood types based on urban planning design and time of construction: (A) grid (or gridiron) pattern core neighbourhoods developed before 1930, (B) fractured grid neighbourhoods developed between 1930 and the mid-1960s, (C) curvilinear pattern neighbourhoods developed between the mid-1960s and 1998 (34) and (D) a modified grid-pattern (or fused-grid pattern) design developed from 1998 to present (**Figure 4.1**) (156).

The grid street network was widely adopted across North American beginning in the 19th century and was embraced for its utilitarian aspects including ease of pedestrian movement and allowance for development extension by city planners. Grid street networks are characterized by, "rectangular blocks of uniform dimensions divided by a perpendicular grid of streets," (157).

Between the end of the Second World War and the mid-1960s many North American cities, including Saskatoon, experienced a dramatic increase in their urban populations. Cities reacted to these rises in their populations with rapid suburban development. These, 'first suburbs,' are characterized by neighbourhoods with predominantly single detached houses and fracture grid-streets patterns. During this same period private motor vehicle ownership became accessible to the masses. Neighbourhoods developed in this era reflect this increase in car ownership with reduced street connectivity for pedestrians and the necessity of a personal vehicle for trips to destinations such as work, retail or recreation (156,158).

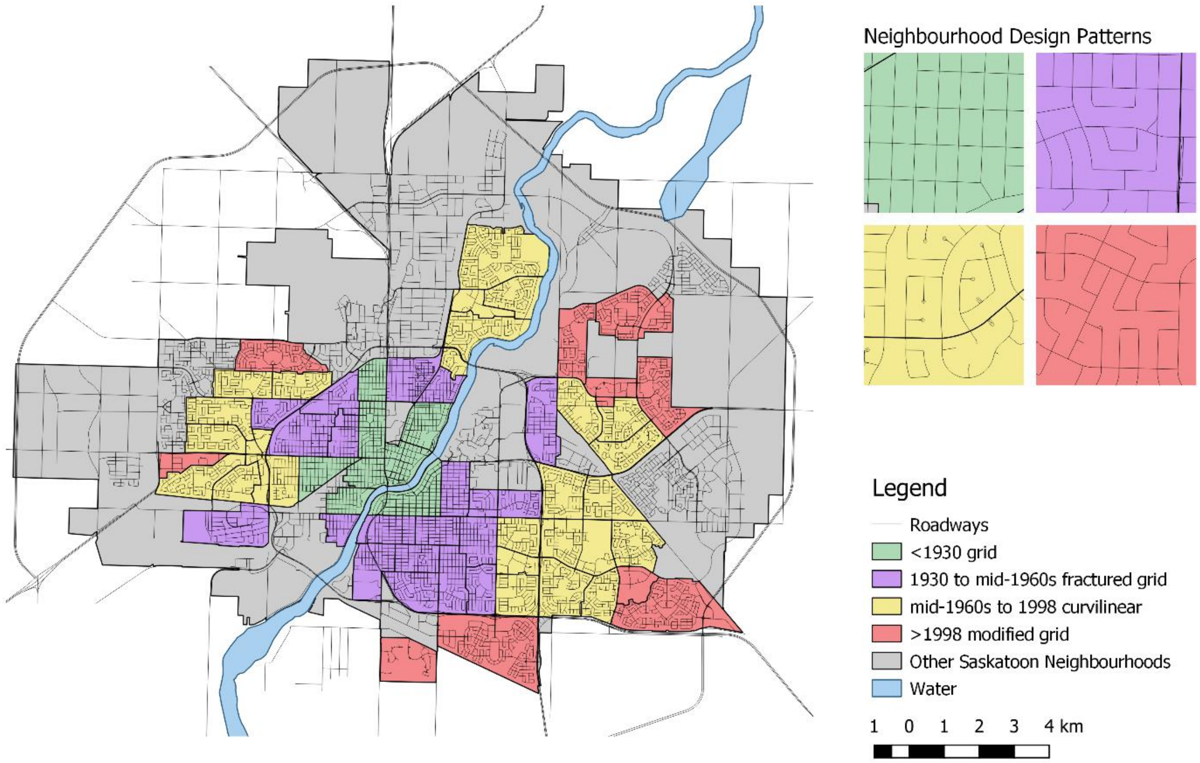


Figure 4.1 City of Saskatoon neighbourhoods by development era.

Neighbourhoods shown in grey (other Saskatoon neighbourhoods) were either in development during the time of the data collection or considered industrial with minimal residential properties.

During the 1960s the population of Saskatoon rose by 30,000 people. To accommodate this rapid increase in the city's population, Saskatoon's city government developed their, "First Community Plan Scheme," which remained in effect from 1966-1982. Neighbourhoods developed in this era followed a, "lazy loops and lollipops," (159) or curvilinear design and followed standardized guidelines, including that each neighbourhood be developed around a school site and a neighbourhood park (156). These curvilinear neighbourhoods entirely abandoned the parallel patterns seen in grid and fracture grid designs, with, "twisted and non-directional," streets, almost entirely made up of curving loops and inwardly focused cul-de-sacs. Additionally, these neighbourhoods were dominated by single detached homes, are self-contained and linked by only by large arterial roads or the modern-style freeway, making them quiet but also greatly limiting their connectivity to other neighbourhoods (159). During this period curvilinear suburban designs were adopted both within North American and internationally (160) and retained as the dominant suburban design until the mid-1990s (156).

Following over half a century of suburban development focused on low-density housing and the necessity of car ownership, public concern over the long-term sustainability and environmental impact of suburban sprawl began to rise (156). In 2002 The Canadian Mortgage and Housing Corporation responded to these concerns by developing a modified- or "fused-grid" street design that incorporates the connectivity of grid patterned neighbourhoods, but the traffic calming measures of lollipop and cul-de-sac designs. The primary objective of this neighbourhood design was to balance the health and safety of residents by passively encouraging active transport through infrastructure and connectivity for short trips but maintaining access for car users (161,162). The city of Saskatoon further responded to this call by creating the, "Official Community Plan," (2010) which outlines a minimum average household density of 5 units/acre, encourages residential-commercial mixed land use and a variety of housing, and utilizes the modified-grid street pattern (156).

4.2 Study Design & Participants

The Smart Cities, Healthy Kids and subsequent Seasonality and Active Saskatoon Kids (SASK) project was developed to improve our understanding of how neighbourhood design can affect child health through PA opportunities (163). The research described here is part of the CIHR funded, "A Step towards Creating Active Urban Communities: Informing Policy by

Identifying and Mapping Locations of Seasonal Activity Accumulation," grant (FRN #133539), led by Dr. Nazeem Muhajarine, which seeks to expand our understanding of the determinants of children's physical movement gained in the first 2010 Smart Cities, Healthy Kids study.

The study, "A Step Towards Creating Active Urban Communities: Informing Policy by Identifying and Mapping Locations of Seasonal Activity Accumulation," was approved by the Behavioural Research Ethics Board at the University of Saskatchewan, Canada (Beh #14-83). An amendment was approved by a delegated review for the addition of the Perceptions and Practices in Predicting Seasonal Differences in Activity Patterns of Children Questionnaire.

Participants were children aged 9-14 years and their parents who were recruited to the "A Step towards Creating Active Urban Communities" project (n=758) in Saskatoon, Canada. Participants were sampled from all 66 residential Saskatoon neighbourhoods.

In the school year prior to study commencement (June – July 2014), children and their parents were invited to participate in the study through a written informed consent letter disseminated by home classroom teachers. Children were instructed to bring the consent letter home to their parents and return it to their homeroom teacher within a specific time frame. Parent/guardian written informed consent was required for children and their parents/guardians to be enrolled in the study. Children and parents were instructed their enrollment was voluntary. Additionally, the consent form provided a section to explicitly decline study participation. Recruitment occurred in classrooms and schools where homeroom teachers and principals permitted research staff to deliver recruitment materials. The school with the most children returning completed consent forms, including both declining and participating children, were awarded a school-wide, "Gym Blast," prize (https://www.gymblast.com/).

Using a prospective longitudinal design, context and location-specific device-based physical behaviour measures in children were collected in conjunction with the Saskatchewan Population Health Evaluation Research Unit research team over three time frames from September 2014 to January 2015, January to April 2015, and May to September 2015 (excluding August 2015) using global-positioning system (GPS) equipped accelerometers. Child and parent demographic factors (using a questionnaire) and detailed child activity behaviours were collected during each collection period. SES was derived from the maximum annual household income reported by the parent (**Figure 4.2**).

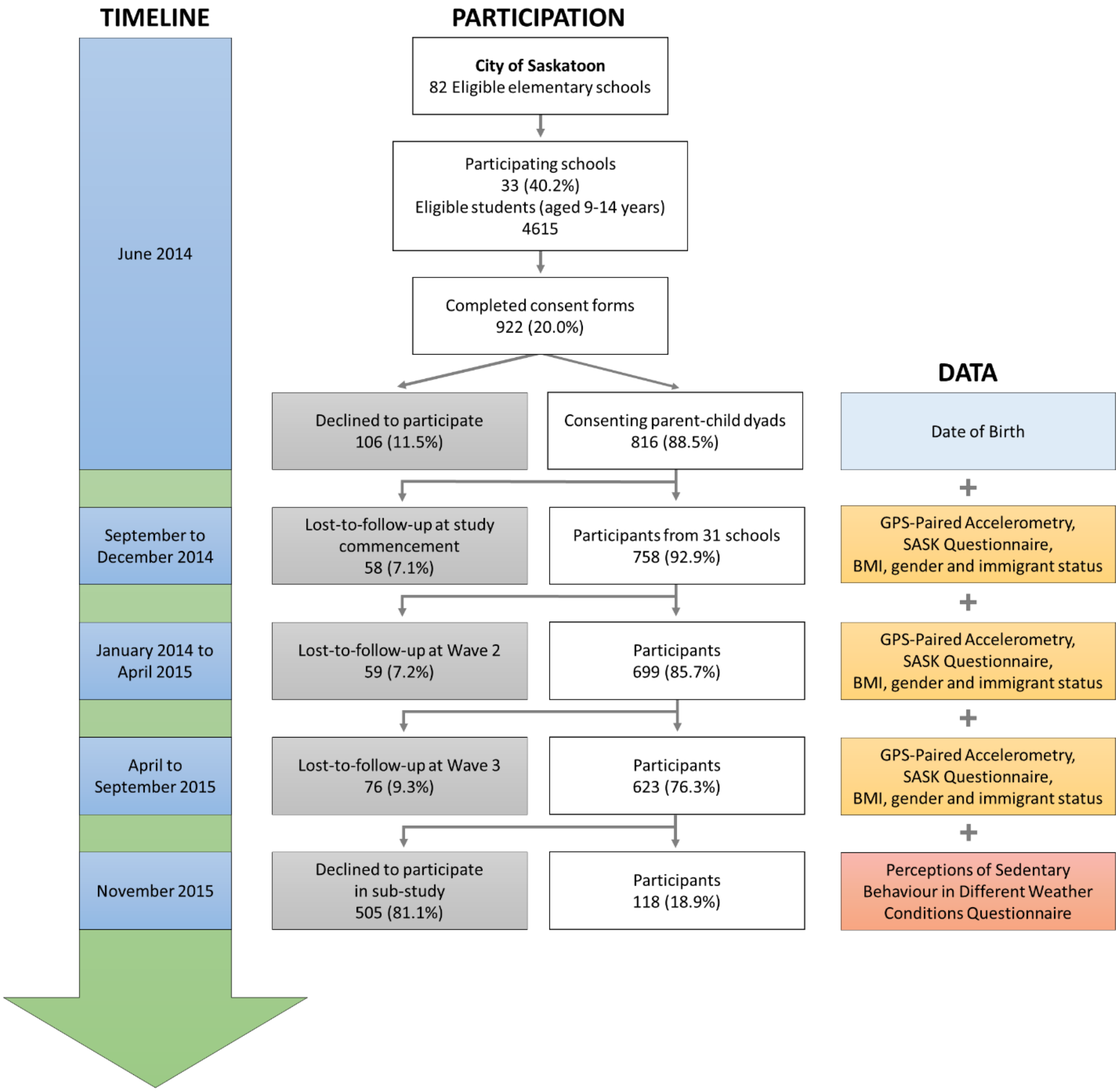


Figure 4.2 Study timeline, participation and data collection

The SASK (Seasonality and Active Saskatoon Kids) Questionnaire included parent-reported annual household income.

A large proportion of parent-child dyads did not report their annual household income during at least one time point. For this reason, the maximum reported annual household income was compressed into four categories: <$20,000 (reference), $20,000-$60,000, $60,000-$100,000, >$100,000, and choose not to answer/unknown/missing data.

4.3 Anthropometric Measures

Standing height (cm) and weight (kg) were measured on the day of accelerometry device deployment using a stadiometer (units: cm) and a digital scale (units: kg), resulting in a maximum of 3 measurements per participant. BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds. As defined by the WHO, BMI weight status was defined as severe thinness (<-3 standard deviations (SD)), thinness (<-2 SD), normal weight (reference category: -2 SD ≤ x ≤ +1 SD), overweight (>+1 SD), and obese (>+2SD). Overweight and obese status are equivalent to a BMI of 25 and 30kg/m^2 at 19 years, respectively (2). Implausible data was removed from the dataset, including extreme values and substantial changes in an individual's BMI between other collection time points. For example, a participant had a recorded BMI weight of 44.7. 46.6 and 26.1 kg, at the first, second and third data collection time points. The third data point resulted in an implausible age-adjusted BMI. Severe thinness and thinness were aggregated into a single category, underweight, due to a small sample size (n=6). BMI values obtained at the first collection time point were used for all subsequent analyses.

4.4 Device-Based Physical Behaviour Measures

SED, LPA and MVPA were measured using ActiGraph GT3X accelerometer devices (ActiGraph Corp., Pensacola, FL). Accelerometers were delivered to study participants' schools, where children were instructed to wear the accelerometer for eight consecutive days (including sleeping hours) unless entering water. For all participants, accelerometry data acquisition began on the following day at 0000h, allowing seven complete days of recording. Parents and children were instructed on how to wear the accelerometer-equipped belt to maintain proper positioning (*i.e.* posterior to the right iliac crest of the hip) (164), both orally by trained research staff and with a brochure included in their participant package on the day of device deployment. Objective activity behaviours were contextualized by pairing accelerometry outputs with GPS-location context.

Accelerometer vector magnitude was used for all physical behaviour cut-point data reduction. Biologically implausible data (34) and non-wear time were defined as >15,000 cpm and 60 minute epochs with <2 minute interruptions of continuous 0s (165), respectively, and were excluded from analysis. Activity level cut points were defined as follows: SED ≤150 counts per minute (cpm) (166), and LPA (150-1951 cpm), MPA (1952-5723 cpm) and VPA (≥5724 cpm) (167). MPA and VPA were aggregated to MVPA for all analyses.

SED outcome variables were expressed as total daily SED, SED accumulated at specific periods during the day or within specific geographical bounds. School hour SED was defined as Monday to Friday from 0915 to 1500h. All participating schools' class hours occurred within the stated time frame to ensure the exclusion of active forms of transport to and from school. Non-school hour SED was defined as Monday to Friday from 0600 to 0915h and 1500 to 2200h and Saturday to Sunday from 0600 to 2200h.

4.5 Sedentary Behaviour Location Context

The use of device-based SED (vs self-reported SB or SED) is considered the ideal method of measuring activity behaviours in children, but often lack contextual information. By pairing accelerometry data with GPS data we improved the limitation of device-based SED (86). Activity spaces, utilized in **Section 5.7** were defined using individual participant data from GPS data loggers. Belts equipped with accelerometers were housed with a Qstarz BT-1000XT Travel Recorder GPS logger (Qstarz International Co. Ltd., Taipei, Taiwan). GPS acquisition occurred at one second epochs. Latitude and longitude were averaged over one minute epochs to allow for pairing with accelerometry data. Over the entire study period a total of 9,055,216 participant minutes of GPS-derived location were collection. All data points falling outside of Saskatoon city limits were excluded from analysis (n=541,695 participant minutes). GPS data points falling within city limits were labelled by activity space/location, including an individual's home, school or school park, public city parks, road and 'other,' using city limits, ownership parcels, public park and road shapefiles obtained from the city of Saskatoon (April-November 2017).

Undefined 'other' locational data was further explored using participants' home property 20m buffer analysis and by designating location based on the city of Saskatoon's zoning designations. On weekdays and weekends, 24.1 and 23.4% of data points designated as 'other' fell within 20m of a participant's home. For all subsequent analyses, data points falling within 20m of a participant's home were included in home-activity analyses.

Public city parks were divided into two categories: school parks and non-school parks (for simplicity, non-school parks are referred to as 'parks' for the remainder of this thesis, unless otherwise stated). School parks are defined as public city parks immediately adjacent to school properties that share a common border, without the division of a roadway. In the city of Saskatoon, school properties and school parks appear continuous with no obvious borders and are visually indistinguishable with the exception of park name signage. Eighty percent (25 of 31) of schools attended by children in this study were immediately adjacent to a public city park. Of the school park visits (60,960 participants minutes), 94.5% (60,035 participant minutes) fell within a child's school neighbourhood. Of school park visits within a child's school neighbourhood, 98.8% occurred on weekdays (59,300 participant minutes) and of these, 96.7% (57,322 participant minutes) occurred within a 1-2 hour window of school hours (0700 to 1700h). School park visits that occurred on weekends, and that were outside of before-and-after school periods or a child's school neighbourhood were redefined as a public park visit for all analyses. Of children attending parks not designated as a school-park (57,326 participant minutes), 20.1 and 30.7% of participant minutes occurred during school hours or within a school-hour time buffer (weekdays from 0915-1500h: 10,950 participant minutes; weekdays from 0700-1700h: 7,165 participant minutes). Of these school-period park visits, only 3.0 and 3.8% occurred within the same neighbourhood as a child's school (1075 school hour and 1358 school hour time buffer participant minutes, respectively).

GPS data reduction to one minute epochs and initial activity space binning analyses were performed by the DISCUS lab (Rui Zhang), led by Dr. K. Stanley. Subsequent geographic information system (GIS) analysis was performed using QGIS (Version 2.18.9) (168) and R: A language and environment for statistical computing (169) using R Studio (170) and packages sp (171), and sf (172).

4.6 Parent and Child Beliefs and Support of Physical Activity and Sedentary Behaviour in Children in All Seasons

While others have explored the role of parent-child relationships in shaping activity outcomes, most have limited their analysis to PA and parental support of PA (91,92,100,103,104). Here, we ask if a parent's perception of their physical weather environment shapes their level of support for outdoor play, and if these perceptions are associated with children's activity behaviour. Children's perceptions of this parental support was also explored. This was done by expanding the concept of affordance and actualization of outdoor play, presented by Ergler *et al.* (91), to encompass PA opportunities in different weather conditions.

Due to a lack of availability of instruments measuring the interaction between perceptions of cold weather and weather condition differences in SB in either children or adults, items were adapted from existing validated questionnaires. Parental practices surrounding outdoor activities in winter weather conditions vs. summer months were assessed using adapted items developed from the ENERGY cross-sectional survey (**Appendix A, Table A.1**) (173). Perceptions of weather-related safety and outdoor activities of children were assessed using a single item adapted from the Neighbourhood Environment Walkability Scale (NEWS) and NEWS-Youth (NEWS-Y), Safety from Crime items (174,175). A final item was developed to explore perceptions of activity affordance by season by parents and children and has not been validated. All item responses utilized a Likert scale (1-strongly disagree, 2-somewhat disagree, 3-somewhat agree, 4- strongly agree) and were appropriately coded so that encouragement of outdoor and active play during all seasons was given the highest score. Scores were dichotomized into binary responses of either favouring or disfavouring outdoor play (**Table 4.1**).

Parents and children's responses were aggregated (stratified by parent or child) to create a total composite score of perceptions in favour (higher score, value of 1) or disfavour (lower score, value of 0) of promoting activity outside/outdoors during all seasons. A second score was created, stratified both by weather condition and parent/child. All scores were created by calculating the percentage of the highest possible score over the span of the specified items. The Shapiro-Wilk normality test was used to assess if each composite score demonstrated a normal distribution. The total parent perception score, total child perception score, and child perception of outdoor play support in mild summer weather conditions (>10°C) score had normal distributions, but the remainder of the composite scores did not.

Table 4.1 Perceptions of sedentary behaviour in different weather conditions parent-child questionnaire.

Item grouping introduction statement	Constructs	Parent Questionnaire Item	Child Questionnaire Item	Adaptation Source
These questions are about activities your child does/you do when weather conditions are -27°C or colder in the WINTER months. Please indicate the degree to which you agree or disagree with the following statements:	Parental Practices - encouragement and permissiveness regarding indoor/outdoor activity	When it is very cold outside (-27°C with the wind chill or colder) I encourage my child to take part in physical activity/sports OUTDOORS	My parents encourage me to play OUTDOORS when it is very cold outside (-27°C or colder with the wind chill)	Rebholz *et al.* (173) **Table A.1**
		When it is very cold outside (-27°C with the wind chill or colder) I encourage my child to play INDOORS	My parents encourage me to play INDOORS when it is very cold outside (-27°C or colder with the wind chill)	
		When it is very cold outside (-27°C with the wind chill or colder) my child is allowed to watch TV/videos or play video/computer games whenever (s)he wants.	My parents allow me to watch TV/videos or play video/computer games whenever I want when it is very cold outside (-27°C or colder with the wind chill)	
	Cold Weather Safety	Cold temperatures (-27°C with the wind chill or colder) make it unsafe for my child to go for walks or play OUTSIDE	Very cold temperatures (-27°C or colder with the wind chill) make it unsafe for me to go for walks or play outside	NEWS (174)
These questions are about activities your child does/you do when weather conditions are around -10°C to -15°C in the WINTER months. Please indicate the degree to which you agree or disagree with the following statements:	Parental Practices - encouragement and permissiveness regarding indoor/outdoor activity	When it is around -10 to -15°C I encourage my child to take part in physical activity/sports OUTDOORS	When it is around -10 to -15°C my parents encourage me to play OUTDOORS	Rebholz *et al.* (173), **Table A.1**
		When it is around -10 to -15°C I encourage my child to play INDOORS	When it is around -10 to -15°C my parents encourage me to play INDOORS	
		When it is around -10 to -15°C my child is allowed to watch TV/videos or play video/computer games whenever (s)he wants.	When it is around -10 to -15°C my parents allow me to watch TV/videos or play video/computer games whenever I want	
	Cold Weather Safety	When temperatures are around -10 to -15°C it makes it unsafe for my child to play OUTSIDE	Temperatures around -10 to -15°C make it unsafe for me to go for walks or play outside	NEWS (174)

Item grouping introduction statement	Constructs	Parent Questionnaire Item	Child Questionnaire Item	Adaptation Source
These questions are about activities your child does/you do when weather conditions are above 10°C with little or no rain in SPRING, SUMMER, or FALL months. Please indicate the degree to which you agree or disagree with the following statements:	Parental Practices - encouragement and permissiveness regarding indoor/outdoor activity	When the weather is warmer (at least 10°C with little or no rain) I encourage my child to take part in physical activity/sports OUTDOORS	When it is warmer outside (at least 10°C with little or no rain) my parents encourage me to play OUTDOORS	Rebholz *et al.* (173), **Table A.1**
		When the weather is warmer (at least 10°C with little or no rain) I encourage my child to play INDOORS	When it is warmer outside (at least 10°C with little or no rain) my parents encourage me to play INDOORS	
		When the weather is warmer (at least 10°C with little or no rain) my child is allowed to watch TV/videos or play video/computer games whenever (s)he wants.	When it is warmer outside (at least 10°C with little or no rain) my parents allow me to watch TV/videos or play video/computer games whenever I want.	
	Seasonal affordance	When the weather is warmer (at least 10°C with little or no rain) there are more activities for my child to do OUTDOOR compared to when the weather is colder	There are more activities for me to do OUTDOORS when it is warmer (at least 10°C with little or no rain) compared to when the weather is colder	N/A

All consenting parent-child dyads who did not actively drop-out from the study were invited to respond to a questionnaire exploring their perceptions of indoor and outdoor play in different weather conditions (n=758). Questionnaire invitations were deployed on November 27, 2015 by e-mail invitation and required the use of an internet connection and web browser. Although participants were asked to complete the questionnaire within two weeks, the online questionnaire remained open until Dec. 31, 2015. A single reminder was delivered to all participants who did not at least complete one questionnaire item on Dec. 10, 2015.

4.7 Neighbourhood Mapping

Saskatoon's six developing and sixty established neighbourhoods were defined by municipal boundaries, development era, and associated urban design. Neighbourhood environment characteristics were collected for Saskatoon's 66 neighbourhoods using two audit tools, the IMI and NALP tools in the summer months of 2010 and updated in July-August 2014. The IMI is "an extensive audit tool aimed at measuring a broad range of BE features that may be linked to active living," (7) and is made up for 160 items. Within the inventory, five themes exists: destinations (density of destinations), accessibility (pedestrian access), pleasurability (attractiveness) and perceived safety from traffic and crime (176). The NALP is a 22 item tool consisting of four domains: universal accessibility, safety, density of destinations, and activity friendliness. NALP has been shown as a reliable environment measure in the context of Saskatoon (177). Neighbourhood era design, NALP cumulative and dimension score, IMI cumulative and dimension/inventory scores, and a combined NALP-IMI cumulative score, were applied to multivariable analysis in the prediction of SED.

4.8 Season and Weather

For all weather-related analyses, Environment Canada's Saskatoon Diefenbaker International Airport and Saskatoon RCS weather stations historical daily and hourly climate data were used (178).

Weather differences in the year of data collection (September 2014 to September 2015) were assessed by comparing Canadian 1981-2000 climate normals from Saskatoon Diefenbaker International Airport station (179) to either Saskatoon RCS station monthly climate summaries for the data collection period (180) or mean monthly wind speed from hourly weather data (178).

Season was defined using northern meteorological seasons, where winter, spring, summer and fall are defined by calendar date, from December 1 to February 28/29, March 1 to May 31, June 1 to August 31, and September 1 to November 30, respectively (181). When season was utilized in analyses winter was defined as the reference variable.

4.9 Data Acquisition, Cleaning and Analysis

Data cleaning, manipulation, analysis and visualization was performed in R: A language and environment for statistical computing (169) using R Studio (170), unless otherwise stated. Critical R packages for analyses included dplyr (182), tidyr (183), lubridate (184), eeptools (185), effects (186), stargazer (187), nlme (188), rmarkdown (189), dplyr (182), psych (190), RMySQL (191), stringr (192), and xlsx (193). All data was visualized using the R package, ggplot2 (194).

Accelerometer data was collected at 100 Hz epochs. Accelerometer-generated data were analyzed using ActiLife 6 data analysis software (Version 6.11.4, ActiGraph Corp., Pensacola, FL). Data were reduced to one second epochs and exported in the ActiLife proprietary format. Accelerometry data reduction from one second epochs to total daily SED, total daily leisure hour and total daily school hour SED (expressed as cpm) was performed by William van der Kamp and Rui Zhang (under the supervision of Dr. Kevin Stanley of the DISCUS lab) using Python (Version 2.7.11) and bash, awk, and C++ code, written by Dr. Tuhin Paul. Biologically implausible data (34) and non-wear time were removed from data inputs on a minute-to-minute basis (165), and total daily wear time was reported. Valid accelerometry data at each collection time point was defined as a minimum daily wear time of 10 hours over at least four days during a seven day collection period. One minute epoch accelerometry data were further partitioned by activity thresholds into SED, LPA or MVPA using the cut-points previously described.

The SASK Questionnaire paper versions were manually entered into Microsoft® Excel® 2013 (Version 15.0.4963.1000). The electronic SASK and the Perceptions of SB in Different Weather Conditions questionnaires were deployed and responses were collected using Fluid Surveys (http://fluidsurveys.com/) online survey software. Fluid Survey questionnaire data was exported and further cleaned in Microsoft® Excel® 2013. After separate data cleaning of the SASK electronic and manually entered questionnaires, versions were aggregated for subsequent cleaning and analyses in Microsoft® Excel® and R: A language and environment for statistical computing.

BMI was calculated using the WHOs 2007 Growth Reference for 5-19 years SPSS Macro (195) and IBM® SPSS® Statistics (Version 24).

GPS data was collected at one second epochs. GPS data reduction from one second to one minute epochs was performed by Rui Zhang using Python (Version 2.7.11). For each one minute epoch, the median latitude and longitude coordinates were used. Velocities >100 km/hr and GPS coordinates falling outside of Saskatoon city limits were excluded. GPS data points were divided into 6 locations: home, school, school-park, park, road and other locations. GQIS (Version 2.18.9) was used for the analysis of location data. (168). Home addresses provided by the participating families were paired with ownership parcel data to create a defined home space. Participating school addresses were paired with ownership parcel data to create school spaces. Park boundaries were predefined using city of Saskatoon shapefiles. The majority of participating school properties are immediately adjacent to a public park. To create distinct school and park spaces, nearest neighbour analysis was performed using GQIS, followed by manual confirmation. Parks immediately adjacent to school properties were labelled as a school-park. Parks adjacent to schools, but separated by a roadway were labelled as a 'park'. Ownership parcels, school, park and city boundary shapefiles were provided by the city of Saskatoon and the University of Saskatchewan (April-November, 2018).

4.9.1 Multilevel Models Predicting Sedentary Behaviour in Children Inclusive and Exclusive of Physical Activity

SED was the primary outcome variable of interest and used as the dependent variable in all univariate and multiple variable multilevel mixed effect models (MLM) presented. Each participant contributing valid accelerometry data had a minimum of four days (or data points) of accelerometry data, resulting in repeated measures nested within the individual. Additionally, participants shared common home or school neighbourhoods. For these reasons, a multilevel modelling approach was used. To confirm the necessity of employing either a random slope or intercept in each set of MLMs, repeated measures of 30 randomly selected valid participant's data from a single time point (i.e. a maximum of seven valid days of accelerometry data per participant) were plotted. With the exception of variation between weekday and weekends, participants repeated measures did not vary greatly enough on a day-to-day basis to warrant the inclusion of a random-slope in the MLM. A model containing only the repeated measures outcome within individuals was used to determine the level of variability on the individual-level and correlation structure applied to the model (autocorrelation structure of order 1, with a continuous time covariate for all models presented). Univariable models included Level 1 season and LPA and MVPA accumulated on the same day as the SED outcome measure. Multivariable MLMs were built using a backwards step-wise approach, first establishing level 1 main effects and then level 2 main effects. Only Level 1 variables demonstrating significant prediction ($p < 0.05$) of SED and improved model fit were included. All Level 2 variables (gender, age, BMI weight status, and maximum reported annual household income) were added to the Level 1 main effects simultaneously and removed when non-significant in a backwards step-wise approach. Level 3 independent variables (neighbourhood era design; NALP dimension scores: aesthetic factors, density of destination, safety, and universal accessibility; IMI dimension scores: density of destination, pedestrian accessibility, safety from crime, safety from traffic; NALP and IMI cumulative scores, and combined NALP and IMI score) were added to each model one at a time, where significance and model fit were assessed. Main effects models were tested for confounding at each step of the model building process. A minimum significance level of 5% was used for all analyses. Model quality and fit were assessed using Akaike's Information Criterion (AIC) and Bayesian Information Criterion (BIC). Both AIC and BIC were used simultaneously to accommodate each other's limitation of favouring larger (more variables/complex) and smaller (less variables/complex) models, respectively. When independent variables did not contribute to the significant prediction of the outcome variables, but provided a model with a lower AIC and/or BIC, the most parsimonious model was chosen (*i.e.* the variable was excluded). With each step-wise elimination, non-significant independent variables were tested for confounding (>10% increase in the beta estimate). After final models were chosen fitted residual plots were created to assess model quality (i.e. plots of fitted values vs. standardized residuals and standardized residuals vs. quantiles of standard normal probabilities), by ensuring even distribution of standard vs predicted error amongst cases. All main effects were tested for collinearity, which no independent variables exhibited.

Multilevel models predicting SED were developed to address the research questions outlined in **Section 1.3**. To understand if season or a child's demographic factors are able to predict SED in children, SED was explored within two main themes, by time- or location-dependence (**Section 1.3, Research Questions Ai, and Aii**). In time-dependent analyses, models exploring season and a child's demographic factors as predictors of SED considered a child's entire waking day, their school period and their non-school period (leisure hours). Additionally, the influence of a child's home (for total daily, leisure hour SED) and school (for school hour SED) neighbourhood level attributes were explored as main effects predictors and moderators in these models (**Section 1.3, Research Questions Ai**). In location-dependant analyses, models exploring season and a child's demographic as predictors of SED only considered a child's activity patterns while they were within 20m of their home, on their school property or within a city park. As with time-dependent models, home (for home- and park-location SED analyses) and school (for school-location SED analyses) neighbourhood level attributes were explored as main effect predictors and moderators in these models (**Section 1.3, Research Question Aii**). Models predicting time dependent outcomes were divided into two subcategories: those excluding other physical behaviours and those including both LPA and MVPA.

The level 1 variable defining weekend/weekday SED was included in MLMs exploring the prediction of location-dependent (home area, school and park) SED, but not in those predicting time-dependent SED. School hour and school-park area SED excluded weekend days, and therefore weekend vs weekday was not included in these MLMs. In time- and location-specific MLMs predicting SED, LPA and MVPA were included as Level 1 variables in the model building strategy. In time-dependent, but not location-dependent MLMs predicting SED, models excluding LPA and MVPA are also presented.

The primary focus of this thesis is to understand what predicts SED in children. Yet, the overarching theme of this research is to better understand how we can create better social and physical environments that can reduce children's SED while simultaneously displacing this activity with healthful PA. While the concept of displacement theory was raised by Mutz *et al.* (48) a quarter of a century ago, little research has explored both PA and SB in concert. In a cohort of over 10,000 adults from the Canadian Health Measures Survey, isotemporal substitution models demonstrated that the displacement of 30 minutes of SED with an equivalent gain in MVPA was associated with a significant improvement in BMI and waist circumference (196). Similarly, all-cause mortality risk was significantly reduced when replacing SED with sleeping, walking, and MVPA (44). These studies provide evidence in part that SB alone is a unique physiological state, that when accumulated in excess can lead to negative health outcomes. Yet, they also demonstrate that while SBs are important, so are the activities we aim to displace them with.

Continuous SED was used as the dependent variable in all presented MLMs in this thesis, either over an entire day, or constrained by time or location. While the data here was not presented in a compositional manner (that is, given as a log-ratio of a child's other waking activity and sleeping behaviours) (50), SED is intrinsically tied to all waking (LPA, MPA and VPA) and sleeping behaviours accumulated by the individual. If one behaviour is altered, other activity behaviours must be altered in concert to replace the loss or gain in one physical action/inaction. Because of the loss-gain relationship between activity behaviours, a portion of the models presented in this thesis are inclusive of LPA and MVPA to better understand the relationship of demographic factors, season, BE and SED in the context of PA accumulated in the same time- or location-specific scenario. As sleep data was not analyzed in this cohort, it was not included in the study. For these reasons, models predicting time-dependent SED in this thesis are inclusive of PA. Additionally, to allow for comparison between PA inclusive and exclusive models predicting SED, both forms of models are presented in time-dependent SED analyses.

4.10 Research and Thesis Project Contributions

Larisa Lotoski (L.L.) made the following contribution to the Seasonality and Active Saskatoon's Kids research project and thesis: (1) Conceptualization – Under the supervision of Dr. Muhajarine and with the guidance of her thesis committee L.L. formulated the research aims, questions and hypotheses outlined in Sections 1.2-1.4; (2) Data Curation: In conjunction with the Saskatchewan Population Health and Evaluation Research Unit research team, L.L. deployed accelerometry and GPS devices, instructions (both orally and in paper format) and study information materials to study participants and collected anthropometric measures of study participants during the study period. L.L. scrubbed and amalgamated the Seasonality and Active Saskatoon Kids questionnaire paper and online survey datasets. L.L. prepared accelerometry and GPS data files for wear time analysis, 1 minute epoch data reduction and data pairing by the DISCUS team. L.L. scrubbed accelerometry and GPS datasets prior to analyses. L.L. developed and electronically deployed the questionnaire exploring parent and child beliefs and support of physical activity and sedentary behaviour in children in all seasons. L.L. calculated study participant's zBMI scores. L.L. amalgamated all weather data. L.L. scrubbed and amalgamated all final accelerometry, GPS, questionnaire, and neighbourhood-level attribute datasets prior to formal analyses; (3) Formal Analysis: L.L. performed all analyses presented in this thesis with the exception of spatial binning of GPS data points to school areas and roadways and wear time analyses of accelerometry data; (4) Methodology: In conjunction with the Seasonality and Active Saskatoon Kids principal investigator (Dr. Nazeem Muhajarine) and co-investigators, L.L. significantly contributed to the methodologies presented throughout this thesis, including accelerometry and GPS data reduction for analysis.

Chapter 5 Results

5.1 Study Participation

5.1.1 Participation

Within Saskatoon's public and Catholic school divisions there are 92 elementary and junior high schools, 82 of which are within Saskatoon city limits. Thirty-three (40.2%) of these schools (i.e. their principals) agreed to allow the distribution of invitations and accompanying consent forms to the SASK study. Within these 33 schools, it is estimated that 4615 students aged 9-14 were eligible for the study. 20% (n=922) of eligible students returned consent forms, of which 88.5% (n=816) of parents consented to their children participating in the study, and 11.5% (n=106) refused. At the first (Sept - Dec 2014), second (Jan - Apr 2015) and third (Apr - Jun 2015) data collection time points 58 (7.1%), 59 (7.2%), and 76 (9.3% of the original consenting population) students were lost to follow up (either absent, had moved to a different school or province, or declined to participate further), respectively. The total number of consenting participants at the first, second and third collection points, therefore, included 758, 699 and 623 child-parent dyads from 31 schools (**Figure 4.2**).

At the beginning of each collection point, anthropometric measures were collected at the school when the accelerometry and GPS equipment were deployed. The presence of a participant's height and weight data (regardless of the validity) was indicative of child's participation at that time point (i.e. they were delivered an accelerometer, GPS device, a paper or online questionnaire and accompanying instructional materials). Therefore, anthropometric measures were used as an indicator of participation during each round. BMI values were not an indicator if children successfully recorded valid movement and location data with accelerometry and GPS data loggers, respectively.

The study population was examined in two ways below. First, count and prevalence of each demographic variable was calculated for each child that participated in one, two and all three data collection rounds. Chi-squared analysis was used to examine if differences between these groups, by demographic category, was significantly different. Participants, and their degree of participation, differed significantly by their era of the neighbourhood in which they lived and self-reported annual household income. Reported gender, age, BMI and immigrant status did not vary between degrees of participation (**Table 5.1**).

Table 5.1 Demographic characteristics of participants by completeness of participation at all three time points.

	Total Number of Time Points Contributed by Participants			
	1	2	3	
Variable	**n(%)**	**n(%)**	**n(%)**	**p-value**
Gender				
Male	26 (3.4)	54 (7.1)	265 (35.0)	0.2296
Female	20 (2.6)	75 (9.9)	318 (42.0)	
Age (years)				
9	1 (0.1)	3 (0.4)	30 (3.9)	0.6097
10	13 (1.7)	38 (5.0)	184 (24.2)	
11	15 (2.0)	35 (4.6)	184 (24.2)	
12	10 (1.3)	31 (4.1)	110 (14.5)	
13	7 (0.9)	22 (2.9)	71 (9.3)	
14	3 (0.4)	0 (0.0)	4 (0.5)	
Body Mass Index †				
Underweight	1 (0.1)	3 (0.4)	5 (0.7)	0.6824
Normal Weight	24 (3.2)	82 (10.8)	359 (47.4)	
Overweight	12 (1.6)	27 (3.6)	134 (17.7)	
Obese	9 (1.2)	17 (2.2)	85 (11.2)	
Immigrant Status §				
Not new immigrants to Canada	43 (5.7)	106 (14.0)	511 (67.7)	0.0816
New Immigrants to Canda	3 (0.4)	23 (3.0)	69 (9.1)	
Annual Household Income ‡				
<$20,000	0 (0.0)	3 (0.4)	11 (1.5)	<0.0001
$20,000 to $60,000	3 (0.4)	16 (2.1)	91 (12.0)	
$60,000 to $100,000	2 (0.3)	23 (3.0)	96 (12.7)	
>$100,000	11 (1.5)	47 (6.2)	237 (31.3)	
Unknown	30 (4.0)	40 (5.3)	148 (19.5)	
Neighbourhood Era				
<1930 grid	3 (0.4)	9 (1.2)	59 (7.8)	<0.0001
1930-1960s fractured grid	15 (2.0)	17 (2.2)	129 (17.0)	
1960-present curvilinear	27 (3.6)	96 (12.7)	362 (47.8)	
Rural	1 (0.1)	7 (0.9)	33 (4.4)	

† BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).

§ New immigrants to Canada included children reported living within Canada for less than two years.

‡ The category "Unknown" for annual household income includes those who actively chose not to answer, didn't know their annual household income, or did not provide an answer.

When degree of participation was stratified by those who either completed less than 3 time points vs all three time points, results did not vary (*data not shown*).

5.1.2 Accelerometry Participation, Collection Distribution, and Wear Time Criteria

Accelerometry data collection occurred over a one week period during three time points from September 2014 – September 2015. At each time point 745, 706, and 592 participants provided accelerometry data. The large study population size (>750), limited number of accelerometry and GPS devices (<150), and time required to download and reinitialize devices for re-deployment resulted in data collection occurring throughout school and non-school periods, over 11 calendar months in total (i.e. excluding August 2015). Data collection occurred during both in-and out-of-school periods. School hour SED analysis excluded all accelerometry data recorded in July. During the final third collection time point 48 participants' accelerometry data were collected in July 2015, a period where children were not attending school (highlighted in green, **Figure 5.1**). Additionally, four participants had their final collection time point in September 2015 during the following school year (**Figure 5.1**).

Three valid accelerometry wear time criteria were compared:

1. A minimum of 4 days, with each day having no less than 10 hours of valid wear time
2. A minimum of 4 days, with each day having no less than 12 hours of valid wear time
3. A minimum of 4 days, with each day having no less than 14 hours of valid wear time

The least restrictive criteria (a minimum of 10 hours per day, over a minimum of four days), which was used for all subsequent analyses, resulted in 50.8-69.7% participants providing valid accelerometry data (**Appendix B, Table B.1**).

To understand the effect of non-wear time on daily activity outcome totals, total daily SED, LPA and MVPA were plotted against total daily non-wear time for all recorded accelerometry days (n=14,326 days of accelerometry data points from 758 participants). Linear regression predicting SED, LPA and MVPA indicated that for every additional minute of non-wear time, participants were predicted to experience a 0.33, 0.46, and 0.21 minute loss of total daily SED, LPA and MVPA data ($p<0.0001$), indicating that LPA data experienced the greatest loss with reduced wear time compliance (**Figure 5.2**). When comparing mean total daily activity levels and non-wear time by valid accelerometry participation, all activity levels (SED, LPA and MVPA) significantly increased with accelerometry participation.

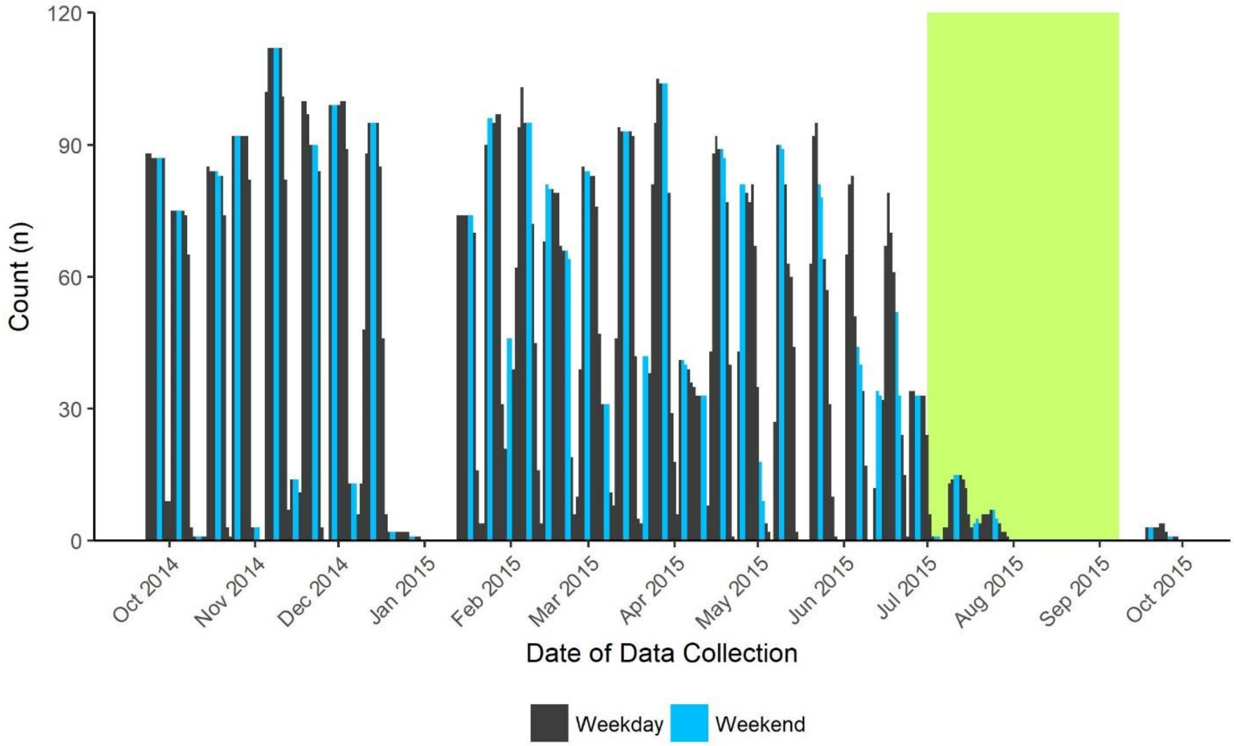


Figure 5.1 Accelerometry data collection daily distribution.

Green shading represents summer vacation days when children were not regularly attending school. Both invalid and valid accelerometry data points are included.

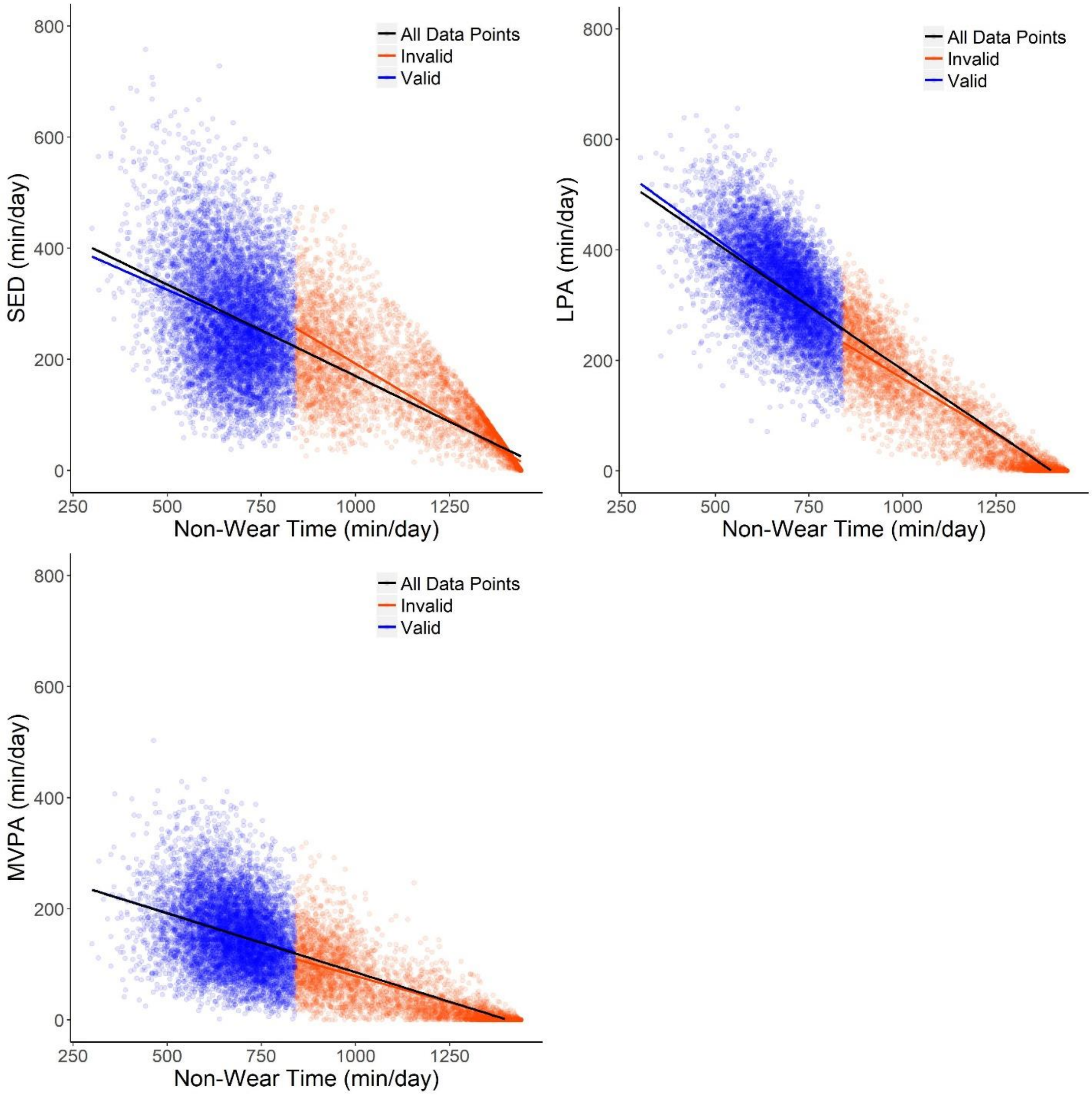


Figure 5.2 Accelerometry device non-wear time effect on activity outcome measures.

Sedentary behaviour (SED), light physical activity (LPA) and moderate-to-vigorous physical activity (MVPA) outcomes are shown stratified by days falling within validation criteria (<840 non-wear time minute per day) and non-valid days (blue and orange, respectively). Linear regression lines are shown for both valid and non-valid days (blue and orange, respectively) and all data points (black).

Non-wear time was significantly lower in participants who provided two and three valid accelerometry time points in comparison to those who only provided a single valid time point (SED, LPA, MVPA, and non-wear time ANOVA $p < 0.0001$, **Figure 5.3**).

When examining all wear time epochs on a minute-to-minute basis, weekday wear time peaked at approximately 0830h and remained relatively constant until 1530h, the approximate time of school dismissal. After 1900h on weekdays, a steady decline in wear time occurred. From 0600h onwards, weekend wear time steadily rose until approximately 1200h, where it remained constant until 1900h when a rapid decline in wear time occurred.

5.1.3 SASK Questionnaire Participation

Accounting for all participants in the study, including those who only participated in the first and second collection time points (*vs* all three), 656 child-parent dyads responded to the SASK questionnaire at least once (86.5% of 758 participants present at the first time point). When comparing participants that completed at least one SASK questionnaire (*vs* those who did not complete any), there were no significant differences in age, gender, weight status, new immigrant status or neighbourhood era of residence form (grid, fractured grid, curvilinear, and modified grid). When comparing participants that completed the SASK questionnaire at all three time points (n=258) vs those who completed less than three or none (n=502), neighbourhood of residence era differed significantly between groups (Chi-squared p=0.001). Those who completed the SASK questionnaire at all three time points, vs less than three or none, were less likely to be from the older grid-patterned (5.81%), or more recent modified-grid (12.8%) or rural (3.88%) neighbourhoods in comparison to non-respondents. Additionally, of those who completed the SASK questionnaire at all three time points vs non-respondents, a greater proportion lived in fractured grid patterned neighbourhoods (27.9%) and curvilinear patterned neighbourhoods (49.6%, non-respondents: 17.7 and 47.6%, respectively).

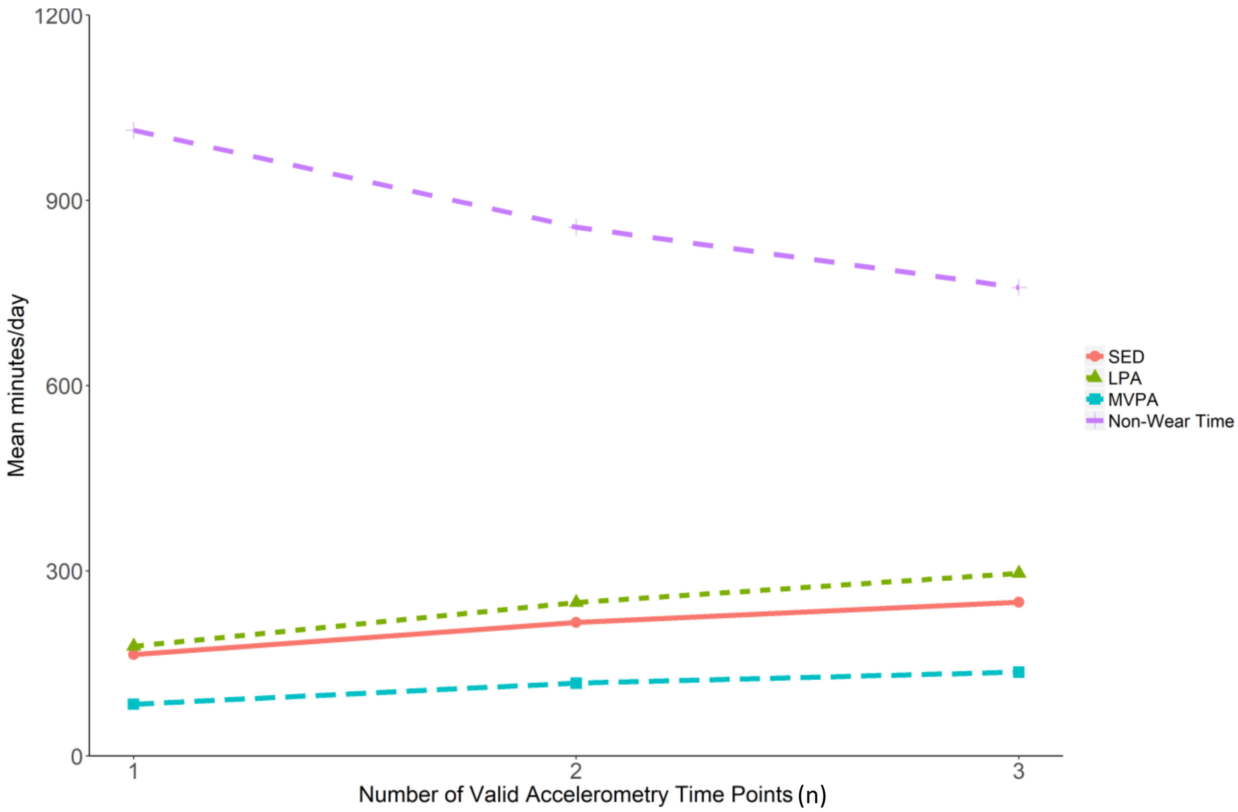


Figure 5.3 Study participant's valid accelerometry time point contribution and activity and non-wear time outcomes.

5.1.4 Global Positioning System Participation, Collection Distribution, and Wear Time Criteria

Contextual activity behaviour location information was collected using GPS during all accelerometry data collection. The accelerometers used, which have no power switch, required no charging during the collection period and were not easily removed from the participants' belts. The GPS devices, however, required daily removal for charging and participants were able to power the device off at will. These GPS device limitations created a need for employing separate validation criteria, independent of accelerometry data, prior to pairing data. GPS daily wear time criteria were compared at each data collection time point. Before employing a minimum number of valid GPS days per timepoint, 64.6 and 57.0% of participants had valid GPS data with a daily minimum wear time of 8 and 10 hours, respectively. After a minimum of three or four valid days/time point criteria was employed, substantial loss was noted using a minimum wear time of 10 hours per day and/or a minimum of four valid days/time point (**Figure 5.4**).

Figure 5.5 and **5.6** summarize valid GPS data contributions based on valid wear time criteria over a minimum of three and four days per time point, respectively. Most notably, choosing a minimum of four valid days per time point resulted in remarkably high data loss, especially during the first collection time point. Weekdays were more susceptible to GPS data loss due to poor wear time compliance in all conditions tested (**Figure 5.7**).

Of study participants, 519, 411 and 301 participants contributed valid accelerometry data during the first, second and third collection time point, respectively (**Table B.1**), resulting in 7142 valid participants days of accelerometry data. Of the valid accelerometry participant days, 30.7% (n=2194 participant days) had no corresponding GPS data. Of the remaining 5218 participant days, 92.8% (n=4320 participants days) were from days where 613 participants recorded at least 8 hours of GPS data. After all erroneous and out-of-city GPS data were removed and only valid GPS and accelerometry data points were retained, 501 (66.1% of 758) participants contributed data for at least one collection time point. During the first, second and third collection time points 307 (40.5%), 345 (45.5%), and 247 (32.6%) of participants contributed both valid accelerometry and GPS data, respectively (**Figure 5.8**).

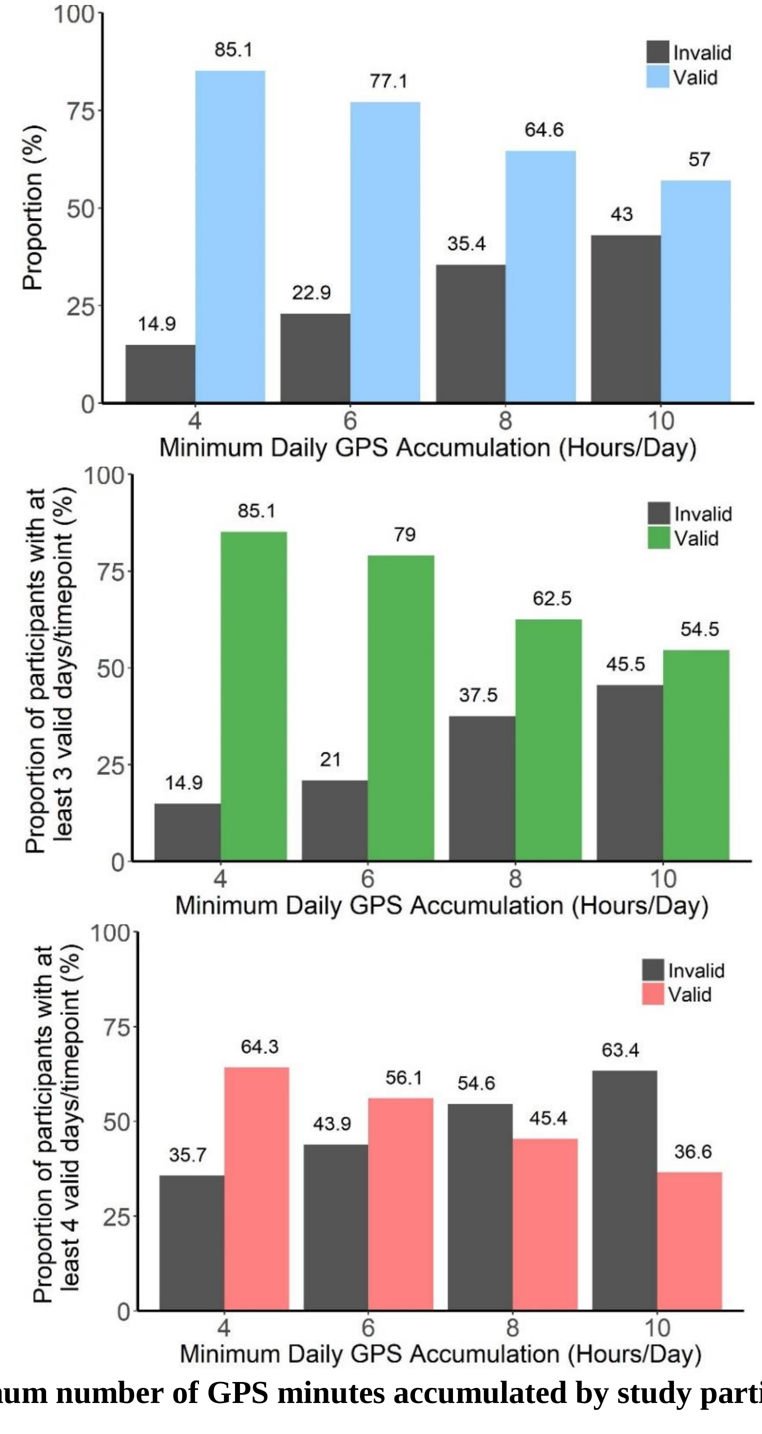


Figure 5.4 Minimum number of GPS minutes accumulated by study participants per day.

A minimum daily wear time of 4, 6, 8 and 10 hours of GPS hours per day are presented. (A) The proportion of GPS participant days that met the minimum wear time criteria (n=9845), (B) and (C) The proportion of participants that met daily hourly wear time criteria on at least 3 and 4 days per collection time point, respectively (n=1781 from 751 participants over 3 collection time points). Values above bars represent proportions (%) within the minimum wear time criteria.

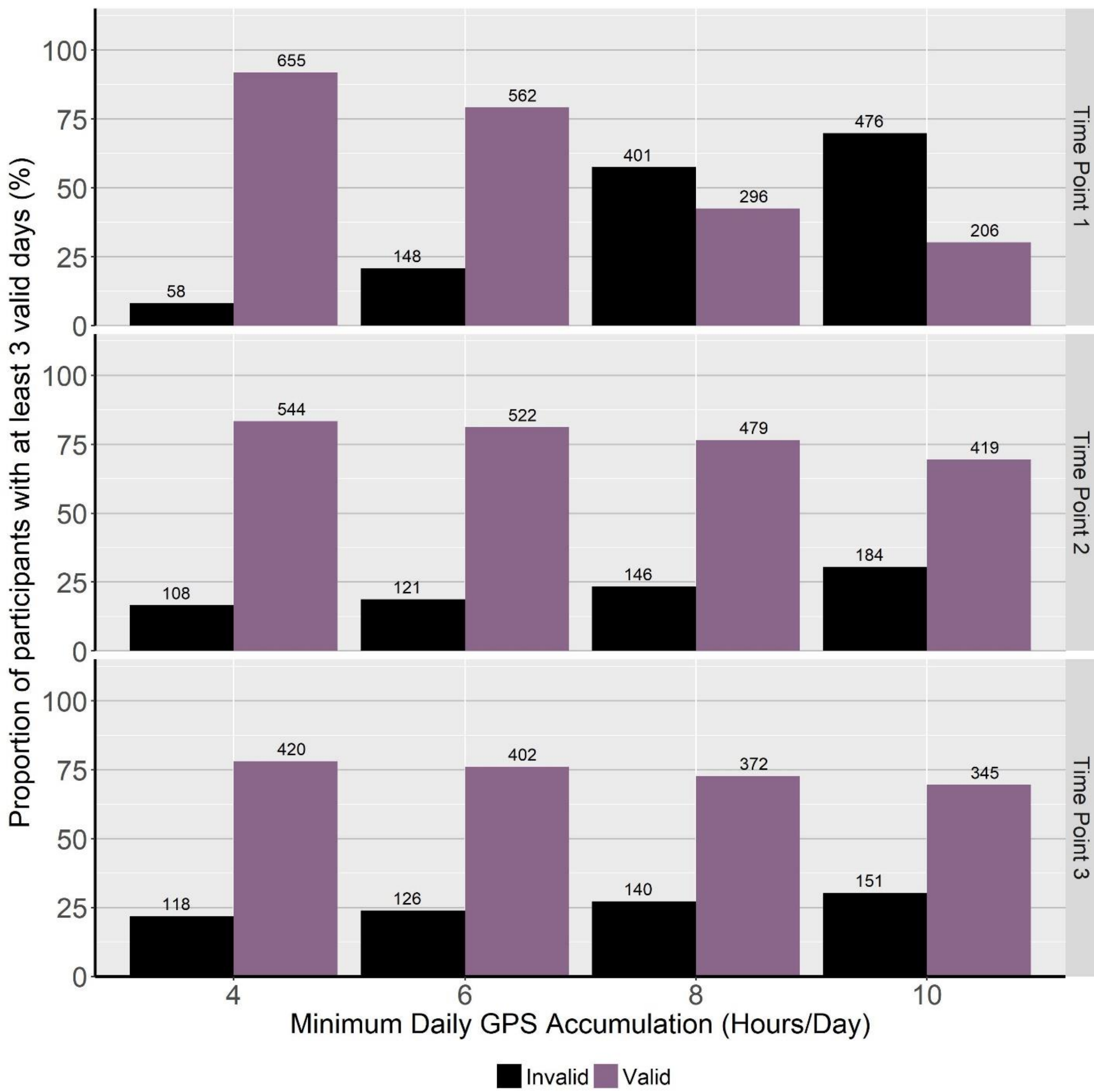


Figure 5.5 The proportion of participants with at least three valid days of GPS data, stratified by time point.

Values plotted represent the percentage of participants with either invalid or valid data, based on minimum daily wear time criteria over a minimum of three days. Values shown above bars represent the total number (n) of participants with either valid or invalid data (i.e. with both the daily minimum wear time and at least three valid days) at each time point.

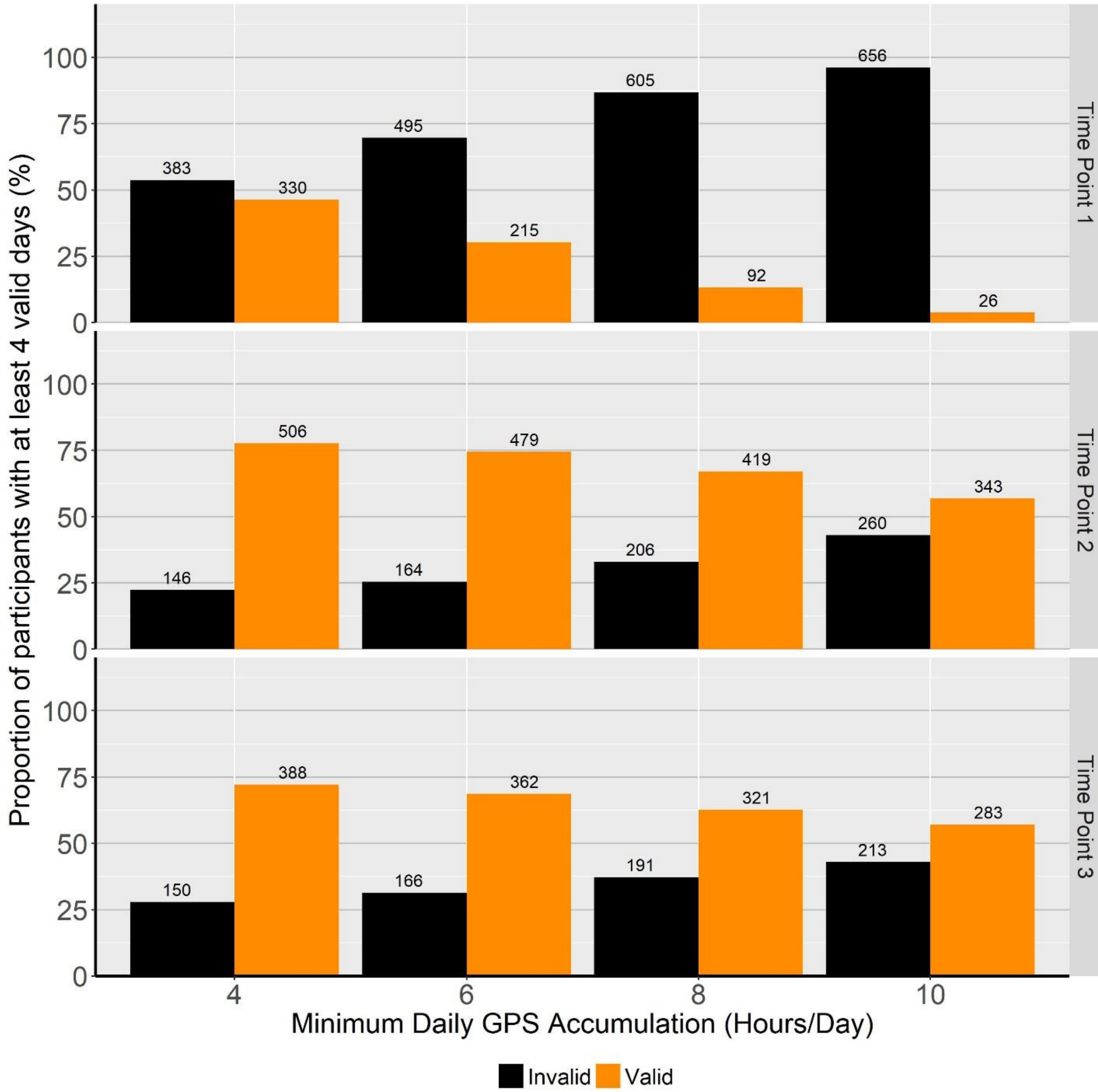
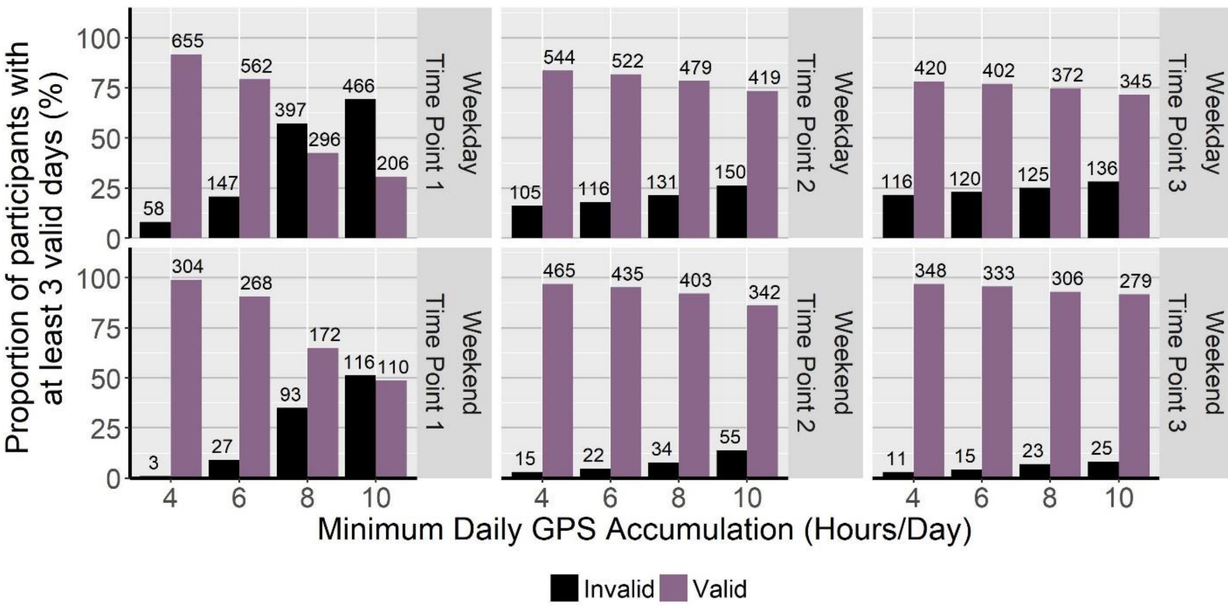


Figure 5.6 The proportion of participants with at least four valid days of GPS data, stratified by time point.

Values plotted represent the percentage of participants with either invalid or valid data, based on minimum daily wear time criteria over a minimum of four days. Values shown above bars represent the total number (n) of participants with either valid or invalid data (i.e. with both the daily minimum wear time and at least four valid days) at each time point.



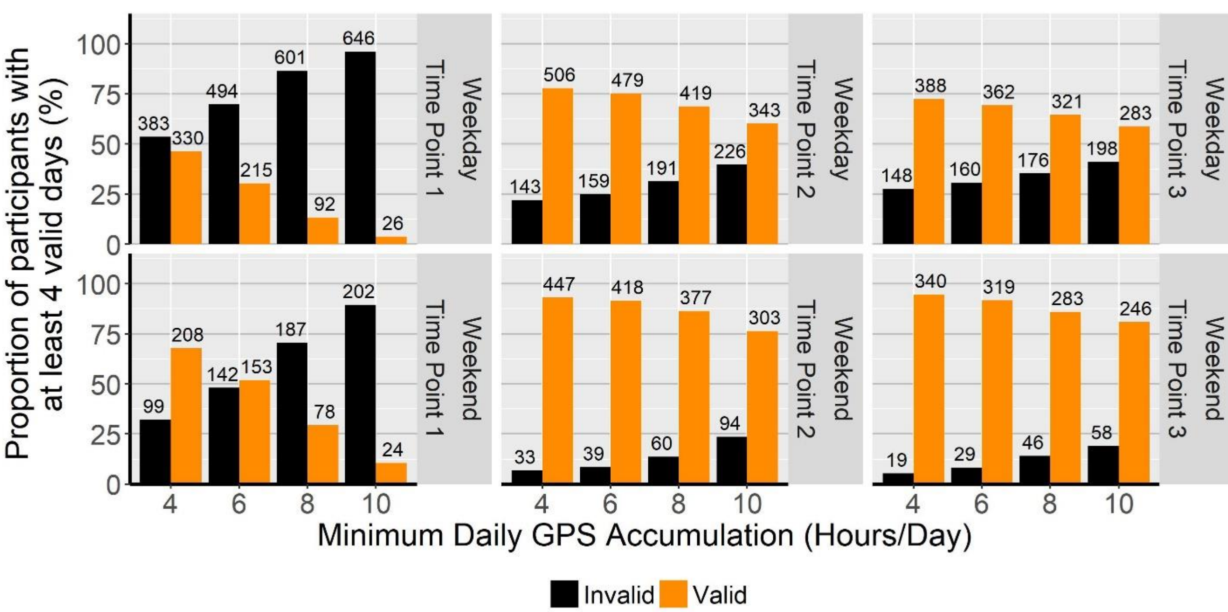


Figure 5.7 The proportion of participants with at least three or four valid days of GPS data, stratified by time point and weekday (vs weekend).

Values plotted represent percentage of participants with either invalid or valid data, based on minimum daily wear time critiria over a minimum of 4 days. Values shown above bars represent the total number (n) of participants with either valid or invalid data (i.e. with both the daily minimum wear time and at least 3 valid days) at each time point.

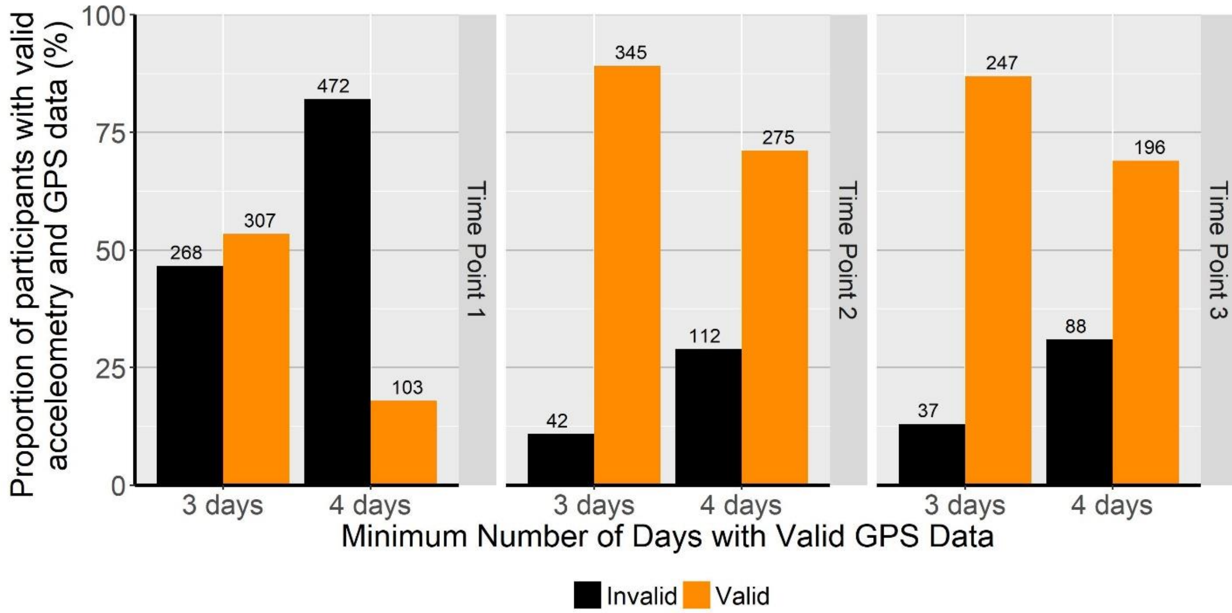


Figure 5.8 The proportion of participants with both valid accelerometry and GPS data over three collection time points.

Only days with valid accelerometry data are shown. Values plotted represent the percentage of participants with either invalid or valid GPS data, based on a minimum of 8 hours of data per day, over a minimum of either three or four days. Values shown above bars represent the total number (n) of participants with either valid or invalid data (i.e. with both the daily minimum wear time and at least three valid days) at each time point.

Therefore, a final GPS data validation criteria of a minimum of an eight hours/day over a minimum of three days/time point was chosen. 96, 159 and 246 participants contributed one, two and three data time points (a total of 501 participants). For the analysis of location-specific activity outcomes in study participants, a validation criteria of a minimum wear time of 10 hours per day over a minimum of four days per time points was retained for all accelerometry data.

5.1.5 Perceptions of Sedentary Behaviour in Different Weather Conditions - Questionnaire Participation

A total of 119 (15.7%) parent-child dyads responded to the Perceptions of SB in different weather conditions questionnaire (of 758 eligible participants who consented to participate in the first time point of the study). Children who responded to the survey varied significantly in their weight status distribution in comparison to those who did not respond (Fisher's exact test p=0.0004). A greater proportion of respondents were of normal weight (71.0 vs 60.0%), and fewer were obese (4.4 vs 16.5%) in comparison to non-respondents, respectively.

A participant's perceptions of SB in different weather conditions questionnaire response(s) were considered valid if any of the items were completed. The majority of respondents answered all 12 items of the questionnaire (77.3%, n=91). Of those who provided incomplete questionnaires, 13.4% (n=16) and 9.24% (n=11) had between 1 to 7 and 12 to 13 item responses missing. Parents provided more complete questionnaires than children, with only 4.20% (n=5) parents not providing responses to all items (vs 19.3%, n=23 children not responding to all items).

The Perceptions of SB in different weather conditions questionnaire was paired with valid accelerometry data from all three time points. 53.4% (n=63) of perception questionnaire participants also provided all three time points of valid accelerometry data. 16.1% (n=19) and 21.2% (n=25) provided only one or two time points of valid accelerometry data, respectively. 11% (n=9) of participants provided no valid accelerometry data and were removed from analyses, leaving 107 (of 119) questionnaires available for complete subsequent analyses (14.1% of the original consenting population). Chi-squared analysis revealed that, in comparison to the consenting study population that did not complete the perceptions questionnaire, there were significant differences in the frequency of valid vs invalid accelerometry data. Perception questionnaire respondents were made up of a greater proportion of participants with three valid time points of accelerometry data (p<0.0001). Children who responded to the survey varied significantly in their weight status distribution in comparison to those who did not respond (Fisher's exact test p=0.0004). A greater proportion of respondents were of normal weight (71.0 vs 60.0%), and fewer were obese (4.4 vs 16.5%) in comparison to non-respondents, respectively.

5.2 Population Characteristics

5.2.1 Population Demographic Characteristics and Representativeness

In the analyses related to Research Question Ai, the entire valid accelerometry dataset was used to examine predictors of time-dependent total daily, leisure hour, and school hour SED (n=619). In the analyses related to Research Question Aii, a subset of the valid GPS-paired accelerometry dataset was used to examine predictors of location-dependent home area-, school-, school-park- and park-based SED, as valid accelerometry data points require the pairing of valid GPS data points (n=501). Similarly, analyses related to **Research Question B** utilized a subset of the valid accelerometry data linked with child-parent perceptions of outdoor play questionnaire responses (n=107). The approach taken to address the research questions of this thesis resulted in three primary participant groups outlined in **Figure 5.9**. The demographic factors of these three population subsets, in comparison to the entire population of the city of Saskatoon and Canada, are described in **Table 5.2**. At the first collection time point in the study, 758 child-parent dyads participated in the study. 45.5% (n=345) and 54.5% (n=413) participation identified as male and female, respectively. Over one-third (37.4%) of study participants were overweight or obese (**Table 5.2**).

Under valid wear time criteria 1, 619 participants provided at least one time point of valid accelerometry data. Of these study participants, 58.5% were female. Pearson's Chi-Squared test and Fisher's exact test were used to analyze if significant differences existed in those who did and did not have valid accelerometry data, as defined by wear time validation methods (Criteria 1, described above). Participants with at least one valid accelerometry time point were significantly more likely to be female (Fisher's Exact Test p<0.0001), and to vary in their annual household income (Fisher's Exact Test p = 0.0173). Specifically, a higher proportion of children did not report their annual household income (59.0% vs 49.5% of those with valid accelerometry data).

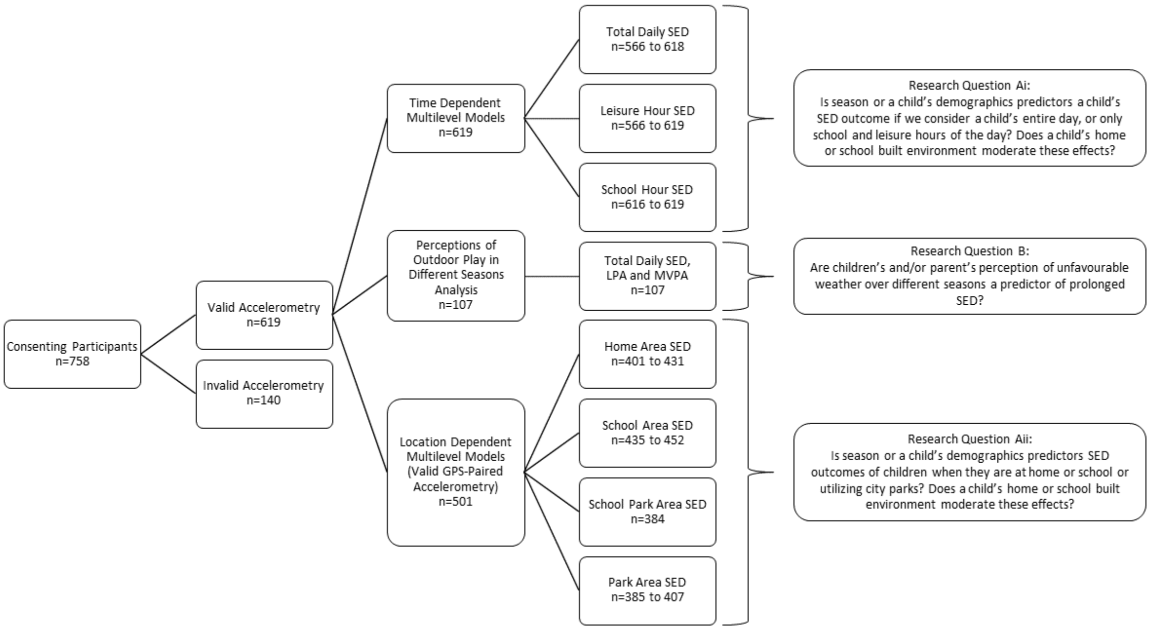


Figure 5.9 Study participation stratified by research question.

The original consenting population that attended at least the first data collection point is shown on left. Datasets utilized in Research Question Aii and B both utilized a subset of the entire valid accelerometry dataset. Analyses tied to Research Question Aii and B required both valid GPS and accelerometry data and completed perceptions of outdoor play in different seasons questionnaires, respectively.

Table 5.2 Study population characteristics and representativeness in comparison to the city of Saskatoon and Canadian census population data.

	Consenting Study Participants*	Valid Accelerometry Data	Accelerometry and GPS Data within city limits	Accelerometry and Perceptions Questionnaire Data	City of Saskatoon	Canada
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)
Total Population**	758	619	455	106	246,376	35,151,728
Gender*						
Male	345 (45.5)	256 (41.5)	172 (37.8)	57 (53.8)	7,050 (51.4%)	985,200 (51.2%)
Female	413 (54.5)	361 (58.5)	283 (62.2)	49 (46.2)	6,655 (48.6%)	937,445 (48.8%)
Age*						
9	33 (4.35)	29 (4.7)	17 (3.74)	1 (0.943)		
10	236 (31.1)	199 (32.3)	158 (34.7)	35 (33)		
11	234 (30.9)	195 (31.6)	147 (32.3)	30 (28.3)		
12	151 (19.9)	118 (19.1)	78 (17.1)	28 (26.4)		
13-14	104 (13.76)	76 (12.3)	55 (12.04)	12 (11.3)		
10-14					13,705	1,922,645
***Body Mass Index* †**						
Neither overweight nor obese	-	-	-	-		4,604,500 (76.0)
Underweight	9 (1.2)	6 (1.0)	1 (0.22)	1 (0.943)	5.30%	-
Normal Weight	465 (61.3)	382 (61.9)	285 (62.6)	75 (70.8)	73.40%	-
Overweight	173 (22.8)	145 (23.5)	111 (24.4)	25 (23.6)		980,300 (16.2)
Obese	111 (14.6)	84 (13.6)	58 (12.7)	5 (4.72)		477,500 (7.9)
Overweight or obese					21.30%	
***Immigrant Status* ‡**						
Newcomer	95 (12.6)	71 (11.5)	52 (11.4)	10 (9.43)	4,160 (7.5)	216,320 (3.6)
Non-Newcomer	660 (87.4)	545 (88.5)	402 (88.4)	96 (90.6)	51,315 (92.5)	5,839,565 (96.4)
***Annual Household Income* §**						
<$20,000	14 (1.8)	12 (1.9)	5 (1.1)	1 (0.943)	7,380 (5.4)	1,369,620 (7.4)
$20,000 to $60,000	110 (14.5)	86 (13.9)	38 (8.35)	10 (9.43)	29,445 (21.7)	4,623,370 (24.8)
$60,000 to $100,000	121 (16.0)	104 (16.9)	49 (10.8)	13 (12.3)	24,340 (17.9)	3,517,155 (18.9)
>$100,000	295 (38.9)	258 (41.8)	157 (34.5)	52 (49.1)	74,810 (55.0)	9,123,845 (49.0)
Unknown	218 (28.8)	157 (25.4)	206 (45.3)	30 (28.3)	-	-
Neighbuurhood Design Era						
<1930, grid pattern	71 (9.37)	56 (9.1)	42 (9.23)	10 (9.43)	-	-
1930-mid to 1960s, fractured grid	161 (21.2)	124 (20.1)	93 (20.4)	25 (23.6)	-	-
mid-1960s to 1998, curvilinear	363 (47.9)	306 (49.6)	233 (51.2)	45 (42.5)	-	-
1998 to present, modified grid	122 (16.1)	96 (15.6)	76 (16.7)	20 (18.9)	-	-
Non-urban	41 (5.41)	35 (5.7)	11 (2.42)	6 (5.66)	-	-
Data Collection Period						
Sep to Dec 2014	745	591	219	-	-	-
Jan to Apr, 2015	706	411	344	-	-	-
Apr to Jul, 2015	592	301	192	-	-	-
Season						
Winter	626 (28.9)	415 (29.6)	277 (33.0)	-	-	-
Spring	635 (29.3)	348 (24.9)	291 (34.6)	-	-	-
Summer	256 (11.8)	119 (8.5)	96 (11.4)	-	-	-
Fall	651 (30)	518 (37.0)	176 (21.0)	-	-	-

*Excludes consenting participants that did not participate in any data collection time points

** From the 2016 Census Profile for Canada [Country] and Saskatoon, CY [Census subdivision], Saskatchewan (table) (197).

† Body Mass Index: Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2). BMI for grades 5-8 children living in the City of Saskatoon was obtained from 2010/2011 Student Health Survey (198) and for children living within Canada from the 2015 Canadian Community Health Survey – Nutrition (199).

‡ Immigrant status: Study population newcomer status were children who reported living within Canada for less than two years. The city of Saskatoon and Canada population newcomers were children aged 0-14 who immigrated to Canada between 2011 and 2016, as reported in the 2016 Census (200).

§ Within the study population, the category "Unknown" for annual household income includes those who actively chose not to answer, didn't know their annual household income, or did not provide an answer. City of Saskatoon and Canada population incomes for families in 2015 are from the 2016 Census Profile for Canada [Country] and Saskatoon, CY [Census subdivision], Saskatchewan (table) (197).

Age, weight status, newcomer immigrant status, and neighbourhood of residency era did not differ significantly between those with at least one valid accelerometry time point (vs those with none) (**Table 5.2**).

Our valid-accelerometry and GPS-paired accelerometry study populations were over-represented by female children in comparison to the 2016 Census Profiles for Saskatoon and Canada (197). All three study populations examined in this study comprised of fewer children with normal weight and a greater number of children who were overweight in comparison to the Canadian population. Participants included in time- (accelerometry only) and location-dependent (GPS-paired accelerometry) SED analysis were comprised of more children with obesity vs Canadian children of a similar age. In contrast, fewer participants contributing data to the perceptions of outdoor play in different seasons analyses were obese (199). Similarly, more study participants were living with overweight or obesity in comparison to grade 5-8 children who participated in the City of Saskatoon 2010/2011 Student Health Survey (198) (**Table 5.2, Figure 5.10**). As one-quarter of participants either refused or did not know their annual household income, making critical comparisons of the likely underrepresentation of low- and middle-income children in this study is not possible (**Table 5.2**).

5.2.2 Study Population Activity Patterns by Time

Over the one-year collection period, participants accumulated a daily mean of 271.4 SED, 335.4 LPA and 157.9 MVPA minutes/day (**Figure 5.11**). Over one-third of a child's day was in a sedentary state (35.5%), which was further pronounced on weekends (weekends 41.2%, weekdays 34.1%. Children accumulated significantly less LPA and MVPA on weekend days in comparison to weekdays. Participants had greater accelerometry device wear time compliance on weekend days vs weekdays (**Figure 5.12**).

Males accumulated significantly less LPA, but significantly more MVPA in comparison to females. Older children accumulated significantly less LPA and MVPA, but significantly more SED. Children's whose weight was normal, compared to those who were over- or under-weight, accumulated the lowest amount of SED, and the highest amount of both LPA and MVPA.

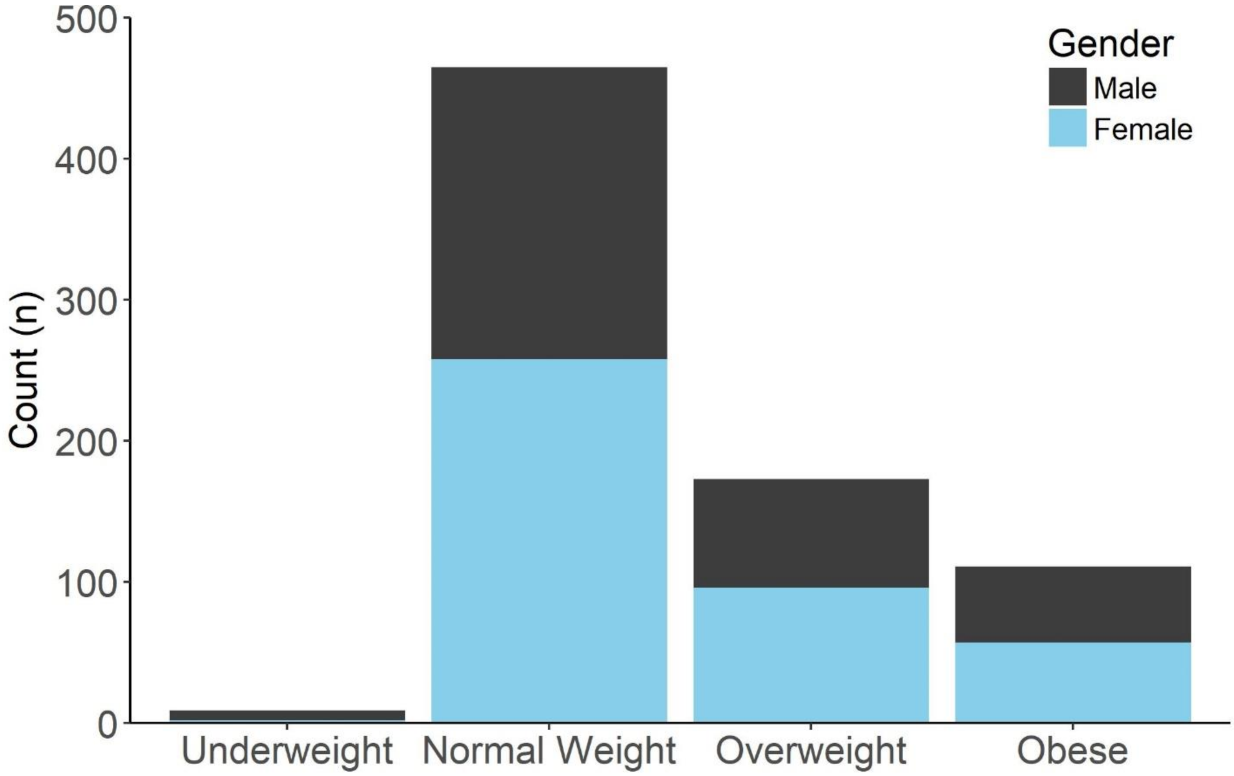


Figure 5.10 Study participant's weight status frequency.

Total counts, stratified by self-reported gender are plotted. Values presented above each bar represent the percentage of the entire study population at the first collection time point.

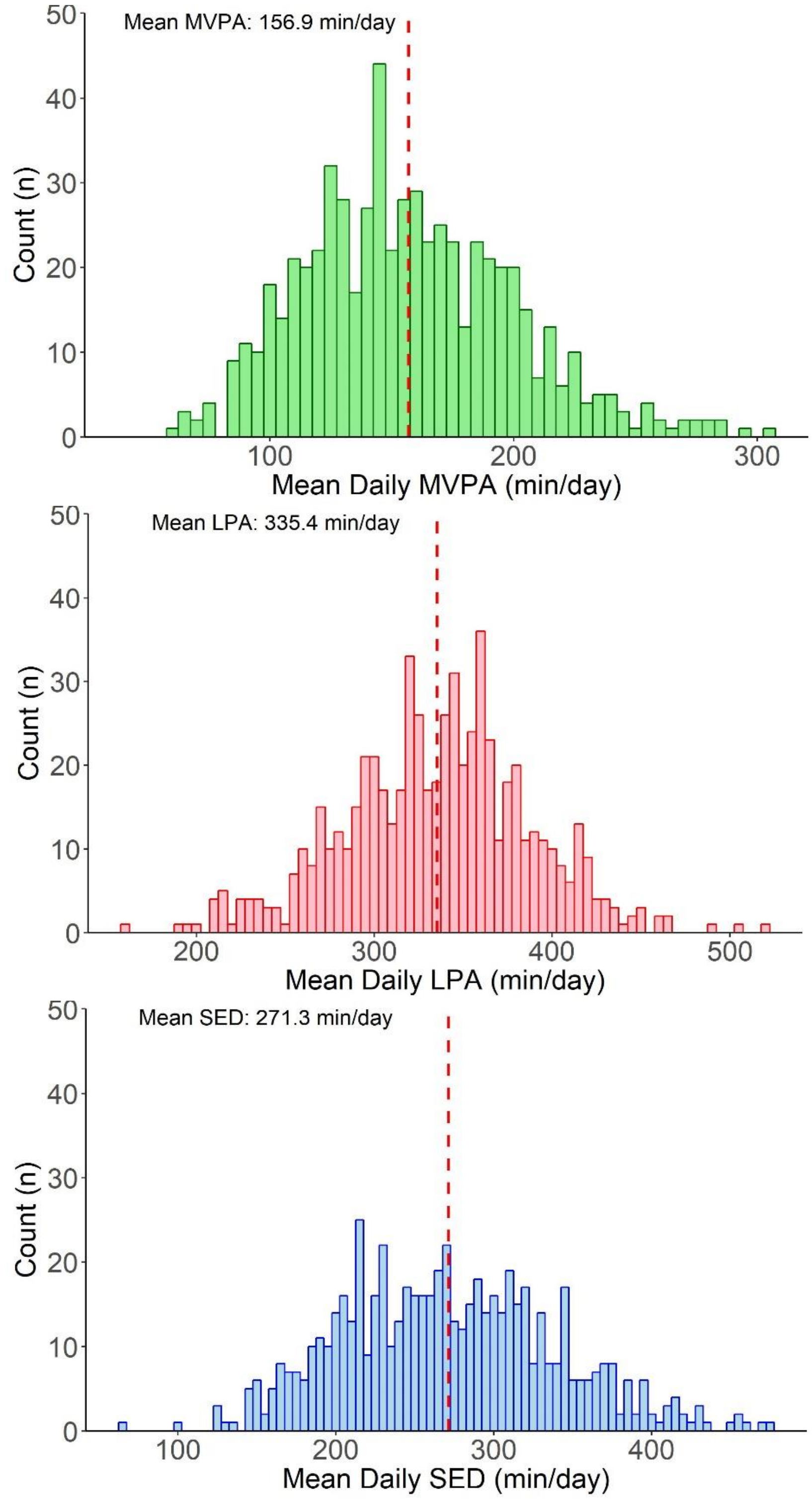


Figure 5.11 Mean total daily sedentary behaviour and physical activity distributions.

Valid accelerometry data points are shown.

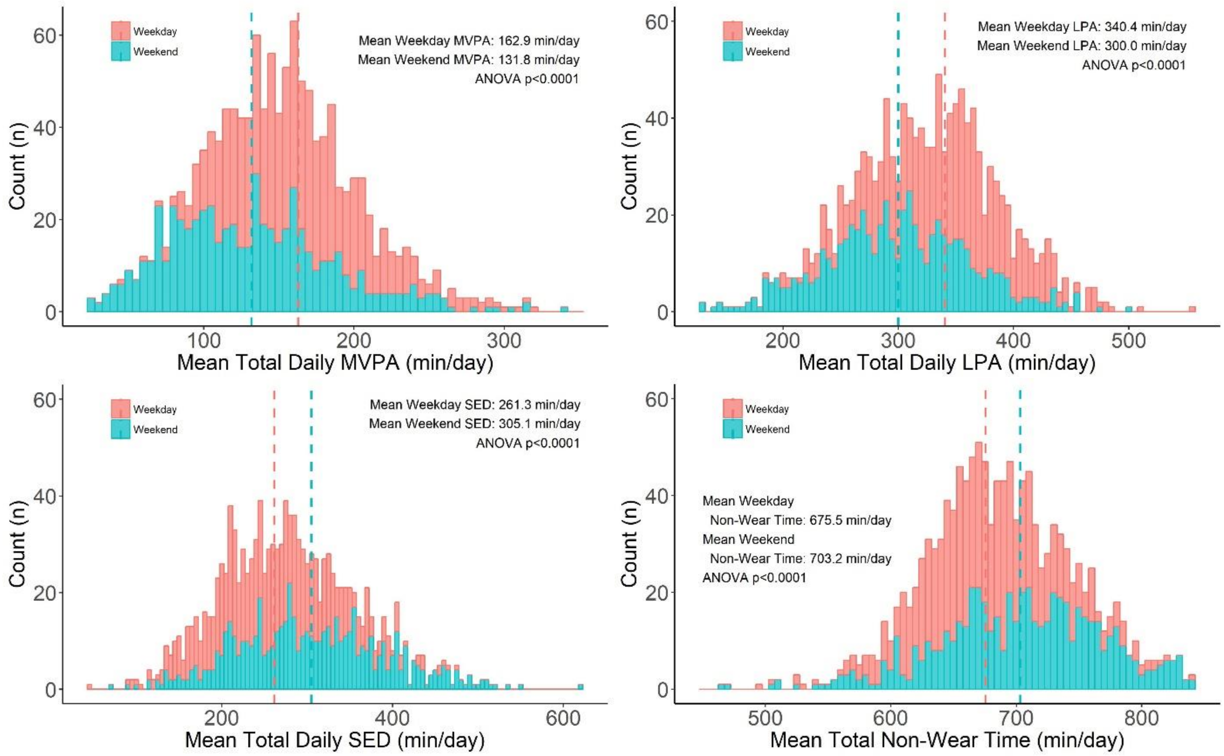


Figure 5.12 Mean total daily sedentary behaviour, physical activity and wear time distributions on weekdays and weekends.

Showing only accelerometry days with a minimum of 10 hours of wear-time per day. Vertical lines represent means, stratified by weekday and weekend. Valid accelerometry data points are shown.

Newcomers to Canada were significantly more active, accumulating an average of 12 additional MVPA minutes/day vs those who were not recent immigrants. Children living in fractured grid patterned neighbourhoods had accumulated the most daily SED, whereas those living in grid patterned and rural neighbourhoods had accumulated the most MVPA (**Table 5.3**).

The relative minute-by-minute compliance of participants was examined by plotting the total counts of valid 1-minute epoch accelerometry data points over the entire study period for all participants. On weekdays, from 0600-0830h, participants steadily increased the number of valid data points provided, with peak wear time occurring from 0830-1900h. From 1900-2200h, participants steadily decreased the number of valid data points. On weekends, wear time contribution patterns steadily increased from 0600-1200h and plateaued for the remainder of the day until a steady drop off from 1900-2200h (**Figure 5.13**).

5.3 Saskatoon Study -- Season and Climate Characterisation

Monthly averages during the study period were compared to 1981-2000 Saskatoon climate normals to understand if the year in which the study occurred was representative of the climate experienced by residents in the past. Mean monthly temperatures during the data collection period all fell within two SDs of Saskatoon climate normal mean temperatures, with temperature differences ranging between -4.9 to 3.8°C from the climate normal mean. Climate normal SDs were not available for the remainder of monthly weather condition means. Notably, November 2014 and February 2015 experienced mean temperatures of -9.7 and -17.4°C, 3.7 and 4.9°C cooler than the climate norm, respectively. In contrast, December 2014 and January 2015 experienced mean temperatures of -9.4 and -11.8°C, 3.8 and 3.7°C warmer than the climate norm, respectively. Mean monthly precipitation was near or below average climate norms in 8 of the 12 months data collection occurred, with a difference range of -52.2 to 24.0 mm. During the collection period, snow ground cover was recorded from December to February and did not include November, a month that generally experiences a minimal amount of ground cover. While ground cover fluctuated from the climate norm both positively and negatively over the winter period, there was almost no mean difference of total snow ground cover over the entire winter as a whole (in comparison to the climate normal means).

Table 5.3 Study population characteristics of those contributing valid accelerometry data.

		n (%)	Mean Daily SED (min/day)	ANOVA p-value	Mean Daily LPA (min/day)	ANOVA p-value	MVPA (min/day)	ANOVA p-value
Gender	Male	256 (41.5)	272	0.8502	317	<0.0001	168	<0.0001
	Female	361 (58.5)	271		348		149	
Age (years)	9	29 (4.7)	239	<0.0001	368	<0.0001	169	<0.0001
	10	199 (32.3)	245		349		167	
	11	195 (31.6)	272		338		155	
	12	118 (19.1)	295		318		151	
	13-14	76 (12.3)	313		309		138	
Weight Status †	Underweight	6 (1.0)	296	<0.0001	309	<0.0001	144	0.0027
	Normal Weight	382 (61.9)	260		345		161	
	Overweight	145 (23.5)	279		330		154	
	Obese	84 (13.6)	309		304		144	
Immigrant Status ‡	Newcomer	71 (11.5)	272	0.7653	146	0.5006	146	0.0089
	Non-Newcomer	545 (88.5)	271		158		158	
Annual Household Income §	<$20,000	12 (1.9)	293	0.347	311	0.0575	145	0.841
	$20,000 to $60,000	86 (13.9)	270		341		155	
	$60,000 to $100,000	104 (16.9)	261		346		159	
	>$100,000	258 (41.8)	275		332		157	
	Unknown	157 (25.4)	271		333		158	
Neighbourhood Era & Style	<1930, grid pattern	56 (9.1)	255	0.0176	336	0.2780	175	0.0006
	1930-mid to 1960s, fractured grid	124 (20.1)	287		334		146	
	mid-1960s to 1998, curvilinear	306 (49.6)	272		333		157	
	1998 to present, modified grid	96 (15.6)	261		346		158	
	Non-urban	35 (5.7)	270		336		167	
Participation by Collection Time Point	Sep to Dec, 2014	591 (46.3)	264	<0.0001	346	0.0001	162	<0.0001
	Jan to Apr, 2015	411 (31.3)	284		335		147	
	Apr to Jul, 2015	301 (22.3)	279		330		162	
Participation by Season	Winter	415 (29.6)	277	0.0991	344	0.0007	149	0.0037
	Spring	348 (24.9)	278		329		159	
	Summer	119 (8.5)	280		328		158	
	Fall	518 (37.0)	267		339		159	

† Body Mass Index: Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).

‡ Immigrant status: Study population newcomer status were children who reported living within Canada for less than two years.

§ Within the study population, the category "Unknown" for annual household income includes those who actively chose not to answer, did not know their annual household income, or did not provide an answer.

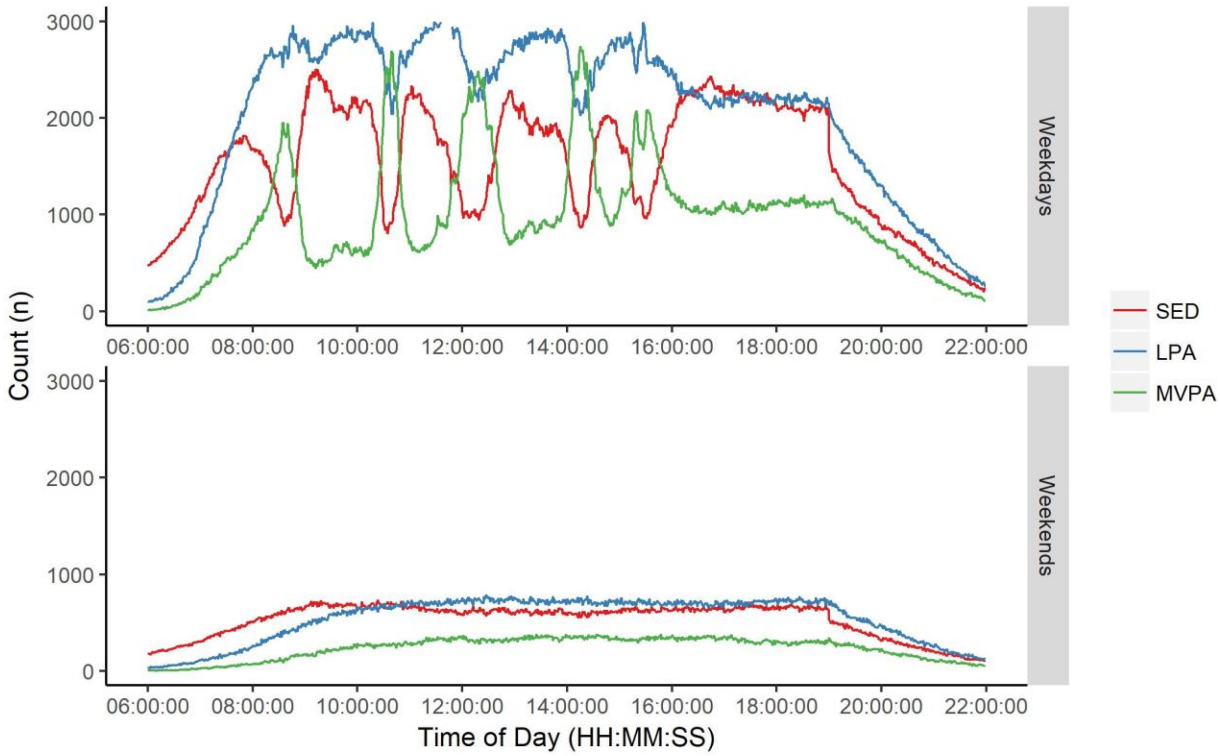


Figure 5.13 9-14-year-old children's daily behaviour by activity level.

Total counts of SED, LPA and MVPA are shown for all participant from 0600-2200h using one second epochs and are stratified by weekday and weekend. Red, blue and green solid lines represent SED, LPA and MVPA. Data points include all valid wear-time accelerometry data points (a minimum of 10 hours per day over a minimum of four days per time points) measured over the entire study period (n=5,640,036 participant minutes).

While four months of the collection period (September 2014 and May, June and September 2015) experienced greater than average wind speeds, the greatest difference was less than 2km/hr (**Figure 5.14**).

5.4 Total daily sedentary behaviour patterns in 9-14-year-old children

The current understanding of how Canadian seasons shape activity outcomes in children is limited. In order to create effective interventions and policies aimed at improving children's activity behaviours, this research aims to improve our understanding of how seasonal changes in children's activity behaviours are moderated by their home neighbourhood environment.
As stated in **Research Question Ai** (**Section 1.3**), this section seeks to understand if seasonal changes and a child's demographic factors are predictors of total daily SED, and if the BE surrounding a child's home significantly moderates the effect of season or demographic factors on SED. As stated in Hypothesis A (**Section 1.4**) and outlined in **Figure 3.2**, it is hypothesized that climate associated with colder months will result in an increase in mean total daily SED in children. Furthermore, a child's home neighbourhood BE will moderate these effects on daily SED.

To understand the association between season and children's activity behaviour patterns, mean daily activity behaviours were stratified by season. Daily activity patterns were collected in study participants over three time frames that occurred over all four seasons. Using ANOVA and Tukey Honest Significant Differences (HSD), seasonal variation in mean total daily activity levels were analyzed for all valid accelerometry data. SED did not differ significantly between seasons, whereas children accumulated both a significantly greater amount of LPA and a significantly lower amount of MVPA in winter months vs. all other months. Children's LPA was significantly lower in spring and summer months in comparison to winter months, resulting in a mean difference of 15.7 and 16.4 fewer minutes of LPA per day, respectively (Tukey HSD Spring vs Winter, -15.7 minutes/day, 95% CIs -26.6, -4.86, p=0.0012; Summer vs Winter, -16.4 minutes/day, 95% CIs -31.9, -0.810, p=0.0347). Mean total daily MVPA varied significantly by season. Study participants accumulated a mean 10.5 additional minutes of MVPA in spring (vs winter) (Tukey HSD Spring vs winter 10.5 minutes/day, 95% CIs 1.47, 19.5, p=0.0150). (**Table 4.1, Figure 5.15**). When comparisons were made within season, but between weekdays and weekends, children accumulated significantly greater levels of SED on weekends in comparison to weekdays.

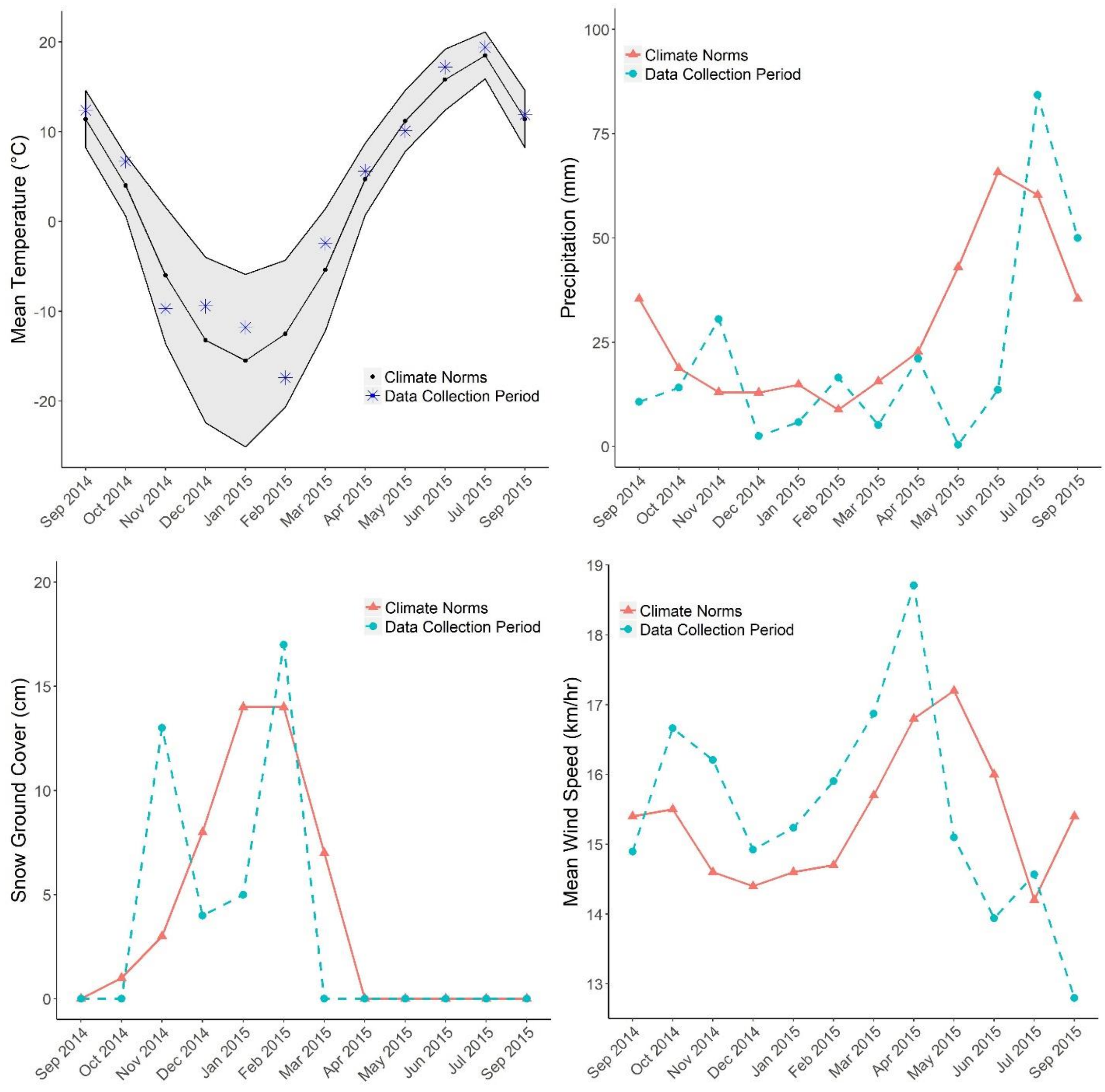


Figure 5.14 A comparison of monthly weather condition during the data collection period to 1981-2010 Saskatoon climate normals.

Temperature climate normals are shown as mean +/- 2 SD (in grey). The month of August 2015 was excluded as no data study were collected in this time period.

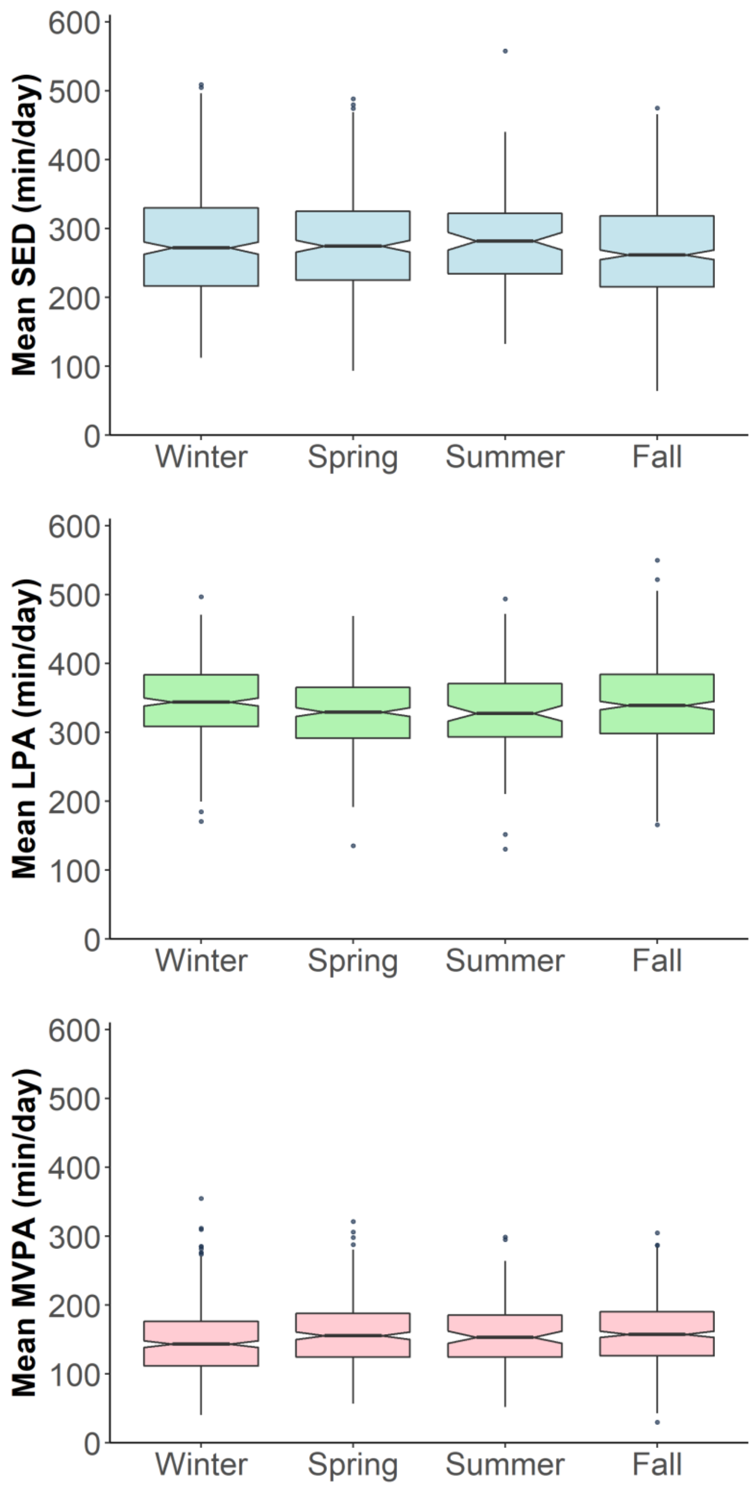


Figure 5.15 Mean daily sedentary behaviour and physical activity patterns of children by season.

Box bar and upper and lower hinges represent the median and interquartile range (25th and 75th centile), respectively. Notches represent upper and lower 95% confidence interval limits. Outliers are shown as dots.

Spring weekends offered the greatest increase in sedentariness, with an additional 44.0 minutes/day, whereas fall weekend days saw the smallest difference, with only a 32.7 minutes/day increase in comparison to weekdays (Tukey's HSD p-values <0.01). Both LPA and MVPA were lowest on weekends vs weekdays in all four seasons (Tukey's HSD p-values: LPA p<0.01, MVPA p<0.0001), with the exception of LPA in summer (p<0.176).

Children's LPA and MVPA saw the greatest reduction on spring weekends (vs weekdays) by an average of 45.4 and 37.6 minutes/day, respectively. Children's LPA and MVPA saw the smallest reduction on spring weekends (vs weekdays) in summer and fall, respectively (LPA 23.1 minutes/day, MVPA 25.2 minutes/day). When activity pattern comparisons were made within weekdays or weekends but between seasons, no significant differences in SED were apparent. Children accumulated 15.1 (95% CI 0.282, 30.0) fewer LPA minutes/day on spring weekdays in comparison to winter weekdays. In contrast, children accumulated 13.1 (95% CI 0.629, 25.6) additional minutes of MVPA on spring weekdays in comparison to winter weekdays. Fall weekends afforded children 17.6 (95% CI 4.38, 30.9) additional minutes of MVPA per day (**Figure 5.16**).

To understand if demographic factors, season or the BE were able to significantly predict total daily SED in children, MLM analysis was employed. In a null model using an autoregression 1 correlation structure with total daily SED repeated measures (continuous, total minutes/day) being nested within an individual, 43.5% of the variation in SED occurred across individuals. Increased levels of daily LPA and MVPA were negatively associated with increased SED. MVPA was associated with 2.4 times greater predicted decrease in SED in comparison to the predictive power of LPA with SED. In this same PA inclusive model (PAIM), in spring, but not in other seasons, PA was associated with increased SED of participating children (**Table 5.4 and 5.5, Figure 5.17**). In contrast, in a PA exclusionary model (PAEM), fall months, but neither spring nor summer months, were associated with decreased SED in children. The effect of increased age and BMI above a normal weight status, both of which significantly predicted increased SED, were moderated by gender. As with PAIM models (**Table 5.5, Figure 5.17**), younger females accumulated significantly less SED than males of the same age, but followed a more rapid increase in SED with age, with the oldest females in our cohort accumulating greater levels of SED. Females who were overweight accumulated significantly less SED than overweight males (**Table 5.5, Figure 5.17 and Table B.2**).

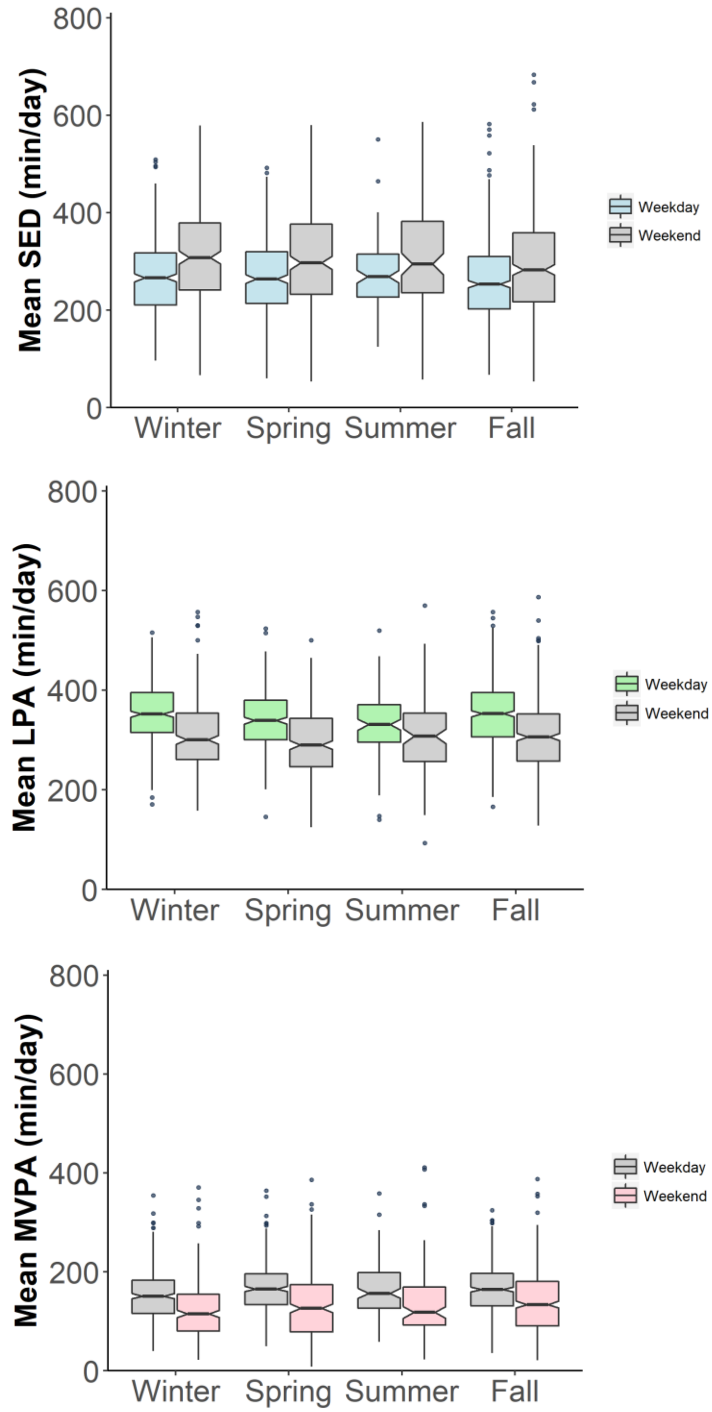


Figure 5.16 Mean daily sedentary behaviour and physical activity patterns of children by season and day weekday category.

Box bar and upper and lower hinges represent the median and interquartile range (25th and 75th centile), respectively. Notches represent upper and lower 95% confidence interval limits. Outliers are shown as dots.

Table 5.4 Factors predicting total daily sedentary behaviour in 9-14-year-old children: univariate and main effects models.

	Univariate Models		Level 1 Main Effects		Level 1 & 2 Main Effects	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population size (n)	618		618		616	
Constant			472	(463, 481)	318	(282, 353)
Level 1 Variables						
LPA	-0.415	(-0.440, -0.389)	-0.284	(-0.308, -0.261)	-0.276	(-0.300, -0.253)
MVPA	-0.749	(-0.778, -0.720)	-0.667	(-0.696, -0.638)	-0.662	(-0.691, -0.633)
Season (reference - winter)						
Spring	3.69	(-2.20, 9.57)	5.65	(0.940, 10.4)	6.14	(1.43, 10.8)
Summer	-1.48	(-10.4, 7.39)	3.85	(-3.17, 10.9)	4.46	(-2.53, 11.5)
Fall	-12.9	(-18.3, -7.39)	-2.89	(-7.26, 1.49)	-2.74	(-7.10, 1.63)
Level 2 Variables						
Gender (reference - male)						
Age					13.1	(10.1, 16.1)
BMI (reference - normal weight)[§]						
Underweight					9.57	(-25.5, 44.6)
Overweight					10.3	(2.41, 18.1)
Obese					27.2	(17.3, 37.0)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).
‡ References Categories: season – winter, gender – male, body mass index – normal weight, neighbourhood era - <1930 grid
Abbreviations: BMI – body mass index, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity.

Table 5.5 Factors predicting total daily sedentary behaviour in 9-14-year-old children: final multilevel models

	Main Effects Models with Interactions					
	Model 1		Model 2		Model 3	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population size (n)	616		616		566	
Constant	315	(279, 351)	365	(310, 419)	365	(307, 424)
Level 1 Variables						
LPA	-0.275	(-0.299, -0.251)	-0.274	(-0.298, -0.250)	-0.271	(-0.296, -0.247)
MVPA	-0.663	(-0.692, -0.634)	-0.662	(-0.692, -0.633)	-0.671	(-0.702, -0.641)
Season (reference - winter)						
Spring	6.17	(1.47, 10.9)	12.1	(-1.41, 25.7)	19.7	(2.47, 36.9)
Summer	4.42	(-2.58, 11.4)	1.19	(-18.6, 21.0)	-5.20	(-29.9, 19.5)
Fall	-2.76	(-7.12, 1.61)	-6.57	(-20.9, 7.77)	-21.7	(-37.2, -6.21)
Level 2 Variables						
Gender (reference - male)	2.33	(-6.09, 10.8)	-87.8	(-155, -20.9)	-85.8	(-156, -15.8)
Age	13.2	(10.2, 16.2)	8.50	(3.89, 13.1)	8.58	(3.68, 13.5)
BMI (reference - normal weight)§						
Underweight	22.4	(-15.5, 60.3)	12.2	(-22.9, 47.3)	11.8	(-23.4, 47.0)
Overweight	20.3	(7.95, 32.6)	9.91	(2.07, 17.8)	9.83	(1.61, 18.1)
Obese	31.6	(16.7, 46.6)	26.5	(16.6, 36.3)	28.5	(18.2, 38.7)
Level 3 Variables						
Neighbourhood Era (reference - <1930 grid)						
1930-1960s fractured grid			9.40	(-6.96, 25.8)		
>1960s curvilinear			4.80	(-9.39, 19.0)		
rural			14.8	(-6.12, 35.8)		
NALP - Universal Accessibility					1.22	(-5.88, 8.31)
Interaction Terms						
BMI*Gender‡						
*Underweight*Female*	-82.3	(-181, 16.6)				
*Overweight*Female*	-16.7	(-32.7, -0.800)				
*Obese*Female*	-7.75	(-27.5, 12.0)				
*Age*Gender*‡			7.67	(1.63, 13.7)	7.69	(1.38, 14.0)
*Season*Neighbourhood Era*‡						
Spring<1930 grid*			-5.41	(-23.0, 12.7)		
Summer<1930 grid*			6.97	(-16.8, 30.7)		
Fall<1930 grid*			3.71	(-13.6, 21.0)		
*Spring*1930-1960s fractured grid*			-5.71	(-20.4, 9.02)		
*Summer*1930-1960s fractured grid*			-0.811	(-22.8, 21.2)		
*Fall*1930-1960s fractured grid*			5.22	(-10.1, 20.6)		
Spring>1960s curvilinear*			-20.2	(-43.6, 3.32)		
Summer>1960s curvilinear*			35.7	(0.142, 71.4)		
Fall>1960s curvilinear*			-10.3	(-33.1, 12.5)		
*Season*NALP Universal Accessibility*‡						
*Spring*NALP Universal Accessibility*					-5.50	(-13.0, 2.02)
*Summer*NALP Universal Accessibility*					4.22	(-7.17, 15.6)
*Fall*NALP Universal Accessibility*					8.85	(1.99, 15.7)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).
‡ References Categories: season – winter, gender – male, body mass index – normal weight, neighbourhood era - <1930 grid
Abbreviations: BMI – body mass index, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, NALP – neighbourhood active living potential.

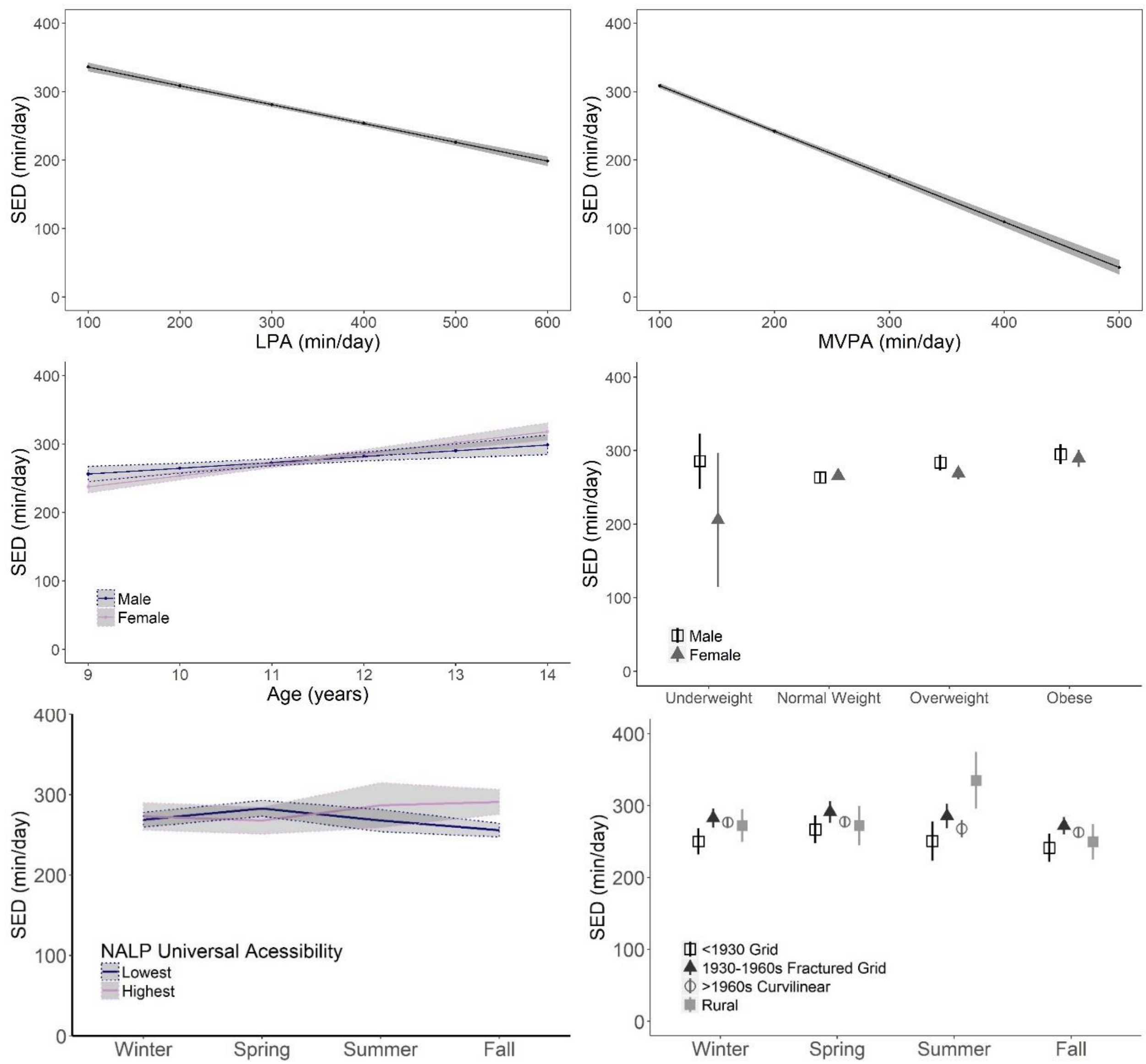


Figure 5.17 Predicted effects of physical activity, demographic factors, BMI and season on total daily sedentary behaviour in children.

Predicted effects presented are derived from multilevel models presented in ***Table 5.5*** *(Model 1: LPA, MVPA, BMI*gender; Model 2: age*gender, season*neighbourhood era; Model 3: season*NALP universal accessibility). 95% CIs are shown as grey ribbons or vertical bars. Reference categories (body mass index (BMI) – normal weight; gender – male, season - winter).*

The effect of season on total daily SED was moderated by home neighbourhood era design. While children living in grid and fractured grid style neighbourhoods experienced no significant differences in SED between seasons, those living in curvilinear neighbourhoods were significantly more sedentary in summer vs winter months. This effect accounted for 35.7 and 62.5 additional minutes of SED per day in models including and excluding PA, respectively. NALP universal accessibility and activity friendliness significantly moderated the effect of season on SED in a PAIM and PAEM, respectively (**PAIM - Table 5.4, Figure 5.17, PAEM – Table B.2)**. Children living in the neighbourhoods most able to accommodate individuals with mobility limitations (NALP universal accessibility) were significantly more sedentary in fall vs winter month (**Table 5.4, Figure 5.17**). Children living in neighbourhoods with the highest activity friendliness score were significantly more SED in spring vs winter months (**Table B.2, Figure B.1**).

Taken together, these findings highlight that both individual factors and home neighbourhood BE features are predictive of a child's SED over their entire day. Notably, increased PA levels performed over the entire day, younger age and normal weight status, but not gender, were predictive of reduced total daily SED. Further, the effect of season was significantly moderated by a child's home BE.

5.5 Leisure hour sedentary behaviour patterns in 9-14-year-old children

As stated in **Research Question Ai** (**Section 1.3**), this section seeks to understand if seasonal changes and a child's demographic factors are predictors of leisure hour SED, and if the BE surrounding a child's home significantly moderates the effect of season or demographic factors on SED. As stated in Hypothesis A (**Section 1.4**) and outlined in **Figure 3.2**, it is hypothesized that climate associated with colder months will result in an increase in mean leisure hour SED in children. Furthermore, a child's home neighbourhood BE will moderate these effects on leisure hour SED.

Leisure hour SED was defined as all waking hours outside of school hours, with the exception of lunch hour. To understand if demographic factors, season or the BE were able to significantly predict total daily leisure hour SED MLM analysis was employed. In the null model using an autoregression 1 correlation structure, 27.6% of the variation in daily leisure hour SED occurred across individuals.

As shown in **Table 5.6** season did not significantly predict leisure hour SED. PA significantly predicted leisure hour SED. For approximately every 2 minutes of LPA or MVPA accumulated, it is estimated that children increased or decreased their leisure hour SED by 1 minute, respectively. Increased age and overweight or obese status were associated with a significant increase in leisure hour SED. Additionally, in a PAIM, female gender and annual household incomes of $20,000-60,000 and $60,00-100,000 were associated with significantly less leisure hour SED in comparison to male gender and an annual household income of <$20,000, respectively (**Table 5.6**). An increase in MVPA was associated with a greater beneficiary reduction in leisure hour SED in children who were overweight or obese vs those with normal weight. Male participants demonstrated a more negative sedentary outcome with increased time spent in LPA during leisure hours. While younger females were significantly less SED during leisure hours, older females participated in similar levels of SED as males. An increase in MVPA was associated with a greater reduction in leisure hour SED in winter vs fall months. Children with obesity were significantly less SED in summer vs winter months (**Table 5.7, Figure 5.18**).

The positive association of LPA on SED during leisure hours was differentially moderated by NALP universal accessibility and density of destinations in PAIM. Children living in neighbourhoods with the lowest level of accessibility, but the highest density of destinations both experienced a smaller increase in sedentariness with increased LPA (in comparison to the highest level of universal accessibility and the lowest level of density of destinations, respectively). Children living in the lowest income group (<$20,000 per year) demonstrated a greater associated reduction in SED if they lived in neighbourhoods with poor safety from crime and overall low activity friendliness scores (IMI cumulative score). The divergent SED outcomes observed in children with varying levels of household income was completely diminished if children's home neighbourhoods had a high degree of safety from crime or level of activity friendliness (IMI cumulative score, **Table 5.7, Figure 5.19**).

In a PAEM, older children and children who were overweight and obese were significantly more sedentary than children with normal weight. Children living in fractured grid neighbourhoods were significantly more sedentary than those living in grid neighbourhoods (**Table B.3**).

Table 5.6 Factors predicting leisure hour sedentary behaviour in 9-14-year-old children: univariate and main effects models.

	Univariate Models		Level 1 Main Effects		Level 1 & 2 Main Effects	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population size (n)	619		619		616	
Constant			114	(108, 121)	0.577	(-48.1, 49.3)
Level 1 Variables						
LPA	0.428	(0.403, 0.454)	0.541	(0.513, 0.568)	0.549	(0.521, 0.576)
MVPA	-0.140	(-0.182, -0.099)	-0.437	(-0.479 -0.395)	-0.437	(-0.478, -0.395)
Season (reference - Winter)						
Spring	3.97	(-2.56, 10.5)				
Summer	3.20	(-6.57, 13.0)				
Fall	-2.50	(-8.53, 3.53)				
Level 2 Variables						
Gender (reference - male)					-14.4	(-21.9, -6.96)
Age					12.9	(9.51, 16.3)
BMI (reference - normal weight)§						
Underweight					17.2	(-22.9, 57.2)
Overweight					13.5	(4.70, 22.4)
Obese					29.7	(18.6, 40.8)
Income (reference - <$20,000)						
$20,000 to $60,000					-32.2	(-60.5, -3.78)
$60,000 to $100,000					-37.5	(-65.7, -9.37)
>$100,000					-25.5	(-52.8, 1.80)
Unknown					-25.7	(-53.3, 2.00)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).
‡ References Categories: season – winter, gender – male, body mass index – normal weight, income - <$20,000
Abbreviations: BMI – body mass index, CI – confidence intervals, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity.

Table 5.7 Factors predicting leisure hour sedentary behaviour in 9-14-year-old children: final multilevel models.

	Main Effects Models with Interaction					
	Model 1		**Model 2**		**Model 3**	
	β Estimate	**95% CI**	**β Estimate**	**95% CI**	**β Estimate**	**95% CI**
Population size (n)	566		566		566	
Constant	198	(-32.1, 428)	22.21	(-56.4, 101)	-10.82	(-61.5, 39.9)
Level 1 Variables						
LPA	0.475	(0.385, 0.565)	0.700	(0.577, 0.823)	0.602	(0.557, 0.647)
MVPA	-0.444	(-0.528, -0.360)	-0.443	(-0.527, -0.359)	-0.448	(-0.491, -0.404)
Season (reference - Winter)						
Spring	13.21	(1.67, 24.8)	12.91	(1.36, 24.5)	12.03	(4.39, 19.7)
Summer	8.077	(-8.06, 24.2)	7.793	(-8.37, 24.0)	10.75	(-0.291, 21.8)
Fall	-14.72	(-25.5, -3.95)	-14.75	(-25.5, -3.98)	-0.25	(-7.42, 6.92)
Level 2 Variables						
Gender (reference - male)	-15.08	(-22.9, -7.23)	-99.44	(-178, -21.0)	-3.62	(-17.1, 9.84)
Age	13.02	(9.52, 16.5)	8.55	(3.03, 14.1)	12.94	(9.44, 16.5)
BMI (reference - normal weight)[§]						
Underweight	-4.378	(-66.3, 57.6)	1.754	(-60.2, 63.7)	6.097	(-52.2, 64.4)
Overweight	29.35	(16.1, 42.6)	27.69	(14.5, 40.9)	18.25	(5.54, 31.0)
Obese	46.27	(29.7, 62.8)	46.88	(30.4, 63.4)	38.58	(22.8, 54.4)
Income (reference - <$20,000)						
$20,000 to $60,000	-281	(-518, -42.4)	-30.96	(-59.4, -2.58)	-34.72	(-63.2, -6.27)
$60,000 to $100,000	-311	(-550, -72.0)	-36.68	(-65.0, -8.41)	-39.97	(-68.3, -11.6)
>$100,000	-234	(-468, -1.26)	-25.91	(-53.3, 1.46)	-29.89	(-57.5, -2.34)
Unknown	-216	(-452, 19.6)	-23.75	(-51.4, 3.92)	-26.65	(-54.4, 1.13)
Level 3 Variables						
IMI Safety from Crime	-21.24	(-47.3, 4.87)				
IMI Cumulative Score					-24.04	(-52.5, 4.37)
NALP Universal Accessibility	-11.15	(-22.4, 0.138)				
NALP Density of Destinations			5.559	(-3.35, 14.5)		
Interactions Terms						
Age*Gender[ǂ]			7.657	(0.574, 14.7)		
LPA*Gender[ǂ]					-0.057	(-0.111, -0.003)
MVPA*BMI[ǂ]						
*MVPA*Underweight*	0.272	(-0.283, 0.826)	0.246	(-0.309, 0.800)		
*MVPA*Overweight*	-0.146	(-0.245, -0.048)	-0.146	(-0.244, -0.047)		
*MVPA*Obese*	-0.176	(-0.308, -0.044)	-0.179	(-0.311, -0.048)		

MVPA*Season‡						
*MVPA*Spring*	-0.022	(-0.124, 0.081)	-0.021	(-0.123, 0.082)		
*MVPA*Summer*	-0.002	(-0.138, 0.134)	0.001	(-0.135, 0.137)		
*MVPA*Fall*	0.121	(0.025, 0.216)	0.119	(0.024, 0.215)		
Season*BMI‡						
*Spring*Underweight*					-29.89	(-117, 57.1)
*Summer*Underweight*					4.091	(-63.7, 71.9)
*Fall*Underweight*					22.99	(-41.2, 87.2)
*Spring*Overweight*					-6.872	(-21.3, 7.51)
*Summer*Overweight*					-2.15	(-23.6, 19.3)
*Fall*Overweight*					-2.752	(-16.1, 10.6)
*Spring*Obese*					1.175	(-17.1, 19.4)
*Summer*Obese*					-35.39	(-67.6, -3.18)
*Fall*Obese*					-16.36	(-33.4, 0.671)
LPA*NALP Universal Accessibility	0.043	(0.003, 0.082)				
LPA*NALP Density of Destinations			-0.036	(-0.067, -0.004)		
Income*IMI Safety from Crime‡						
*$20,000 to $60,000*IMI Safety from Crime*	29.3	(1.60, 57.0)				
*$60,000 to $100,000*IMI Safety from Crime*	32.15	(4.43, 59.9)				
*>$100,000*IMI Safety from Crime*	24.41	(-2.58, 51.4)				
*Unknown*IMI Safety from Crime*	22.66	(-4.67, 50.0)				
Income*IMI Cumulative Score‡						
*$20,000 to $60,000*IMI Cumulative Score*					32.49	(2.38, 62.6)
*$60,000 to $100,000*IMI Safety from Crime*					35.18	(5.01, 65.4)
*>$100,000*IMI Safety from Crime*					27.69	(-1.63, 57.0)
*Unknown*IMI Safety from Crime*					25.28	(-4.46, 55.0)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).
‡ References Categories: season – winter, gender – male, body mass index – normal weight, income - <$20,000
Abbreviations: BMI – body mass index, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity.

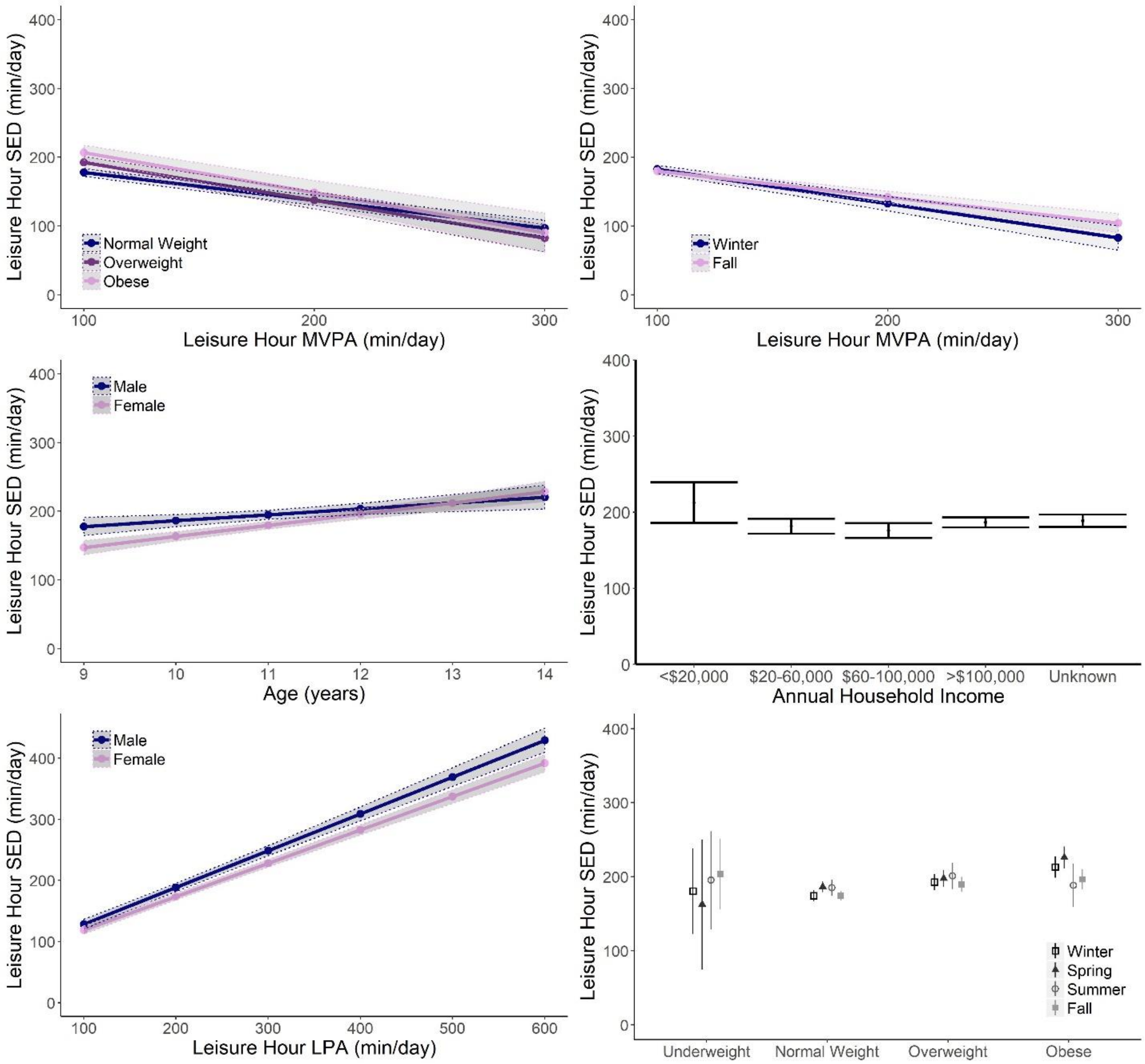


Figure 5.18 Predicted effects of physical activity, demographic factors, BMI and season on total daily leisure hour sedentary behaviour in children.

Predicted effects presented are derived from multilevel models presented in ***Table 5.7*** *(Model 1: MVPA*BMI, MVPA*season; Model 2: age*gender, income; Model 3: LPA*gender, season*BMI). 95% CIs are shown as grey ribbons or vertical bars. Reference categories: BMI – normal weight, season – winter, gender – male, annual household income - <$20,000 per year.*

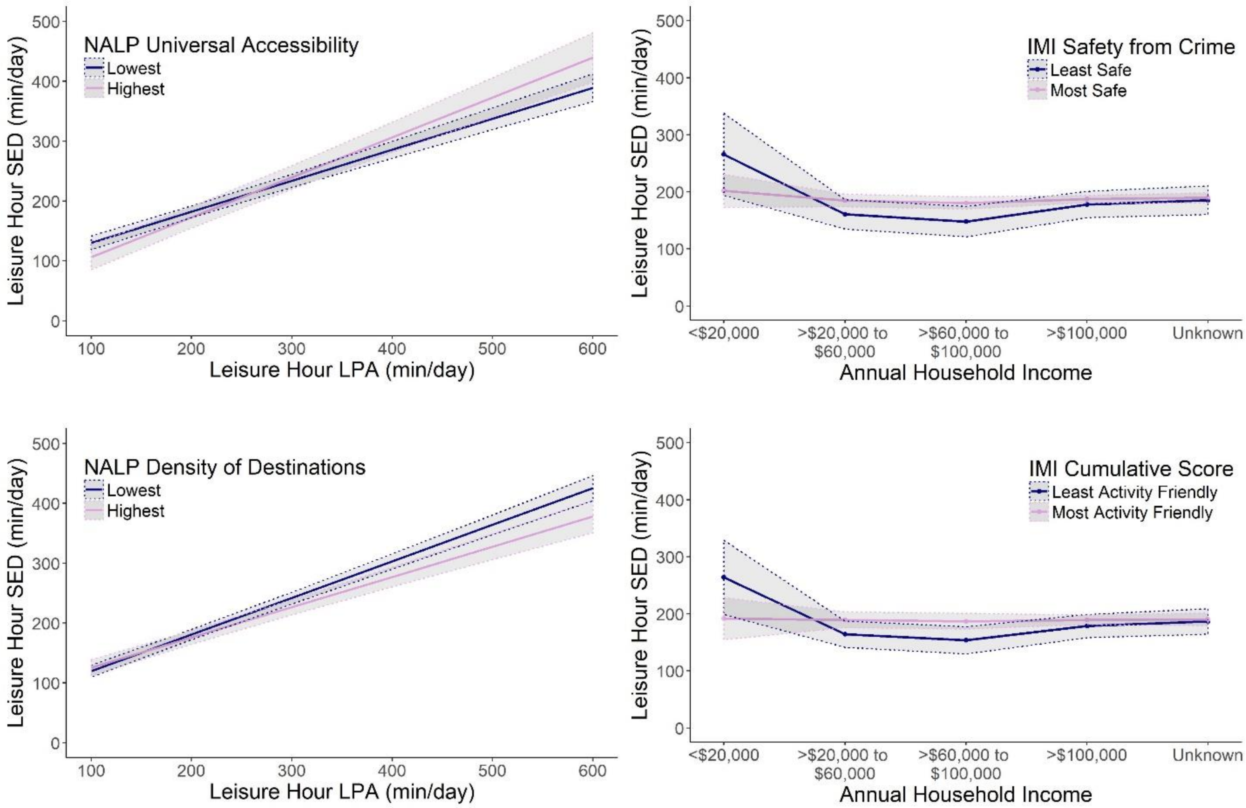


Figure 5.19 Predicted effects of physical activity, demographic factors and the built environment on total daily leisure hour sedentary behaviour in children.

*Predicted effects presented are derived from multilevel models presented in **Table 5.7** (Model 1: LPA*NALP universal accessibility, income*IMI safety from crime; Model 2: LPA*NALP density of destinations; Model 3: income*IMI cumulate score). 95% CIs are shown as grey. Reference category: annual household income - <$20,000 per year.*

These findings highlight that, outside of school hours, younger age, female gender and normal weight status were predictive of lower leisure hour SED. While the effects of season were moderated by a child's BMI, season alone was not predictive of leisure hour SED. The effects of income and a child's PA were moderated by home neighbourhood BE.

5.6 School Hour Sedentary Behaviour Patterns in 9-14-Year-Old Children

As stated in **Research Question Ai** (**Section 1.3**), this section seeks to understand if seasonal changes and a child's demographic factors are predictors of school hour SED, and if the BE surrounding a child's school significantly moderates the effect of season or demographic factors on SED. As stated in Hypothesis A (**Section 1.4**) and outlined in **Figure 3.2**, it is hypothesized that climate associated with colder months will result in an increase in mean school hour SED in children. Furthermore, a child's school neighbourhood BE will moderate these effects.

The participating study population of children were registered participants of public and Catholic schools within Saskatoon, both of which are publically funded. Saskatoon elementary schools (Kindergarten through Grade 8, or ages 5 through 13), of which all of the participants attended, offer programming for approximately 7 hours per day from Monday to Friday (or 35 hours/week), from September until June (inclusive), a substantial proportion of their waking hours. As elementary schooling consumes a large portion of a child's day and is highly structured, there is great worth in understanding both the activity outcomes of children during school hours and what predicts positive activity outcomes in elementary aged school children. The structured manner of a school day also provides opportunity for population-scale interventions to improve children's health.

During school hours study participants accumulated an average of 106, 163 and 73.8 minutes of SED, LPA and MVPA per day. The average total daily activity behaviour contributed by study participants was 342 of a possible 345 minutes (from 0915-1500h), indicating wear time compliance in the valid accelerometry cohort was exceptionally high during this period.

To understand what predicts school hour SED in children, MLMs were created, taking into consideration seasonality, demographic variables and school-neighbourhood variables. In the null model using an autoregression 1 correlation structure, 48.1% of the variation in school hour SED occurred across individuals.

During school hours LPA, and to a greater extent, MVPA negatively predicted SED. When PA was included in the model, season did not significantly predict SED (**Table 5.8**). In the absence of PA in the MLM, children were significantly less sedentary in summer and fall months in comparison to winter months (**Table B.4**). In PAEM, females, older children, and those living with the greatest annual household income (>$100,000) were significantly more likely to accumulate greater levels of SED in comparison to males, younger children and those living in a household with an income of <$20,000, respectively. Children living in fractured grid neighbourhoods were significantly more sedentary than those living in grid neighbourhoods. In the PAEM, BMI was a confounder of both income and gender. When neighbourhood era design was included in the model, income no longer significantly predicted school hour SED and was therefore not retained in subsequent model building (**Table B.4**).

A shown in **Table 5.8**, in PAIM, older children and children who were overweight or obese were significantly more sedentary than younger children and children with normal weight. Children attending schools in neighbourhoods with the lowest level of attractiveness and highest level of safety from crime and overall activity friendliness accumulated significantly more SED in comparison to their counterparts (**Table 5.8**). Additionally, BE dimensions promoting active environments moderated the effect of PA on SED. With increased levels of LPA and MVPA, children significantly reduced their SED, but the effect of this decrease was significantly reduced to the greatest extent in children attending schools in neighbourhoods with the lowest attractiveness scores (LPA only). In contrast, children attending schools in neighbourhoods with high degrees of safety from crime and overall activity friendliness (IMI cumulative score) showed a greater reduction in SED with increased LPA (**Table 5.9**, **Figure 5.20**).

In PAIMs predicting school hour SED, season moderated the negative association of PA on SED. With increased levels of LPA and MVPA, children reduced their SED, but the effect of this decrease was greater in winter vs summer months (**Table 5.9**, **Figure 5.21**). The effect of season was also moderated by the BE. Children attending school in neighbourhoods with higher levels of safety from crime and overall activity friendliness (IMI cumulative score) were significantly more sedentary in summer months vs those attending school in less activity-friendly and safe neighbourhoods (**Table 5.9**, **Figure 5.22**).

Table 5.8 Factors predicting school hour sedentary behaviour in 9-14-year-old-children: univariate and main effects models.

	Univariate		Level 1 Main Effects		Level 1 & 2 Main Effects		Level 1-3 Main Effects					
							Model 1					
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population size (n)	619		619		616		616		616		616	
Constant			315	(313, 317)	285	(276, 295)	297	(284, 310)	277	(264, 289)	285	(276, 295)
Level 1 Variables												
LPA	-0.798	(-0.821, -0.775)	-0.872	(-0.882, -0.861)	-0.863	(-0.874, -0.852)	-0.864	(-0.875, -0.853)	-0.863	(-0.874, -0.852)	-0.863	(-0.874, -0.852)
MVPA	-0.826	(-0.855, -0.798)	-0.91	(-0.924, -0.897)	-0.905	(-0.918, -0.891)	-0.905	(-0.918, -0.892)	-0.906	(-0.919, -0.893)	-0.906	(-0.919, -0.893)
Season (reference - winter)												
Spring	2.27	(-0.730, 5.26)										
Summer	-5.78	(-10.6, -0.990)										
Fall	-6.07	(-8.91, -3.24)										
Level 2 Variables												
Age					1.55	(1.07, 2.03)	1.55	(1.07, 2.02)	1.54	(1.06, 2.024)	1.54	(1.06, 2.02)
BMI (reference - normal weight)§												
Underweight					4.97	(-0.635, 10.6)	4.89	(-0.654, 10.4)	4.86	(-0.689, 10.4)	4.86	(-0.69, 10.4)
Overweight					6.00	(0.343, 11.7)	5.99	(0.386, 11.6)	6.03	(0.422, 11.6)	6.03	(0.422, 11.6)
Obese					8.71	(2.96, 14.5)	8.77	(3.08, 14.4)	8.78	(3.08, 14.5)	8.78	(3.08, 14.5)
Income (reference - <$20,000)												
$20,000 to $60,000					3.62	(-0.338, 7.58)	3.38	(-0.54, 7.29)	3.34	(-0.585, 7.3)	3.34	(-0.585, 7.26)
$60,000 to $100,000					5.73	(1.78, 9.68)	5.7	(1.8, 9.61)	5.50	(1.59, 9.41)	5.50	(1.59, 9.41)
>$100,000					5.21	(1.39, 9.03)	5.02	(1.24, 8.8)	4.86	(1.08, 8.65)	4.86	(1.08, 8.65)
Unknown					4.39	(0.511, 8.26)	4.29	(0.468, 8.11)	4.13	(0.300, 7.96)	4.13	(0.3, 7.96)
Neighbourhood Level Variables												
IMI Attractiveness							-2.25	(-4.21, -0.279)				
IMI Safety from Crime									1.04	(0.0256, 2.06)		
IMI Cumulative Score											1.13	(0.0269, 2.24)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).

Abbreviations: BMI – body mass index, IMI – Irvine Minnesota Inventory, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity

Table 5.9 Factors predicting school hour sedentary behaviour in 9-14-year-old children: final multilevel models.

	Main Effects Models with Interactions					
	Model 1		Model 2		Model 3	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population size (n)	616		616		616	
Constant	370	(340, 401)	230	(199, 260)	289	(279, 299)
Level 1 Variables						
LPA	-1.31	(-1.47, -1.14)	-0.512	(-0.663, -0.36)	-0.867	(-0.887, -0.847)
MVPA	-0.907	(-0.92, -0.893)	-0.922	(-0.946, -0.898)	-0.907	(-0.92, -0.894)
Season (reference - winter)						
Spring	-3.94	(-8.47, 0.597)	-7.02	(-24.1, 10.0)	-3.08	(-7.66, 1.50)
Summer	-20.9	(-27.6, -14.2)	-94.1	(-126, -62.4)	-21.7	(-28.5, -14.9)
Fall	-0.786	(-4.98, 3.40)	-3.92	(-20.1, 12.2)	-0.533	(-4.81, 3.75)
Level 2 Variables						
Age	1.49	(1.01, 1.97)	1.32	(0.837, 1.8)	1.35	(0.866, 1.83)
BMI (reference - normal weight)§						
Underweight	5.20	(-0.335, 10.7)	5.34	(-0.194, 10.9)	5.27	(-0.293, 10.8)
Overweight	6.16	(0.567, 11.8)	6.08	(0.486, 11.7)	6.01	(0.387, 11.6)
Obese	8.85	(3.16, 14.5)	8.88	(3.19, 14.6)	8.82	(3.10, 14.5)
Income (reference - <$20,000)						
$20,000 to $60,000	2.88	(-1.03, 6.79)	2.80	(-1.11, 6.72)	2.79	(-1.14, 6.72)
$60,000 to $100,000	5.06	(1.16, 8.97)	4.82	(0.914, 8.72)	4.84	(0.926, 8.76)
>$100,000	4.41	(0.637, 8.18)	4.17	(0.39, 7.95)	4.16	(0.365, 7.95)
Unknown	3.65	(-0.173, 7.47)	3.48	(-0.342, 7.29)	3.48	(-0.351, 7.32)
Neighbourhood Level Variables						
IMI Attractiveness	-16.3	(-22.6, -10.0)				
IMI Safety from Crime			7.14	(3.7, 10.6)		
IMI Cumulative Score					7.90	(4.15, 11.6)
Interaction Terms						
*Season*LPA* ‡						
*Spring*LPA*	0.0270	(-0.000174, 0.0541)	0.0206	(-0.00647, 0.0476)	0.0214	(-0.00564, 0.0485)
*Summer*LPA*	0.123	(0.0836, 0.163)	0.125	(0.0846, 0.165)	0.126	(0.0855, 0.166)
*Fall*LPA*	0.00384	(-0.0208, 0.0285)	0.00100	(-0.0236, 0.0256)	0.00174	(-0.0229, 0.0264)
Season*MVPA‡						
*Spring*MVPA*			0.0222	(-0.0111, 0.0555)		
*Summer*MVPA*			0.0698	(0.0214, 0.118)		
*Fall*MVPA*			0.00753	(-0.0238, 0.0388)		
LPA*IMI Attractiveness	0.0861	(0.0520, 0.120)				
Season*IMI Safety from Crime‡						
*Spring*IMI Safety from Crime*			0.296	(-1.55, 2.14)		
*Summer*IMI Safety from Crime*			7.99	(4.48, 11.5)		
*Fall*IMI Safety from Crime*			0.355	(-1.37, 2.08)		
*LPA*IMI Safety from Crime*			-0.0420	(-0.059, -0.025)		
Season*IMI Cumulative Score‡						
*Spring*IMI Cumulative Score*					0.330	(-1.68, 2.34)
*Summer*IMI Cumulative Score*					8.16	(4.36, 12.0)
*Fall*IMI Cumulative Score*					0.321	(-1.56, 2.20)
*LPA*IMI Cumulative Score*					-0.0463	(-0.0648, -0.0278)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (3).

‡ References Categories: season – winter, gender – male, body mass index – normal weight, income - <$20,000

Abbreviations: BMI – body mass index, IMI – Irvine Minnesota Inventory, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, NALP – Neighbourhood Active Living Potential

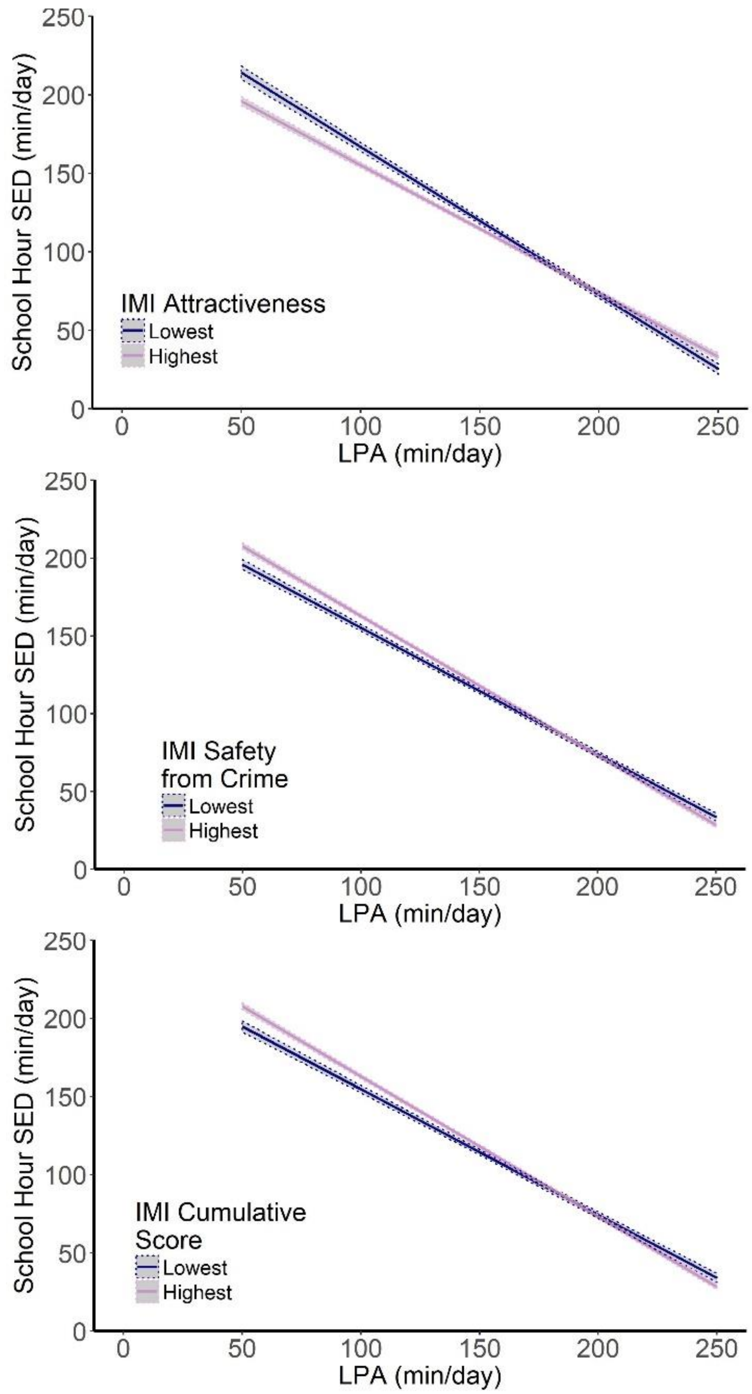


Figure 5.20 Predicted moderating effects of physical activity and built environment on school hour sedentary behaviour in children.

Predicted effects presented are derived from physical activity inclusive multilevel models presented in ***Table 5.7*** *(Model 1: LPA*IMI Attractiveness; Model 2: LPA*IMI Safety from Crime; Model 3: LPA*IMI Cumulative Score). 95% CIs are shown as grey ribbons. Graphs have been simplified for clarity, with only extreme built environment scores being shown.*

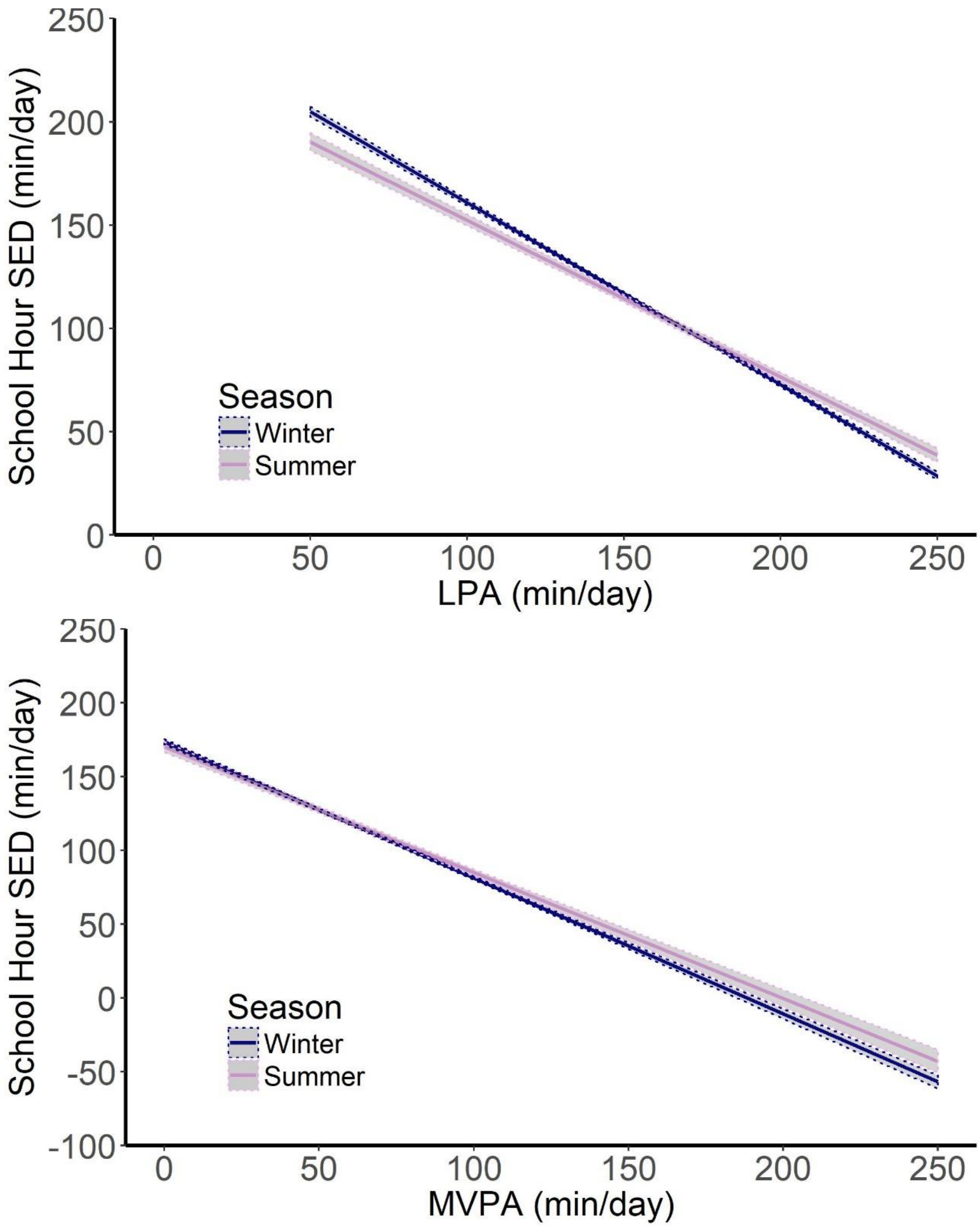


Figure 5.21 Predicted moderating effects of physical activity and season on daily school hour sedentary behaviour in children.

Predicted effects presented are derived from physical activity inclusive multilevel models presented in ***Table 5.7*** *(Model 5: LPA*Season; Model 7: MVPA*Season). 95% CIs are shown as grey ribbons. Reference category (winter) is shown as light purple. Graphs have been simplified for clarity, with non-significant season categories being omitted.*

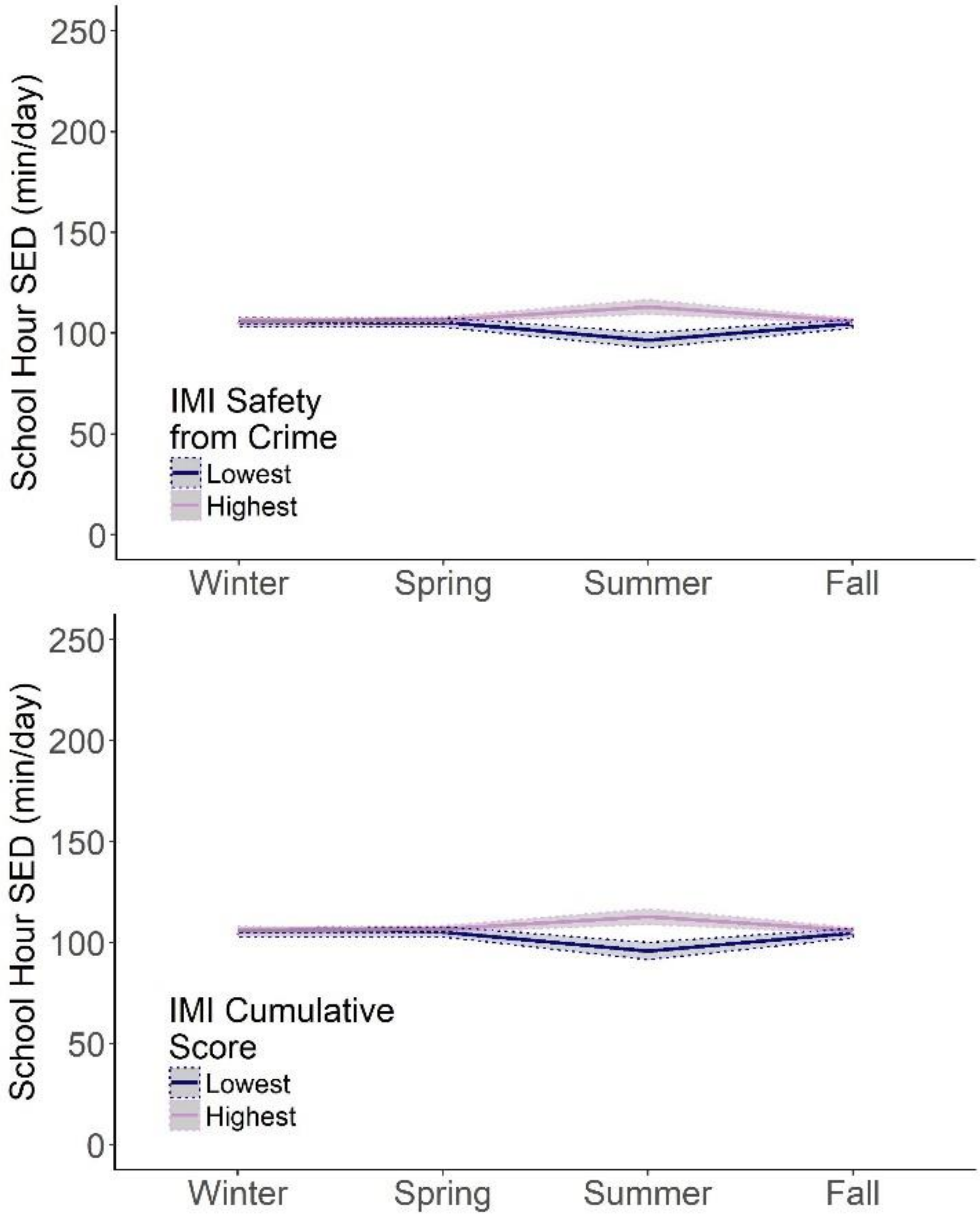


Figure 5.22 Predicted moderating effects of physical activity and built environment on school hour sedentary behaviour in children.

Predicted effects presented are derived from physical activity inclusive multilevel models presented in ***Table 5.7*** *(Model 2: Season*IMI Safety from Crime; Model 3: Season*IMI Cumulative Score). 95% CIs are shown as grey ribbons. Graphs have been simplified for clarity, with only extreme built environment scores being shown.*

In a PAEM model, both gender and age moderated the effect of season on school hour SED. While females were likely to participate in higher levels of SED during winter, spring and summer, this difference was diminished in fall. As children age, they participate in greater levels of SED, but this relationship is lessened during summer months, where older children are predicted to participate in less SED (vs winter months) (**Table B.4**, **Figure B.2).** In these same PAEMs, all four NALP dimension scores differentially moderated the effect of season on school hour SED. Children attending schools in neighbourhoods with the highest density of destinations were significantly less sedentary during school hours in winter, but this difference did not exist in fall months. During winter months, children attending school in neighbourhoods with high levels of activity friendliness were more sedentary in comparison to those attending school in lower activity-friendly neighbourhoods. In spring and fall months, children's SED did not differ between school neighbourhood activity friendliness, but summer months afforded slightly higher levels of school hour SED in those with low activity-friendly school neighbourhoods. While children's SED outcomes did not vary between those attending school in lower vs more highly safe neighbourhoods in winter, spring and fall months, SED was significantly lower during summer months in those attending school in the least safe neighbourhoods. Lastly, SED was higher in children attending school in neighbourhoods with the lowest degree of universal accessibility in winter, spring and summer months, but the opposite was true in fall months (**Table B.4**, **Figure B.3**).

As with NALP dimension scores, IMI dimension scores moderated the effect of season on school hour SED in PAEM. While children attending schools in highly attractive neighbourhoods were more sedentary in winter months, the opposite held true in fall. In winter months, increased school neighbourhood pedestrian access was associated with increased SED. Whereas in summer months, pedestrian access was associated with significantly lower levels of SED. Increased sedentariness with age was also moderated by school neighbourhood pedestrian access, with children experiencing a greater likelihood of sedentarism with increased age in school neighbourhoods with reduced pedestrian access. Children attending schools in neighbourhoods with different degrees of safety from traffic and crime did not vary in their school hour SED during winter months. However, in spring months SED was higher in those attending school in neighbourhoods with the lowest level of safety from crime. In summer months, SED was lower in children attending school in neighbourhoods with the lowest level of safety from traffic. (**Table B.5**, **Figure B.4**).

NALP and IMI cumulative scores and a NALP and IMI combined score all differentially moderated the effect of season in PAEM predicting school hour SED. In winter months, SED did not differ significantly between children attending schools in neighbourhoods with varying degrees of activity friendliness (i.e. cumulative NALP and IMI scores or NALP and IMI combined score). Whereas, in summer months, increased school neighbourhood cumulative NALP scores were associated with greater levels of SED. In contrast, in spring months, increased school neighbourhood IMI cumulative scores and NALP and IMI combined scores were associated with reduced levels of SED (**Table B.4 and B.5, Figure B.5**).

These findings highlight that during school hours, school hour PA and a child's demographics are predictive of school hour SED, with the exception of a child's gender and immigrant status. Children of a younger age, accumulating greater levels of MVPA and with normal weight status were significantly less SED during the school period. School neighbourhood safety from crime, attractiveness and cumulative score were significant predictors of school hour SED. Season did not significantly predict school hour SED.

5.7 Location-Specific Sedentary Behaviour in Children

Over the entire collection period, participants accumulated a daily mean of 218, 275 and 130 minutes/day of SED, LPA and MVPA, respectively (derived from GPS-paired accelerometry data).

To examine the relative activity behaviour of this study's participants throughout the day, activity behaviour and location time series were plotted for all days. On weekday mornings, distinct peaks in SED occurred at 0800, 0900, and 1100. After 1200-1300h (school lunch hour), a steady rise in SED occurs for the remainder of the day, with two breaks occurring between 1400-1430h (the approximate time of afternoon recess) and 1515-1545 (school dismissal). The greatest amount of SED recorded by participants occurred in the late afternoons and evenings, from 1620-1900h. MVPA, and to a lesser extent LPA, showed an inverse relationship with SED. The greatest amount of MVPA recorded occurred between 1400-1430h. On weekends, participants contributed similar total counts of SED and LPA throughout the day. No distinct activity patterns were present on weekends (**Figure 5.13**).

Over the entire study period, 56.8% of all participant activity minutes fell within a participant's home neighbourhood. When activity behaviour was mapped by location, weekdays, but not weekends, offered predictable patterns in children's daily locations. On weekdays, children spent the majority of their before- and after-school periods within their home properties. During school hours, children unsurprisingly accumulated the greatest amount of activity within school boundaries. Additionally, during school hours, the use of school park's showed three distinct peaks that closely align with morning recess, lunch hour and afternoon recess. Children spent the majority of their weekday evenings and their entire weekend at home, in areas categorized as 'other,' and in roadways (**Figure 5.23**).

On weekdays, children spent 42.1 and 31.1% of their day at school and within 20m of their home property, respectively. 'Other' locations and roadways comprised 12.1 and 9.76% of children's weekdays, respectively. Only 4.54% of a child's weekday was spent in a school park (3.15%) or park (1.39%). On weekends children spent more than half their day at home (59.9%). The remainder of their weekend was primarily spent in 'other' locations (26.3%) or in roadways (9.73%). Collectively, less than 5% of children's weekends were spent in public city parks (1.87%) or on a school property (2.25%) (**Figure 5.24**).

As a large proportion of participating children's leisure hours were spent in unspecified ("other") locations, these data points were further investigated using the city of Saskatoon's zoning designations and GIS shapefiles. The majority of GPS-paired accelerometry data points defined as 'other' fell within residential properties (66.7 and 62.9% on weekdays and weekends, respectively). The remainder of 'other' location data points fell within commercial (16.0 and 17.6%), institutional (5.22 and 5.80%), industrial (4.64 and 6.00%), and unified development (2.22 and 4.42%) zoning designations (weekdays and weekends, respectively). Only 5.18 and 3.29% of data points fell collectively within areas designated for agriculture, within-city-rural, planned development, mixed land use and non-defined areas on weekdays and weekends, respectively (**Figure 5.25**). **Table A.2** outlines the difficulty in delineating information from the city of Saskatoon's zoning designations, as a substantive amount of uses are allowed within each designation and many of these uses overlap between designations. **Figure 5.26** shows the proportion of SED, LPA and MVPA stratified by location. At least half of the time children spent in school parks and parks was in a MVPA state.

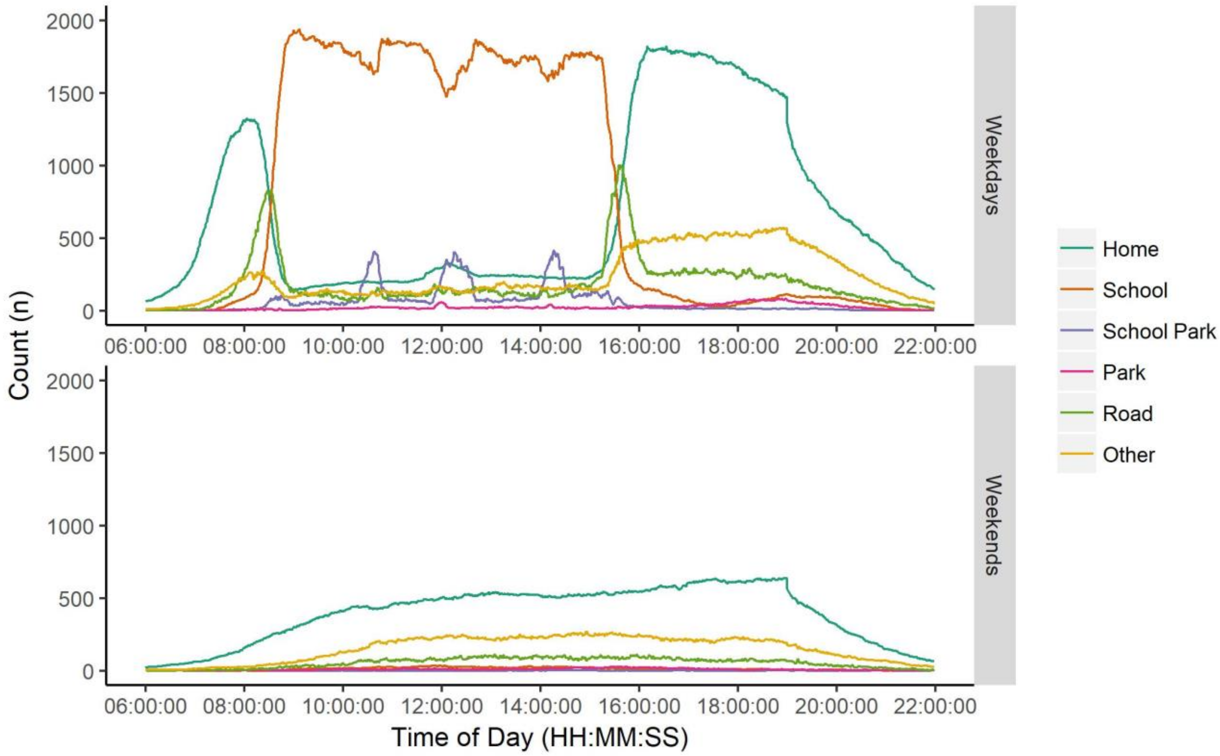


Figure 5.23 9-14 year-old children's daily behaviour by location.

Valid accelerometry-paired GPS data points shown for all participant from 0600-2200h using one second epochs and are stratified by weekday and weekend and location type. Data points include all valid GPS-paired accelerometry measured over the entire study period (n=2,375,876 participant minutes).

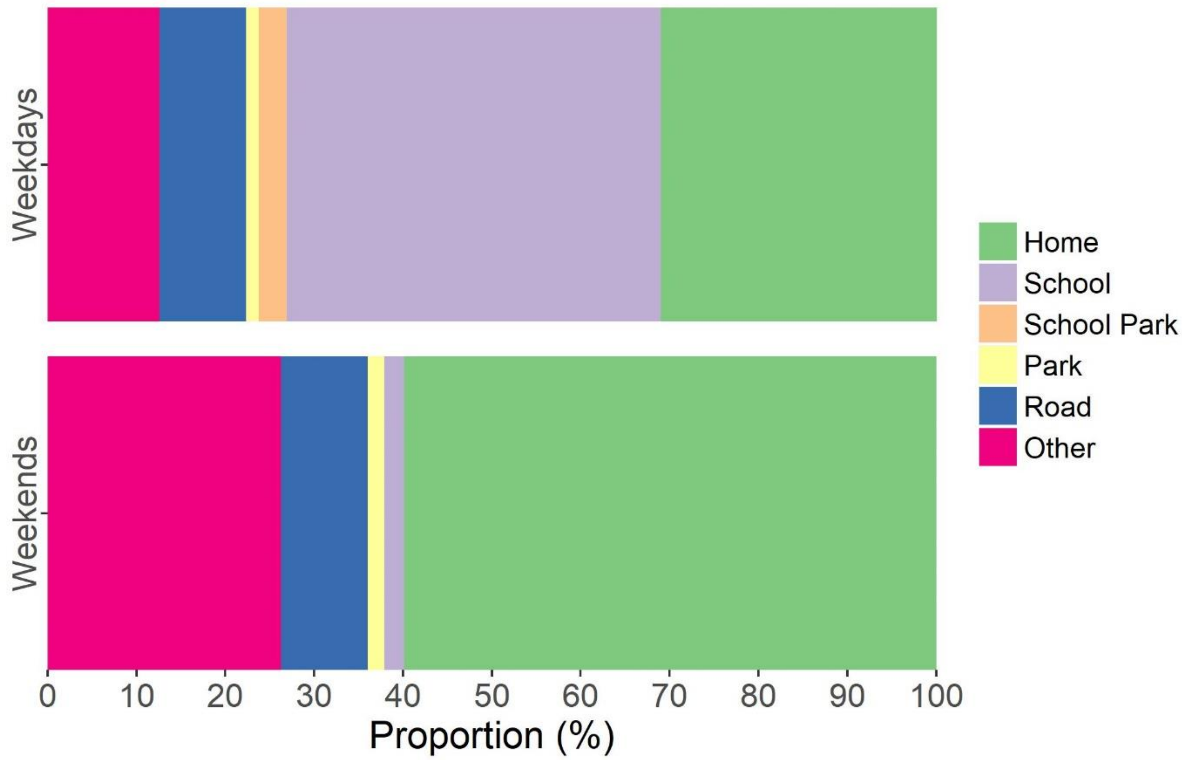


Figure 5.24 GPS-derived location of study participants.

Valid GPS-paired accelerometry data points are presented as participant minutes (n=2,375,876) and stratified by location and weekday vs weekend.

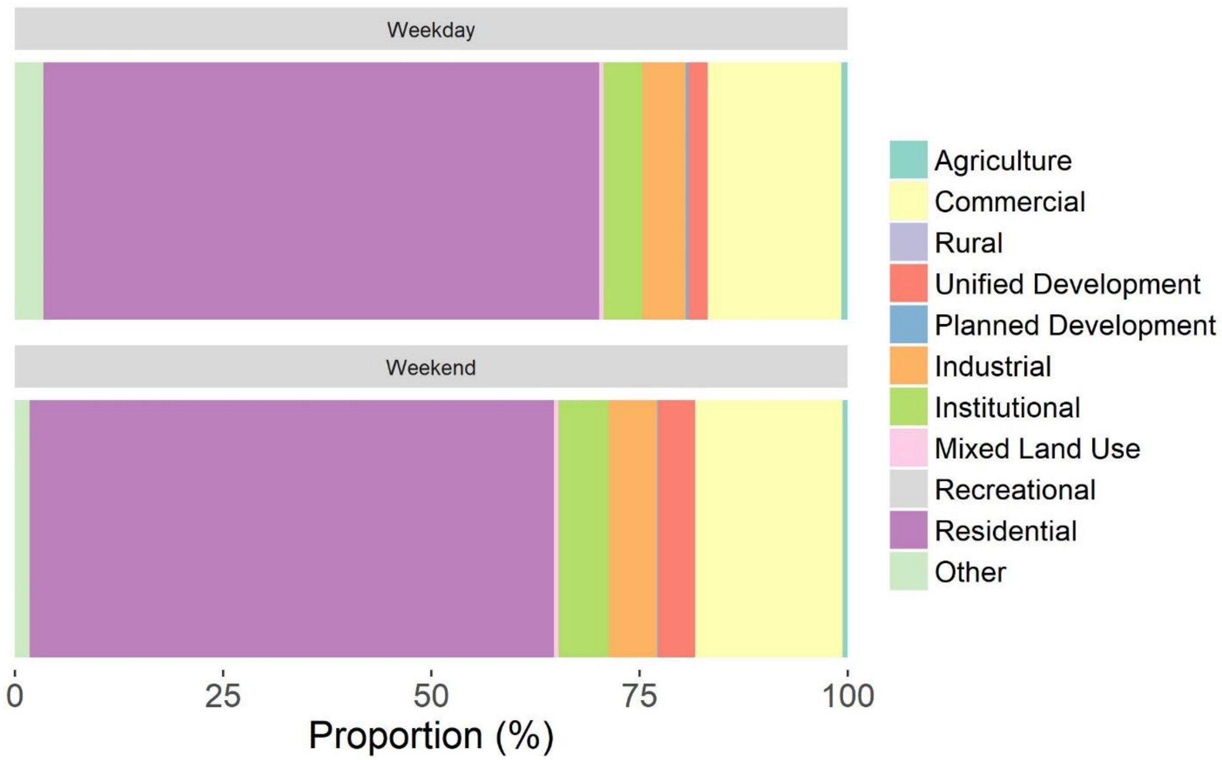


Figure 5.25 Proportion of valid accelerometry-paired GPS data points falling within the city of Saskatoon city limits that were not confined participant's home, school, parks, or roadways.

Valid GPS-paired accelerometry data points are presented as participant minutes and stratified by location and weekday vs weekend.

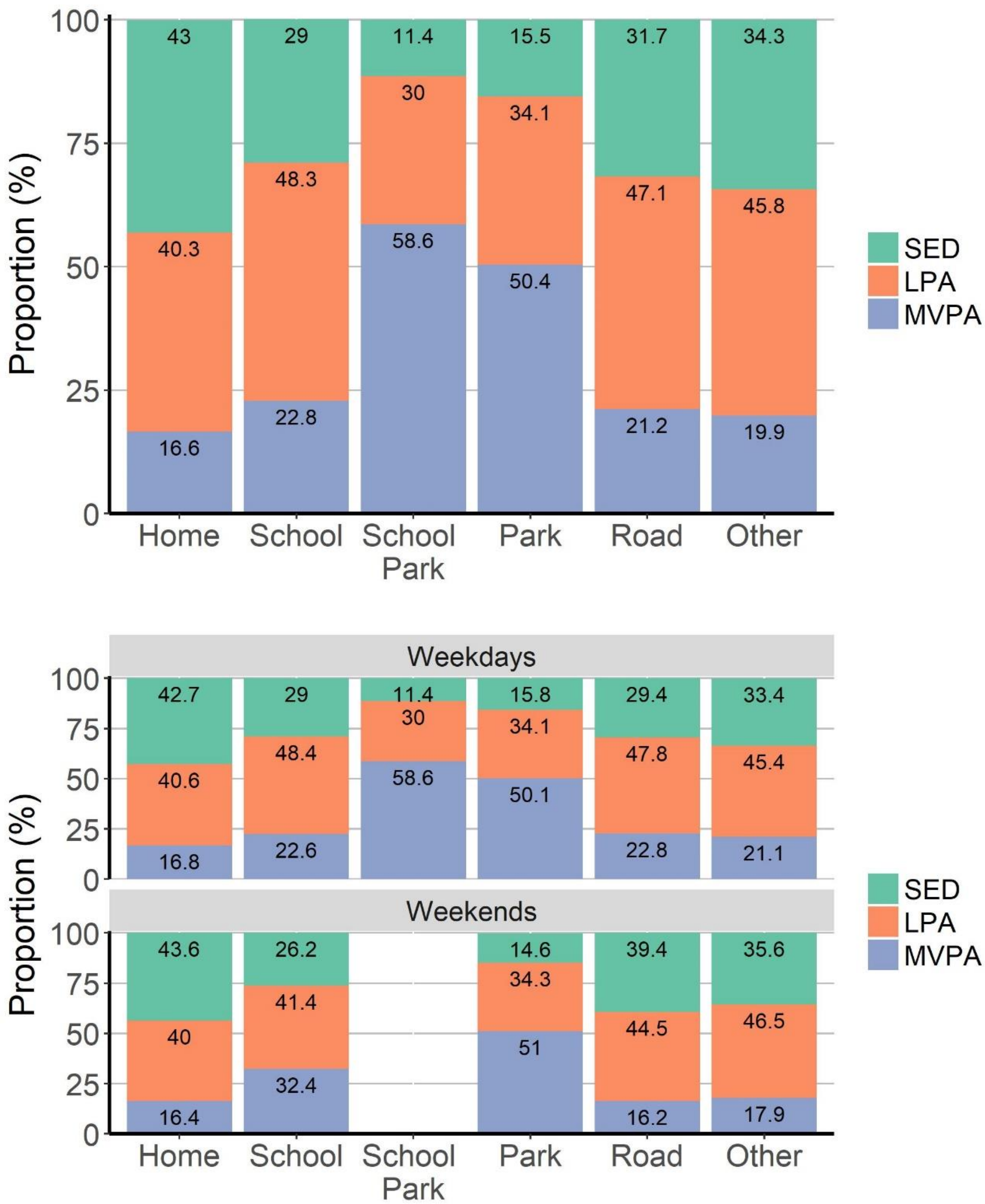


Figure 5.26 Location specific activity outcomes in 9-14-year-old children.

Values shown represent the proportion of SED, LPA and MVPA within each location. Data is presented as participant minutes, which include all valid GPS-paired accelerometry data points (n=2,375,876).

Participants also recorded the least amount of SED in school parks and parks, but spent only 2.25% of their time in these locations (**Figure 5.25**). Schools and roadways offered the greatest opportunity for sedentariness.

5.7.1 Home Area Sedentary Behaviour in Children

To better understand if a child's demographic factors, the season they are experiencing and the BE in which they live can significantly predict their SED while in their home environment, MLMs predicting home area SED were generated. As stated in **Research Question Aii** (**Section 1.3**), this section seeks to understand if seasonal changes and a child's demographic factors are predictors of home area SED, and if the BE surrounding a child's home significantly moderates the effect of season or demographic factors on SED. As stated in Hypothesis A (**Section 1.4**) and outlined in **Figure 3.2**, it is hypothesized that the climate associated with colder months will result in an increase in home area SED in children. Furthermore, a child's home neighbourhood BE will moderate these effects.

In the null random intercept MLM using an autoregression 1 correlation structure, 37.4% of the variation in home area SED occurred across individuals. Within the main effects models (**Table 5.10**) children accumulated a modest additional ~6 additional minutes of SED per day during spring months while within their home area, in comparison to winter months. In contrast, fall months afforded children 12 fewer minutes of SED per day (vs winter months). When children were within their home properties they were more sedentary if they reported male gender, were older, had an obese weight status or had immigrated to Canada within the past two years, or if it was a weekend day. Children living in a household with an annual income of $20,000-60,000 were significantly more sedentary than children living in households with an annual income of less than $20,000. This association between annual household income and home area SED was no longer significant with the addition of neighbourhood level main effects.

As shown in **Table B.6 and B.7**, multiple home-neighbourhood BE attributes significantly predicted a child's SED while in their home environment. While at home, those situated within Saskatoon neighbourhoods with fractured grid, curvilinear and modified grid patterns were significantly more sedentary than those living in Saskatoon's grid neighbourhoods. The increased SED effect of weekends on children's home SED was moderated by home neighbourhood era design.

Table 5.10 Factors predicting home area sedentary behaviour in 9-14-year-old children: univariate and individual level main effects models.

	Univariate Model		Level 1 Main Effects		Level 1 & 2 Main Effects	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population Size (n)	401		401		400	
Constant			27.6	(22, 33.2)	-29.1	(-81.7, 23.5)
Level 1 Variables						
LPA	0.756	(0.728, 0.784)	0.844	(0.806, 0.882)	0.842	(0.804, 0.88)
MVPA	0.809	(0.742, 0.877)	-0.374	(-0.448, -0.301)	-0.369	(-0.442, -0.295)
Season (reference - Winter)						
Spring	-0.0556	(-7.00, 6.89)	6.12	(0.975, 11.3)	6.38	(1.25, 11.5)
Summer	-13.6	(-23.8, -3.38)	1.35	(-6.23, 8.93)	1.72	(-5.82, 9.25)
Fall	-17.6	(-26.5, -8.69)	-11.6	(-18.2, -4.94)	-11.5	(-18.1, -4.94)
Weekend Day (reference - Weekdays)	47.6	(42.7, 52.5)	19.2	(15.2, 23.2)	19.4	(15.4, 23.4)
Level 2 Variables						
Age					7.65	(4.37, 10.9)
Gender (reference - Male)					-12.6	(-19.9, -5.22)
BMI (reference - normal weight)§						
Underweight					-37.3	(-105, 30.1)
Overweight					6.71	(-1.77, 15.2)
Obese					12.7	(1.52, 24)
Income (reference - <$20,000)						
$20,000 to $60,000					-36.7	(-72.8, -0.73)
$60,000 to $100,000					-31.4	(-67, 4.31)
>$100,000					-20.9	(-55.5, 13.7)
Unknown					-25.0	(-59.3, 9.39)
Newcomer to Canada‡					18.1	(6.52, 29.7)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).
‡ References Categories: season – winter, gender – male, body mass index – normal weight, income - <$20,000
Abbreviations: BMI – body mass index, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, Newcomer to Canada – living in Canada for less than two years

On weekends, children living in curvilinear neighbourhoods experienced a greater increase in sedentariness than children living in Saskatoon's grid style neighbourhoods (**Table B.6, Figure 5.27**). Children living in neighbourhoods with the highest NALP density of destination and NALP-IMI combined scores experienced significantly lower levels of SED while at home. Neighbourhood destination density and NALP-IMI Combined Scores moderated the increased effect of weekend sedentariness. Children living in neighbourhoods with the highest density of destinations and overall activity friendliness experienced almost no increase in weekend sedentariness vs children living in neighbourhoods with lower density of destinations or activity friendliness, respectively. Children living in neighbourhoods with the least amount of social and physical disorder (IMI safety from crime) and overall activity friendliness (IMI cumulative score) were significantly more SED at home than children living in neighbourhoods with higher levels of safety from crime and overall activity friendliness, respectively. The effect of income was moderated by both neighbourhood safety and activity friendliness. Children with low SES (annual household income <$20,000) living in neighbourhoods with the lowest safety from crime and activity friendliness were significantly more sedentary than children living in safer, more activity-friendly neighbourhoods. This dramatic difference was significantly diminished, and even reversed, in children living with high SES. Within the home area MLM analysis, only five children's parents reported having an income of <$20,000. This small sample size is reflected in the large confidence intervals shown in the predicted effects involving annual household income (**Table B.7**, **Figure 5.27**), and may have led to spurious significant associations.

In the same models describing neighbourhood level effects of home area SED the effects of both LPA and MVPA were significantly moderated by a child's home neighbourhood environment. Increases in home area LPA were associated with almost an equivalent increase in SED. In contrast, for every three additional minutes of MVPA accumulated within the home property, participants were predicted to spend 1 minute less in a sedentary state (**Table 5.10**). Children living in neighbourhoods with the highest density of destinations and overall activity friendliness (NALP-IMI combined score) accumulated 6.04 (95% CI -12.0, -0.00756) and 6.06 (95% CI -11.3, -0.0819) fewer minutes of SED per day while in their home area in comparison to their counterparts.

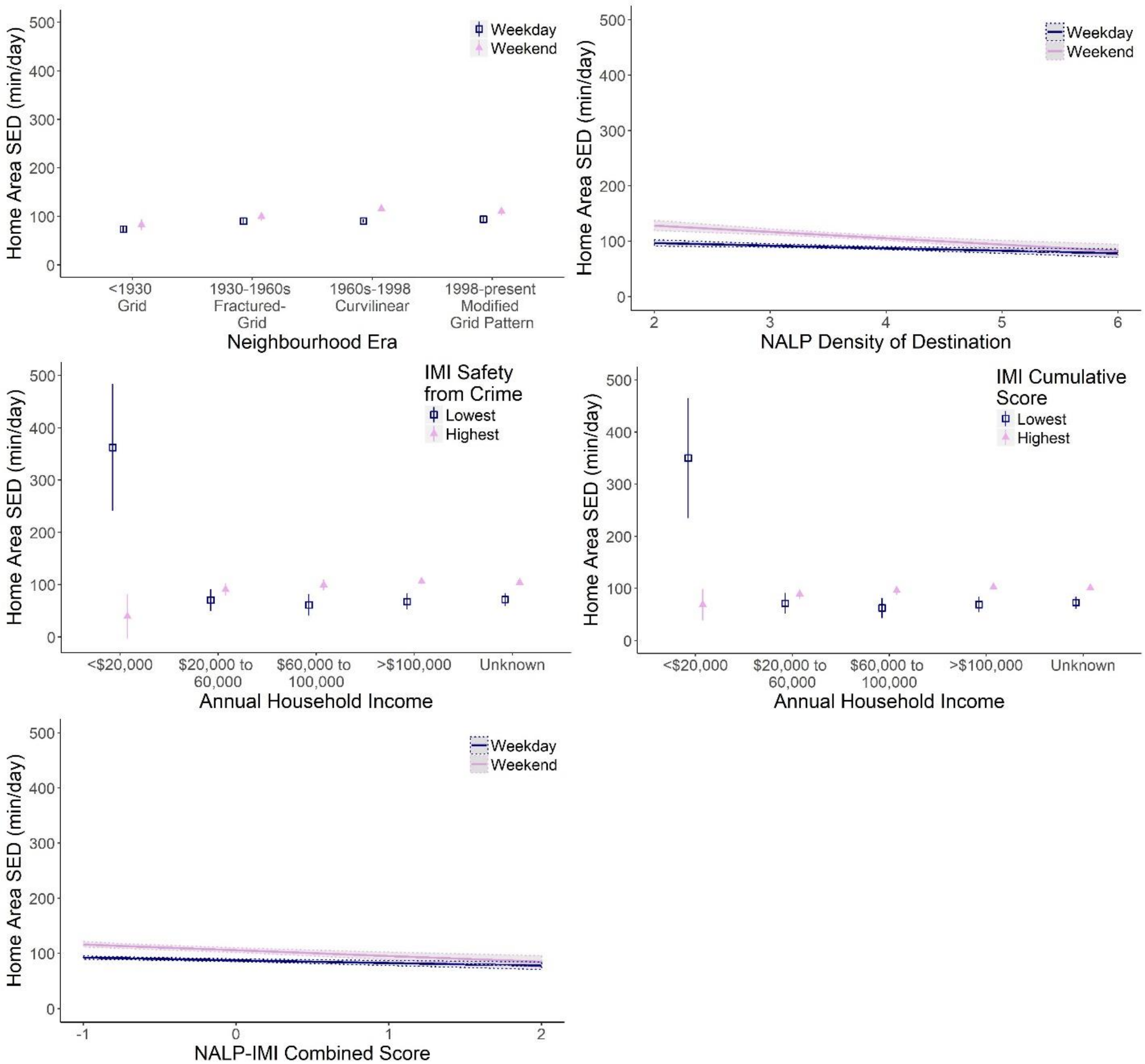


Figure 5.27 The effect of annual household income and weekends (vs weekdays) on home area sedentary behaviour in children are moderated home-neighbourhood built environment.

*Predicted effects presented are derived from physical activity inclusive multilevel models presented in **Appendix B**, **Table B.6** (Model 11: Weekday*Era) and **Table B.7** (Model 12: Weekday*NALP Density of Destination; Model 13: Income*IMI Safety from Crime; Model 14: Income*IMI Cumulative Score; Model 15: Weekday*NALP-IMI Combined Score). 95% CIs are shown as vertical bars or grey ribbons.*

In contrast, children living in neighbourhoods with the highest level of safety from crime and activity friendliness (IMI cumulate score) accumulated 6.15 (95% CI 1.42, 10.9) and 6.69 (95% CI 1.55, 11.8) additional minutes of SED per day while in their home area in comparison to their counterparts (**Table 5.11**).

When children were in their home area, those living in Saskatoon fractured grid, curvilinear and modified grid patterned neighbourhoods accumulated between 17.2-22.4 additional minutes of SED per day in comparison to those living in grid patterned neighbourhoods. Additionally, children living in curvilinear patterned neighbourhoods accumulated significantly more SED on weekends vs weekday in comparison to children living in grid style neighbourhoods (**Table B.6, Figure 5.27**).

Children living in neighbourhoods with the lowest NALP density of destinations or NALP-IMI cumulative scores experienced a significantly greater rise in SED with increased home area LPA. Differentially, children living in neighbourhoods with higher levels of safety from crime experienced a greater increase in home area SED with increased LPA. Finally, children living in the least activity-friendly neighbourhoods (IMI cumulative score) experienced reduced home area SED with increased LPA (**Table B.7, Figure 5.28**).

In MLMs predicting home area SED, the effect of season was significantly moderated by a child's home BE. Children living in neighbourhoods with highest levels of activity friendliness (spring only), pedestrian access (spring and summer) and safety from traffic (summer only) accumulated more SED in spring and summer month (vs winter months) in comparison to children living in neighbourhoods with lower levels of activity friendliness, pedestrian access, and safety from traffic, respectively (**Table 5.12, Figure 5.29**).

These findings highlight that spring months, reduced MVPA, increased age, male gender, new immigrant status and overweight or obesity status were predictive of greater home area SED accumulation. Additionally, the effects of season on a child's home area SED were moderated by a child's home neighbourhood's BE.

Table 5.11 Factors predicting home area sedentary behaviour in 9-14-year-old children: main effects models with neighbourhood level characteristics.

	Level 1-3 Main Effects Models							
	Model 3		Model 4		Model 5		Model 6	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population Size (n)	420		420		420		420	
Constant	-7.63	(-63.8, 48.6)	-83.2	(-148, -18.1)	-31.2	(-82.8, 20.4)	-31.0	(-82.7, 20.6)
Level 1 Variables								
LPA	0.844	(0.805, 0.883)	0.844	(0.805, 0.882)	0.844	(0.805, 0.882)	0.844	(0.805, 0.883)
MVPA	-0.382	(-0.458, -0.307)	-0.382	(-0.458, -0.307)	-0.382	(-0.458, -0.307)	-0.382	(-0.458, -0.307)
Season (reference - Winter)								
Spring	6.90	(1.66, 12.1)	6.75	(1.51, 12)	6.75	(1.51, 12)	6.83	(1.6, 12.1)
Summer	1.42	(-6.31, 9.16)	0.791	(-6.92, 8.5)	0.792	(-6.92, 8.5)	1.37	(-6.36, 9.09)
Fall	-11.6	(-18.3, -4.79)	-11.6	(-18.4, -4.86)	-11.6	(-18.4, -4.86)	-11.5	(-18.3, -4.72)
Weekend Day (reference - Weekdays)	19.8	(15.7, 23.9)	19.8	(15.7, 24)	19.8	(15.7, 24)	19.8	(15.7, 23.9)
Level 2 Variables								
Age	7.66	(4.46, 10.9)	7.64	(4.45, 10.8)	7.64	(4.45, 10.8)	7.65	(4.45, 10.9)
Gender (reference - Male)	-11.2	(-18.6, -3.89)	-11.1	(-18.4, -3.75)	-11.1	(-18.4, -3.75)	-11.2	(-18.5, -3.83)
BMI (reference - normal weight)§								
Underweight	-24.1	(-89.1, 40.9)	-27.1	(-91.9, 37.7)	-27.1	(-91.9, 37.7)	-24.3	(-89.2, 40.6)
Overweight	6.51	(-1.88, 14.9)	6.85	(-1.54, 15.2)	6.85	(-1.54, 15.2)	6.77	(-1.63, 15.2)
Obese	14.8	(3.55, 26.1)	15.0	(3.78, 26.3)	15.0	(3.78, 26.3)	14.9	(3.67, 26.2)
Income (reference - <$20,000)								
$20,000 to $60,000	-34.3	(-69.5, 0.927)	-33.0	(-68.2, 2.16)	-33.0	(-68.2, 2.15)	-34.2	(-69.3, 1.02)
$60,000 to $100,000	-30.9	(-66, 4.23)	-30.6	(-65.6, 4.47)	-30.6	(-65.7, 4.47)	-31.3	(-66.4, 3.76)
>$100,000	-22.9	(-56.8, 11.1)	-23.4	(-57.4, 10.5)	-23.4	(-57.4, 10.5)	-23.7	(-57.7, 10.2)
Unknown	-24.6	(-58.3, 8.99)	-24.6	(-58.1, 9)	-24.6	(-58.1, 9)	-25.3	(-58.8, 8.32)
Newcomer to Canada‡	16.1	(4.25, 28)	15.5	(3.68, 27.4)	15.5	(3.68, 27.4)	16.1	(4.25, 27.9)
Level 3 Variables								
NALP Density of Destination	-6.04	(-12, -0.0756)						
IMI Safety from Crime			6.15	(1.42, 10.9)				
IMI Cumulative Score					6.69	(1.55, 11.8)		
NALP-IMI Combined Score							-6.06	(-11.3, -0.819)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).
‡ References Categories: Newcomer to Canada (living in Canada for less than two years) - Living in Canada for more 2 or more years.
Abbreviations: BMI – body mass index, IMI – Irvine Minnesota Inventory, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, Newcomer to Canada – Living in Canada for less than two years, NALP – Neighbourhood Active Living Potential

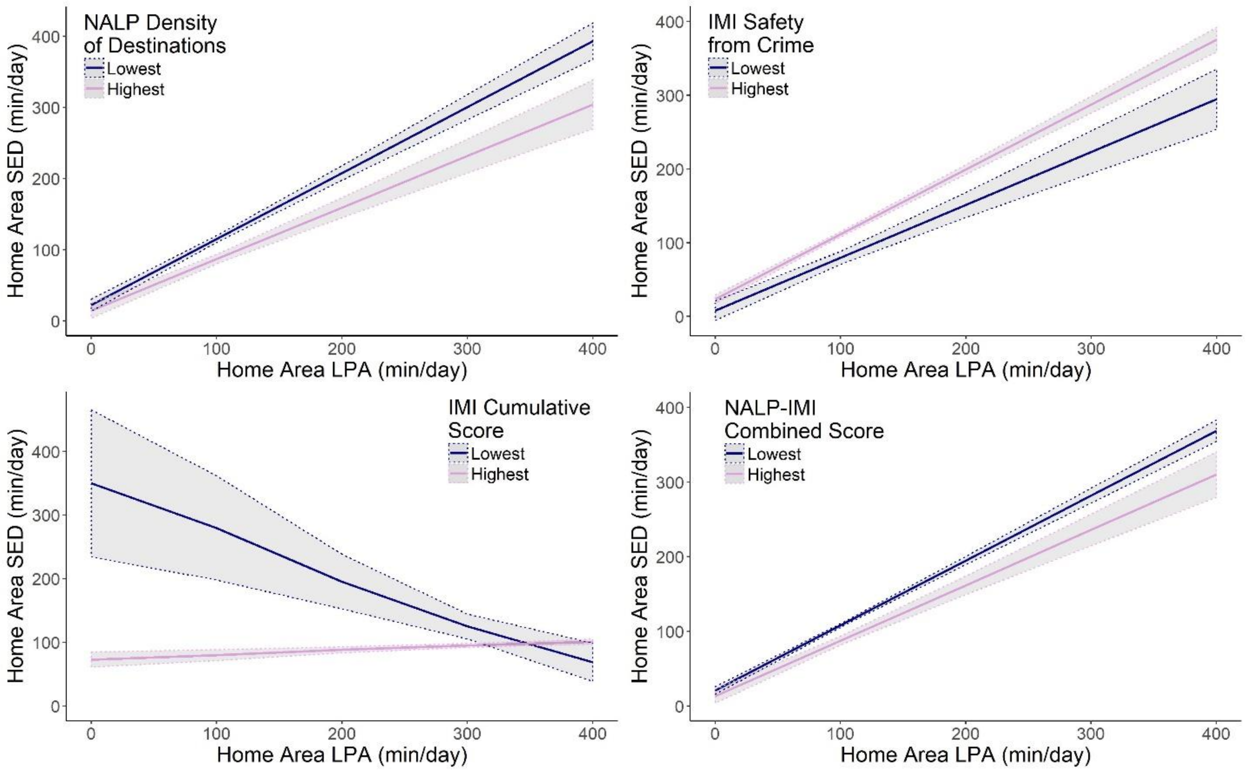


Figure 5.28 The effect of home area light physical activity on sedentary behaviour in children is moderated home-neighbourhood built environment.

Predicted effects presented are derived from physical activity inclusive multilevel models presented in ***Table B.7*** *(Model 12: LPA*NALP Density of Destination; Model 13: LPA*IMI Safety from Crime; Model 14: LPA*IMI Cumulative Score; Model 15: LPA*NALP-IMI Combined Score). 95% CIs are shown as grey ribbons.*

Table 5.12 Factors predicting home area sedentary behaviour in 9-14-year-old children: final multilevel models.

	Main Effects Models with Interactions					
	Model 7		Model 8		Model 9	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population Size (n)	420		420		420	
Constant	3.78	(-63.2, 70.8)	1.59	(-81.5, 84.7)	-42.0	(-109, 24.7)
Level 1 Variables						
LPA	0.843	(0.804, 0.882)	0.844	(0.805, 0.883)	0.844	(0.805, 0.883)
MVPA	-0.380	(-0.455, -0.304)	-0.382	(-0.457, -0.306)	-0.382	(-0.458, -0.307)
Season (reference - Winter)						
Spring	-38.9	(-80.6, 2.77)	-64.4	(-125, -3.73)	-17.4	(-54.9, 20)
Summer	-32.7	(-88.7, 23.3)	-129.7	(-210, -49.4)	-57.3	(-115, 0.652)
Fall	-33.5	(-87.2, 20.2)	-12.9	(-88.6, 62.7)	7.15	(-43.6, 57.9)
Weekend Day (reference - Weekdays)	19.7	(15.6, 23.9)	19.8	(15.7, 23.9)	19.7	(15.6, 23.9)
Level 2 Variables						
Age	7.79	(4.59, 11)	7.70	(4.48, 10.9)	7.83	(4.61, 11.1)
Gender (reference - Male)	-11.2	(-18.6, -3.86)	-11.1	(-18.6, -3.7)	-11.4	(-18.8, -3.97)
BMI (reference - normal weight)§						
Underweight	-27.6	(-92.7, 37.5)	-28.9	(-94.4, 36.7)	-29.1	(-94.6, 36.3)
Overweight	6.12	(-2.3, 14.5)	5.88	(-2.58, 14.3)	6.22	(-2.24, 14.7)
Obese	15.0	(3.64, 26.3)	14.3	(2.89, 25.7)	15.3	(3.87, 26.7)
Income (reference - <$20,000)						
$20,000 to $60,000	-34.3	(-69.6, 1.02)	-36.4	(-72, -0.856)	-35.9	(-71.4, -0.469)
$60,000 to $100,000	-30.9	(-66.1, 4.34)	-33.8	(-69.3, 1.738)	-33.3	(-68.6, 2.08)
>$100,000	-22.0	(-56.1, 12.2)	-25.1	(-59.4, 9.29)	-24.8	(-59.1, 9.45)
Unknown	-23.9	(-57.6, 9.85)	-26.6	(-60.6, 7.35)	-26.0	(-59.9, 7.82)
Newcomer to Canada‡	16.1	(4.24, 28)	15.5	(3.58, 27.5)	16.1	(4.18, 28.1)
Level 3 Variables						
NALP Activity Friendliness	-9.65	(-21.6, 2.32)				
IMI Pedestrian Access			-5.81	(-18.9, 7.33)		
IMI Safety from Traffic					1.92	(-4.94, 8.79)
Interactions Terms						
Season*NALP Activity Friendliness‡						
*Spring*Activity Friendliness*	12.2	(1.19, 23.2)				
*Summer*Activity Friendliness*	9.10	(-5.89, 24.1)				
*Fall*Activity Friendliness*	5.93	(-8.19, 20.1)				
Season*IMI Pedestrian Access‡						
*Spring*Pedestrian Access*			13.8	(2.06, 25.5)		
*Summer*Pedestrian Access*			25.1	(9.74, 40.6)		
*Fall*Pedestrian Access*			0.349	(-14.3, 15)		
Season*IMI Safety from Traffic‡						
*Spring*Safety from Traffic*					3.83	(-2.05, 9.71)
*Summer*Safety from Traffic*					9.18	(0.115, 18.2)
*Fall*Safety from Traffic*					-2.96	(-10.9, 5.02)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19 year olds (3).
‡ References Categories: season – winter, Newcomer to Canada - Living in Canada for more 2 or more years
Abbreviations: BMI – body mass index, IMI – Irvine Minnesota Inventory, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, Newcomer to Canada – Living in Canada for less than 2 years, NALP – Neighbourhood Active Living Potential

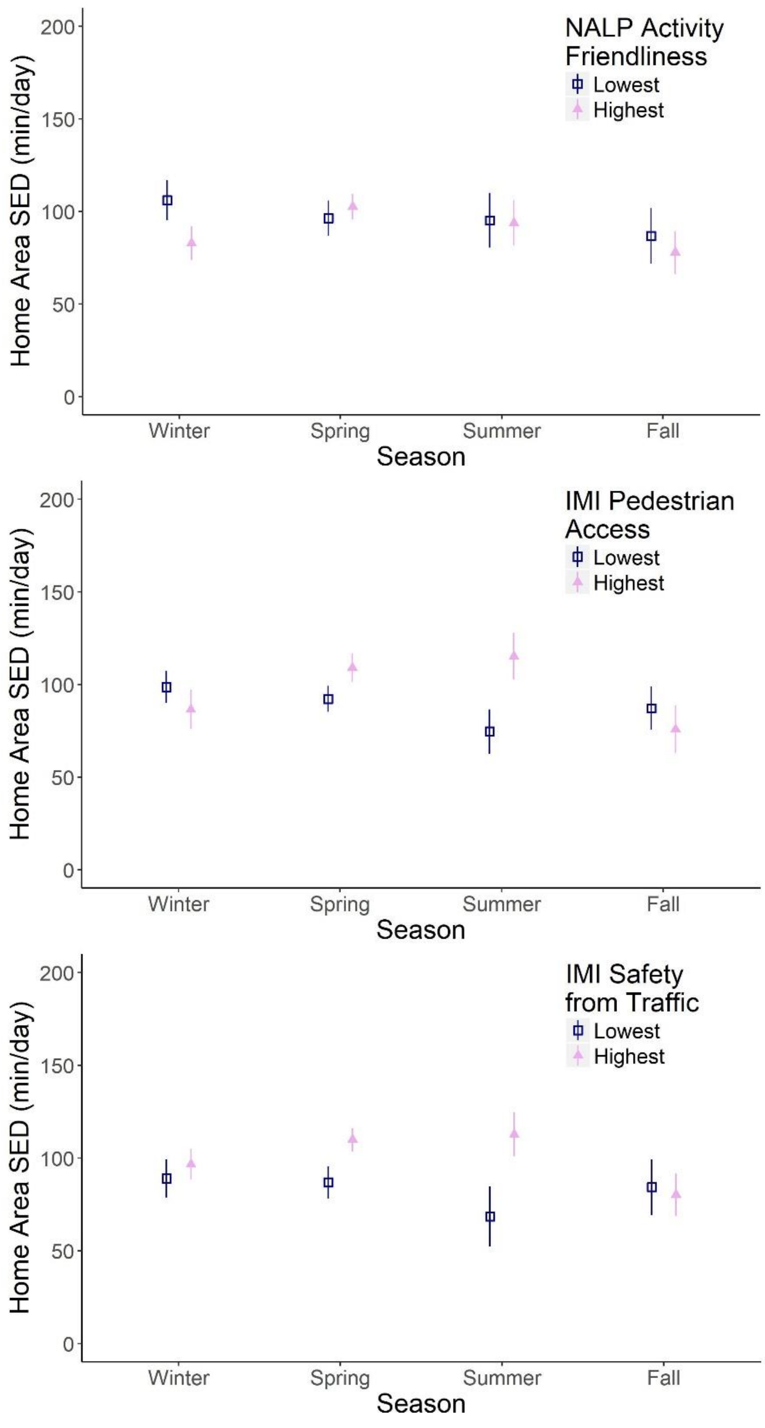


Figure 5.29 The effect of season on sedentary behaviour in children is moderated home-neighbourhood built environment.

*Predicted effects presented are derived from physical activity inclusive multilevel models level 3 non-main effects interaction terms presented in **Table 5.12** (Model 7: season*NALP activity friendliness; Model 8: season*IMI pedestrian access; Model 9: IMI safety from traffic). 95% CI are shown as vertical bars.*

5.7.2 School Area Sedentary Behaviour in Children

To better understand what factors predict school area SED (i.e. a child's demographic factors, season, and school BE), MLMs predicting school area SED were generated. As stated in **Research Question Aii** (**Section 1.3**), this section seeks to understand if seasonal changes and a child's demographic factors are predictors of school area SED, and if the BE surrounding a child's school area significantly moderates the effect of season or demographic factors on SED. As stated in Hypothesis A (**Section 1.4**) and outlined in **Figure 3.2**, it is hypothesized that the climate associated with colder months will result in an increase in school area SED in children. Furthermore, a child's school neighbourhood BE will moderate these effects.

In the null random intercept MLM using an autoregression 1 correlation structure, 45.5% of the variation in school area SED occurred across individuals. In the main effects model predicting school area SED, LPA was positively associated with SED. MVPA showed no association with school area SED. In spring and summer months, children accumulated 6.39 and 8.21 additional minutes of SED while on school properties vs winter months. In contrast, fall months afforded children significantly less SED opportunities, resulting in 10.5 fewer sedentary minutes per day while on school properties. When children entered school areas on weekends, they accumulated 29 fewer minutes of SED. When within school grounds, children with obesity were significantly more likely to be sedentary than their normal weight counterparts. (**Table 5.13**). Older children were also more sedentary than younger children (**Table 5.13**), but this difference was significantly diminished in summer and fall (vs winter) months. Unlike children attending schools in the most attractive neighbourhoods, children attending schools in the least attractive neighbourhoods experience little to no increase in sedentariness with age (**Table 5.14, Figure 5.30**). No neighbourhood level variables were main effects in models predicting school area SED.

As shown in **Table 5.14**, school neighbourhood BEs moderated seasonal differences in school area SED. During summer months, children attending schools in neighbourhoods with the lowest degree of universal accessibility were significantly more SED than those attending schools in neighbourhoods with higher accessibility for people with mobility challenges. In winter months, SED did not differ by school neighbourhood universal accessibility. Contrasting this, children attending schools in neighbourhoods with varying levels of safety from traffic experienced no difference in SED in spring and fall months.

Table 5.13 Factors predicting school area sedentary behaviour in 9-14-year-old children: univariate and main effects models.

	Univariate Model		**Level 1 Main Effects**		**Level 1 & 2 Main Effects**	
	β Estimate	**95% CI**	**β Estimate**	**95% CI**	**β Estimate**	**95% CI**
Population Size (n)	452		435		452	
Constant			27.6	(22.0, 33.2)	-130	(-166, -94.9)
Level 1 Variables						
LPA	0.402	(0.381, 0.424)	0.844	(0.806, 0.882)	0.348	(0.324, 0.371)
MVPA	0.471	(0.426, 0.516)	-0.374	(-0.448, -0.301)		
Season (reference - Winter)						
Spring	5.67	(0.878, 10.5)	6.12	(0.975, 11.3)	6.39	(2.60, 10.2)
Summer	11.1	(3.62, 18.6)	1.35	(-6.23, 8.93)	8.21	(2.26, 14.2)
Fall	-12.4	(-18.5, -6.20)	-11.6	(-18.2, -4.94)	-10.5	(-15.3, -5.58)
Weekend Day (reference - Weekdays)	-69.1	(-74.7, -63.4)	19.2	(15.2, 23.2)	-29.0	(-34.6, -23.5)
Level 2 Variables						
Age					14.4	(11.2, 17.5)
BMI (reference - normal weight)§						
Underweight					-34.6	(-102, 33.2)
Overweight					5.92	(-2.14, 14)
Obese					21.2	(10.7, 31.7)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (3).
Abbreviations: BMI – body mass index, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity

Table 5.14 Factors predicting school area sedentary behaviour in 9-14-year-old children: final multilevel models.

	Main Effects Models with Interactions					
	Model 1		Model 2		Model 3	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population Size (n)	452		452		452	
Constant	-164	(-213, -115)	540	(20.2, 1060)	-205	(-292, -118)
Level 1 Variables						
LPA	0.341	(0.317, 0.364)	0.341	(0.318, 0.365)	0.342	(0.319, 0.366)
Season (reference - Winter)						
Spring	39.8	(1.2, 78.4)	7.09	(3.27, 10.9)	70.1	(16.9, 123)
Summer	114	(51.5, 177)	9.02	(2.94, 15.1)	63.0	(-11.2, 137)
Fall	48.6	(-2.99, 100)	-10.9	(-15.8, -6.02)	66.8	(-8.87, 142)
Weekend Day (reference - Weekdays)	-29.7	(-35.3, -24.1)	-29.5	(-35.1, -23.9)	-29.8	(-35.4, -24.2)
Level 2 Variables						
Age	16.6	(12.9, 20.3)	-47.2	(-93.4, -0.96)	14.1	(11, 17.2)
BMI (reference - normal weight)§						
Underweight	-22.7	(-89, 43.5)	-30.5	(-96.2, 35.2)	-25.9	(-92, 40.2)
Overweight	5.77	(-2.07, 13.6)	6.43	(-1.38, 14.2)	6.32	(-1.54, 14.2)
Obese	19.7	(9.38, 30.0)	21.2	(10.9, 31.5)	20.6	(10.3, 31.0)
Level 3 Variables						
NALP Universal Accessibility	5.47	(-6.84, 17.8)				
IMI Attractiveness			-135	(-247, -23.7)		
IMI Safety from Traffic					13.2	(-0.338, 26.6)
Interactions Terms						
Season*Age^ƚ						
*Spring*Age*	-2.16	(-5.44, 1.11)				
*Summer*Age*	-6.44	(-11.8, -1.11)				
*Fall*Age*	-5.84	(-10.2, -1.51)				
Season*NALP Universal Accessibility^ƚ						
*Spring*Universal Accessibility*	-4.39	(-10.8, 2.01)				
*Summer*Universal Accessibility*	-17.6	(-28.4, -6.82)				
*Fall*Universal Accessibility*	2.37	(-6.87, 11.6)				
Season*IMI Safety from Traffic^ƚ						
*Spring*IMI Safety from Traffic*					-10.4	(-19.2, -1.65)
*Summer*IMI Safety from Traffic*					-9.00	(-21.5, 3.57)
*Fall*IMI Safety from Traffic*					-12.8	(-25.1, -0.382)
Age*IMI Attractiveness			12.5	(3.05, 21.9)		

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (3).
ƚReference categories: season – winter.
Abbreviations: BMI – body mass index, IMI – Irvine Minnesota Inventory, LPA – light physical activity, NALP – Neighbourhood Active Living Potential.

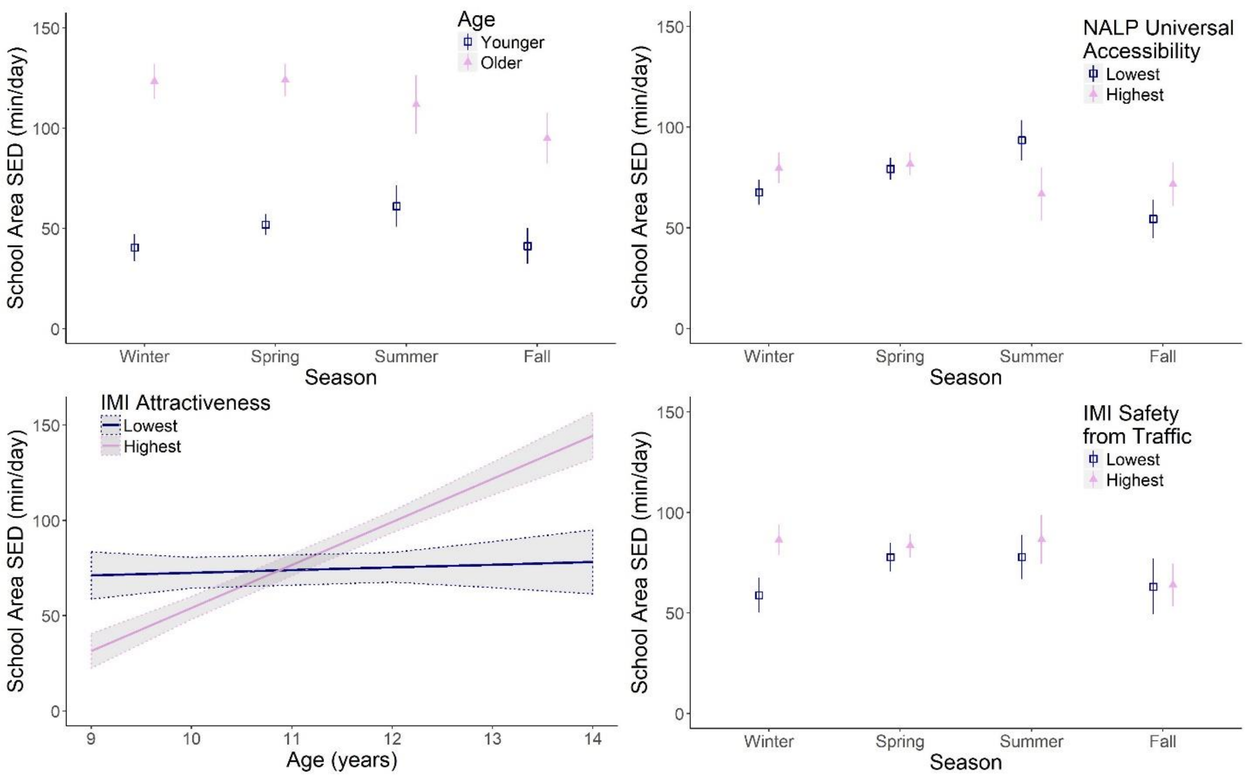


Figure 5.30 The predicted effects of age, season and built environment on school area sedentary behaviour in children.

Predicted effects presented are derived from physical activity inclusive multilevel models presented in ***Table 5.14*** *(Model 1: Season*age, season*NALP universal accessibility; Model 2: season*IMI attractiveness; Model 3: season*IMI safety from traffic). 95% CI are shown as vertical bars and grey ribbons.*

Yet, those attending school in areas with the highest level of safety from traffic were significantly more sedentary in winter months vs those attending schools in neighbourhoods with lower levels of safety from traffic.

These results highlight that when children were within their school properties, older aged children and children with obesity accumulated significantly greater levels of SED. Gender and immigrant status did not significantly predict school area SED. Season significantly predicted school area SED, and was moderated by neighbourhood BE features.

5.7.3 Public Park Sedentary Behaviour in Children

The city of Saskatoon contains 251 public parks. As stated in **Research Question Aii** (**Section 1.3**), this section seeks to understand if seasonal changes and a child's demographic factors are predictors of park area SED, and if the BE surrounding a child's home (for city park use) and school (for school park use) significantly moderates the effect of season or demographic factors on SED. As stated in Hypothesis A (**Section 1.4**) and outlined in **Figure 3.2**, it is hypothesized that the winter season will result in an increase in park area SED in children. A child's home neighbourhood BE will moderate these effects.

Of individuals with valid GPS-paired accelerometry data, 97.4% (443 of 455) participants entered a public city park at least once during the study collection period, 31.6% of which occurred within a child's home neighbourhood. The mean distance from a child's home to a city park was 462 m (minimum 68.2 m, maximum 1140 m). Of the participants who visited parks, 407 and 384 visited a school park and public city park, respectively (57,322 and 35,660 participant minutes, respectively).

Figure 5.24 demonstrated that while attending public schools in Saskatoon resulted in a predictably highly structured day, children's activity patterns and locations surrounding the school period were also highly predictable. It was within these shoulder periods of school commencement and dismissal, school recesses and lunch hours that children were highly likely to attend public city parks. As discussed in **Section 9.5**, 25 public city parks were immediately adjacent to participating school properties. Attendance of these parks coincided with school attendance. For this reason, school parks were treated as distinct locations in subsequent analyses.

During weekdays, participating children had five predictable periods to visit school parks: the period before school start, morning recess, lunch hour, afternoon recess and the period after school dismissal. To better understand if a child's demographic factors, season and school neighbourhood BE significantly predict school park SED, a multilevel analysis strategy was employed.

In a null random intercept MLM using an autoregression 1 correlation structure predicting school park SED, 42.7% of the SED variation occurred across individuals. In the main effects model predicting school park SED, children who accumulated higher levels of LPA in school parks, older children and those with obesity were significantly more sedentary than those accumulating less school park LPA, younger children and normal weight children, respectively. Participants accumulated greater levels of SED while in school parks during summer months vs winter months. Increased levels of school park MVPA were associated with reduced level of school park SED (**Table 5.15**). The positive association of school park LPA and SED was significantly diminished in spring, summer and fall months in comparison to winter months (**Table 5.16, Figure 5.31**). No school neighbourhood level attributes significantly predicted school park SED.

As shown in **Figure 5.31** and **Table 5.16**, school park neighbourhood activity friendliness also demonstrated a subtle but significant protective effect against the increased sedentariness observed with increased age. The positive association of school park area LPA and SED was significantly diminished in spring, summer and fall months in comparison to winter months. School neighbourhood BE moderated the positive effect of LPA on school park SED. In children utilizing school parks within fractured grid, curvilinear and modified grid neighbourhoods, their increased LPA was positively associated with increased sedentariness. In contrast, LPA demonstrated no significant association with SED if children's school parks were within grid patterned neighbourhoods (**Table 5.16, Figure 5.31**). The positive effect of LPA on SED was significantly diminished in children utilizing schools parks in neighbourhoods with the lowest destination densities (NALP and IMI), universal accessibility (NALP), safety from traffic (IMI), and overall activity friendliness (NALP cumulative score). In contrast, a high degree of school park neighbourhood activity friendliness demonstrated a protective effect against increased school park SED with increased LPA. (**Table 5.16, Figure 5.32**).

Table 5.15 Factors predicting school park area sedentary behaviour in 9-14-year-old children: univariate and main effects models.

	Univariate Model		Level 1 Main Effects		Level 1 & 2 Main Effects	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population Size (n)	384		384		384	
Constant			1.23	(0.596, 1.86)	-3.41	(-7.6, 0.766)
Level 1 Variables						
LPA	0.249	(0.229, 0.268)	0.268	(0.246, 0.29)	0.267	(0.244, 0.289)
MVPA	0.0634	(0.047, 0.0799)	-0.0319	(-0.0488, -0.0149)	-0.0310	(-0.0479, -0.0142)
Season (reference - Winter)						
Spring	0.777	(-0.0122, 1.57)	0.101	(-0.598, 0.8)	0.182	(-0.515, 0.88)
Summer	2.43	(1.24, 3.62)	1.31	(0.292, 2.34)	1.37	(0.349, 2.38)
Fall	0.602	(-0.409, 1.61)	0.149	(-0.738, 1.04)	0.232	(-0.651, 1.12)
Level 2 Variables						
Age					0.383	(0.00781, 0.757)
BMI (reference - normal weight)§						
Underweight					-2.07	(-8.72, 4.59)
Overweight					0.756	(-0.212, 1.72)
Obese					1.96	(0.702, 3.21)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19 year olds (3).
Abbreviations: BMI – body mass index, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity

Table 5.16 Factors predicting school park area sedentary behaviour in 9-14-year-old children: final multilevel models.

	Main Effects Models with Interactions					
	Model 1		Model 2		Model 3	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population Size (n)	384		384		384	
Constant	-2.77	(-8.25, 2.71)	-27.0	(-56.3, 2.37)	4.72	(-6.40, 15.8)
Level 1 Variables						
LPA	0.0882	(-0.107, 0.284)	0.300	(0.0538, 0.547)	-0.0264	(-0.299, 0.246)
MVPA	-0.0199	(-0.0364, -0.00342)	-0.0204	(-0.0368, -0.00404)	-0.0200	(-0.0366, -0.00337)
Season (reference - Winter)						
Spring	1.53	(0.734, 2.32)	1.72	(0.932, 2.51)	1.77	(0.97, 2.56)
Summer	1.34	(0.105, 2.57)	1.18	(-0.045, 2.40)	1.16	(-0.0844, 2.40)
Fall	1.14	(0.163, 2.11)	0.947	(-0.021, 1.91)	0.932	(-0.0531, 1.92)
Level 2 Variables						
Age	0.327	(0.0104, 0.645)	3.10	(0.512, 5.69)	0.334	(-0.000834, 0.668)
BMI (reference - normal weight)§						
Underweight	-1.05	(-6.38, 4.28)	-1.21	(-6.44, 4.01)	-1.30	(-7.01, 4.41)
Overweight	0.823	(0.0111, 1.63)	0.718	(-0.0766, 1.51)	0.840	(-0.0151, 1.70)
Obese	1.13	(0.0713, 2.19)	1.13	(0.0961, 2.17)	1.25	(0.132, 2.36)
Level 3 Variables						
Era (reference - <1930 grid)						
1930-1960s fractured grid	-0.737	(-5.49, 4.02)				
1960s-1998 curvilinear	-0.717	(-5.29, 3.86)				
1998-present modified grid	-0.586	(-6.31, 5.14)				
NALP Cumulative Score	-1.07	(-2.47, 0.337)				
NALP Density of Destinations			-0.233	(-1.53, 1.06)		
NALP Activity Friendliness			6.84	(-1.17, 14.8)		
NALP Universal Accessibility			-0.855	(-2.29, 0.576)		
IMI Density of Destinations					-0.132	(-0.549, 0.286)
IMI Safety from Traffic					-1.33	(-3.11, 0.443)
Interactions Terms						
Season*LPA‡						
*Spring*LPA*	-0.183	(-0.245, -0.122)	-0.202	(-0.263, -0.141)	-0.227	(-0.288, -0.166)
*Summer*LPA*	-0.145	(-0.228, -0.062)	-0.176	(-0.258, -0.0939)	-0.128	(-0.209, -0.047)
*Fall*LPA*	-0.156	(-0.222, -0.0897)	-0.122	(-0.188, -0.0565)	-0.130	(-0.196, -0.0643)
LPA*Neighbourhood Era‡						
*LPA*1930-1960s fractured grid*	0.443	(0.259, 0.627)				
*LPA*1960s-1998 curvilinear*	0.302	(0.110, 0.494)				
*LPA*1998-present modified grid*	0.202	(-0.0373, 0.442)				
LPA*NALP Cumulative Score	0.0773	(0.0355, 0.119)				
LPA*NALP Density of Destinations			0.205	(0.147, 0.264)		
LPA*NALP Activity Friendliness			-0.179	(-0.264, -0.093)		
Age*NALP Activity Friendliness			-0.737	(-1.404, -0.0696)		
LPA*NALP Universal Accessibility			0.0511	(0.0194, 0.0828)		
LPA*IMI Density of Destinations					0.0178	(0.00741, 0.0281)
LPA*IMI Safety from Traffic					0.0665	(0.0250, 0.108)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19 year olds (3).
‡ References Categories: season – winter.
Abbreviations: BMI – body mass index, IMI – Irvine Minnesota Inventory, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, NALP – Neighbourhood Active Living Potential.

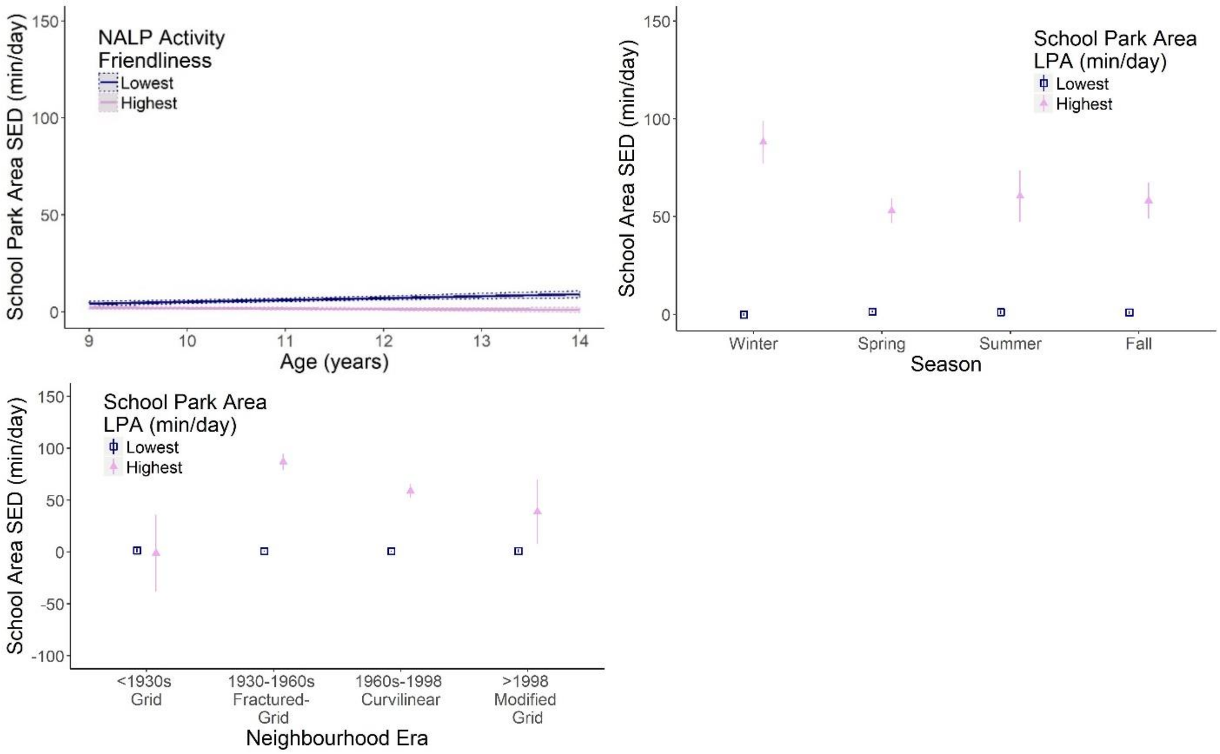


Figure 5.31 The predicted effects of season, light physical activity, and age on school park area sedentary behaviour are moderated by school neighbourhood environment.

Predicted effects presented are derived from physical activity inclusive multilevel models presented in ***Table 5.16*** *(Model 1: season*age; LPA*neighbourhood era; Model 2: age*NALP activity friendliness). 95% CI are shown as vertical bars and grey ribbons. Reference category: season – winter, neighbourhood era – <1930 grid.*

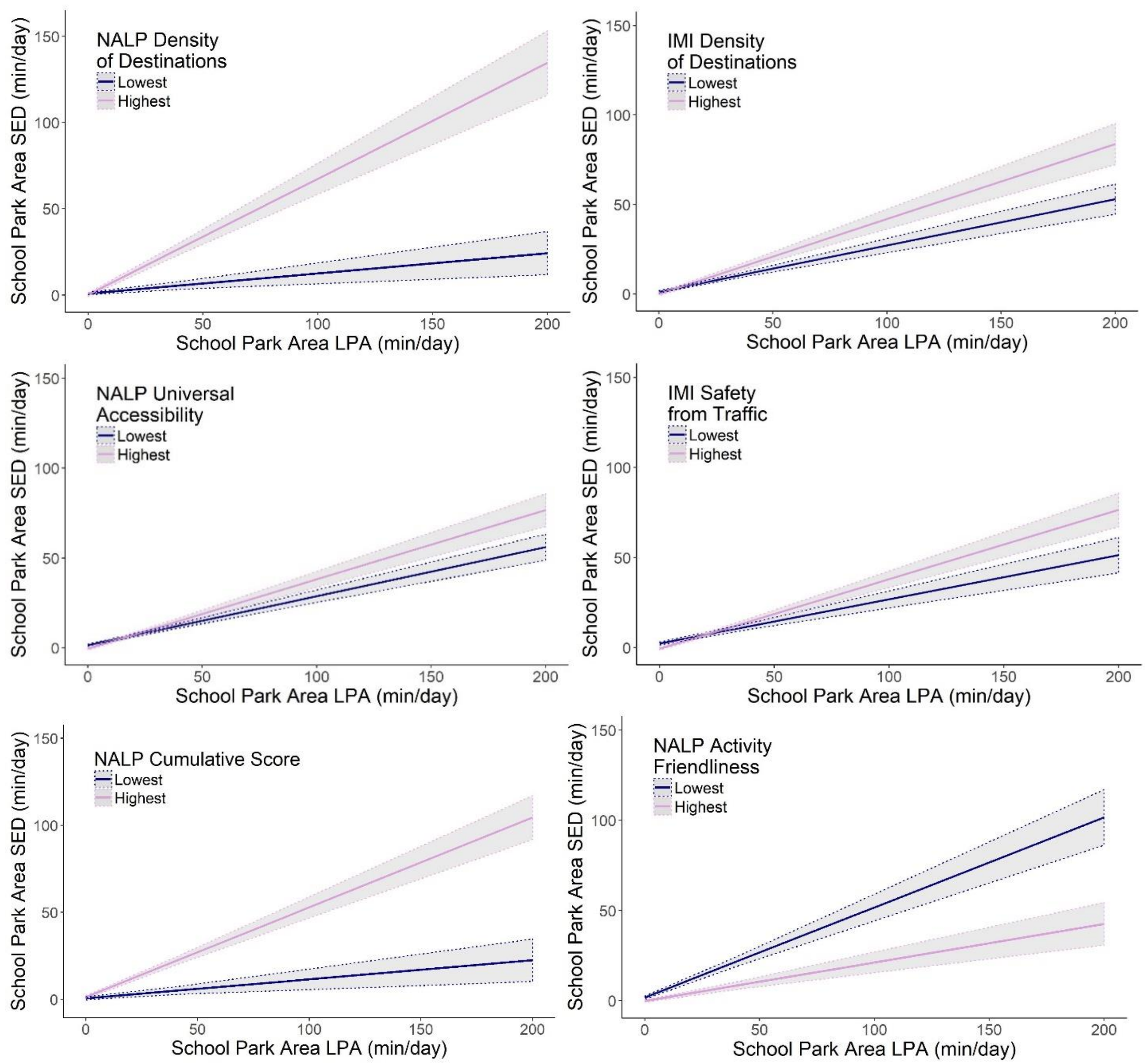


Figure 5.32 The predicted effects of light physical activity on school park area sedentary behaviour are moderated by school neighbourhood build environment.

*Predicted effects presented are derived from physical activity inclusive multilevel models presented in **Table 5.16** (Model 1: LPA*NALP cumulative scores; Model 2: LPA*NALP Density of Destinations, LPA*NALP Universal Accessibility, LPA*NALP Activity Friendliness; Model 3: LPA*IMI density of destinations, LPA*IMI safety from traffic). 95% CI are shown as vertical bars and grey ribbons.*

All other public city park visits attended by participating children outside of school hour time buffers, and on weekends were designated simply as a "park" visit. Here, multilevel modelling was used to determine if a child's demographic factors or home neighbourhood environment, and season was able to significantly predict park specific SED.

In a null random intercept MLM using an autoregression 1 correlation structure predicting park SED, 6.69% of the SED variation occurred across individuals. In the main effects model predicting park SED, both increased park area LPA and summer (vs winter) months significantly predicted higher levels of park area SED in children. Greater levels of park area MVPA were associated with significant reductions in park area SED. No home area neighbourhood attributes significantly predicted SED in children while they were in public city parks. While in parks, children living in fractured grid, curvilinear and modified grid patterned neighbourhoods were significantly less sedentary in summer (vs winter) months in comparison to those living in Saskatoon's grid style neighbourhoods. While there were no significant differences in winter month park area SED between children living in neighbourhoods with different levels of universal accessibility, those living in the most accessible neighbourhoods were significantly more sedentary in summer months (**Table 5.17, Figure 5.33**).

These findings highlight that increased age, obese weight status, but not overweight status, and summer months were associated with greater levels of park area SED. While summer months were predictive of increased park area SED, the effect of season was not moderated by a child's home neighbourhood BE. Additionally, home area BE features were not main effect predictors of park area SED.

5.8 Perceptions of Physical Behaviour in Different Weather Conditions

As stated in **Section 1.3**, Research Question B, this section aims to ask to what extent do parenting support practices, attitudes and beliefs contribute to a child's SED outcomes? Are children's and/or parent's perceptions of unfavourable weather over different seasons a predictor of prolonged SED? It is hypothesized (in **Section 1.4**, Hypothesis B, **Figure 3.3**) that children who perceive low levels of support for or have negative attitudes towards outdoor play will be significantly more sedentary than their counterparts. Additionally, children whose parents report low levels of support for or negative attitudes toward outdoor play will be significantly more sedentary than their counterparts.

Table 5.17 Factors predicting park area sedentary behaviour in 9-14-year-old children.

	Univariate Models		Level 1 Main Effects		Main Effect Model with Interactions	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Population Size (n)	407		407		385	
Constant			0.689	(-0.294, 1.67)	0.082	(-4.49, 4.66)
Level 1 Variables						
LPA	0.308	(0.276, 0.339)	0.404	(0.363, 0.445)	0.403	(0.36, 0.446)
MVPA	0.0782	(0.0532, 0.103)	-0.122	(-0.152, -0.0921)	-0.124	(-0.156, -0.0933)
Season (reference - Winter)						
Spring	0.932	(-0.466, 2.33)	0.599	(-0.647, 1.84)	1.06	(-4.81, 6.94)
Summer	5.99	(4.17, 7.82)	4.01	(2.37, 5.65)	2.31	(-5.57, 10.0)
Fall	0.226	(-1.54, 1.99)	0.0623	(-1.51, 1.63)	2.22	(-5.99, 10.4)
Weekend Day (reference - Weekdays)	0.752	(-0.571, 2.07)				
Level 3 Variables						
Era (reference - <1930 grid)						
1930-1960s fractured grid					0.892	(-2.85, 4.63)
1960s-1998 curvilinear					1.26	(-1.94, 4.46)
1998-present modified grid					0.673	(-3.56, 4.91)
NALP Universal Accessibility					-0.134	(-1.95, 1.69)
Interaction Terms						
Season*Neighbourhood Era‡						
*Spring*1930-1960s fractured grid*					0.655	(-4.17, 5.48)
*Summer*1930-1960s fractured grid*					-5.72	(-11.4, -0.0847)
*Fall*1930-1960s fractured grid*					-3.43	(-9.92, 3.06)
*Spring*1960s-1998 curvilinear*					-0.302	(-4.43, 3.83)
*Summer*1960s-1998 curvilinear*					-11.8	(-16.9, -6.76)
*Fall*1960s-1998 curvilinear*					-4.08	(-10, 1.89)
*Spring*1998-present modified grid*					-0.721	(-5.96, 4.52)
*Summer*1998-present modified grid*					-10.8	(-17.6, -4.06)
*Fall*1998-present modified grid*					-4.56	(-11.7, 2.61)
Season*NALP Universal Accessibility‡						
*Spring*Universal Accessibility*					-0.0868	(-2.38, 2.20)
*Summer*Universal Accessibility*					4.85	(1.68, 8.02)
*Fall*Universal Accessibility*					0.702	(-2.25, 3.65)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (3).
‡ References Categories: season – winter, neighbourhood era - <1930 grid.
Abbreviations: BMI – body mass index, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, NALP – Neighbourhood Active Living Potential.

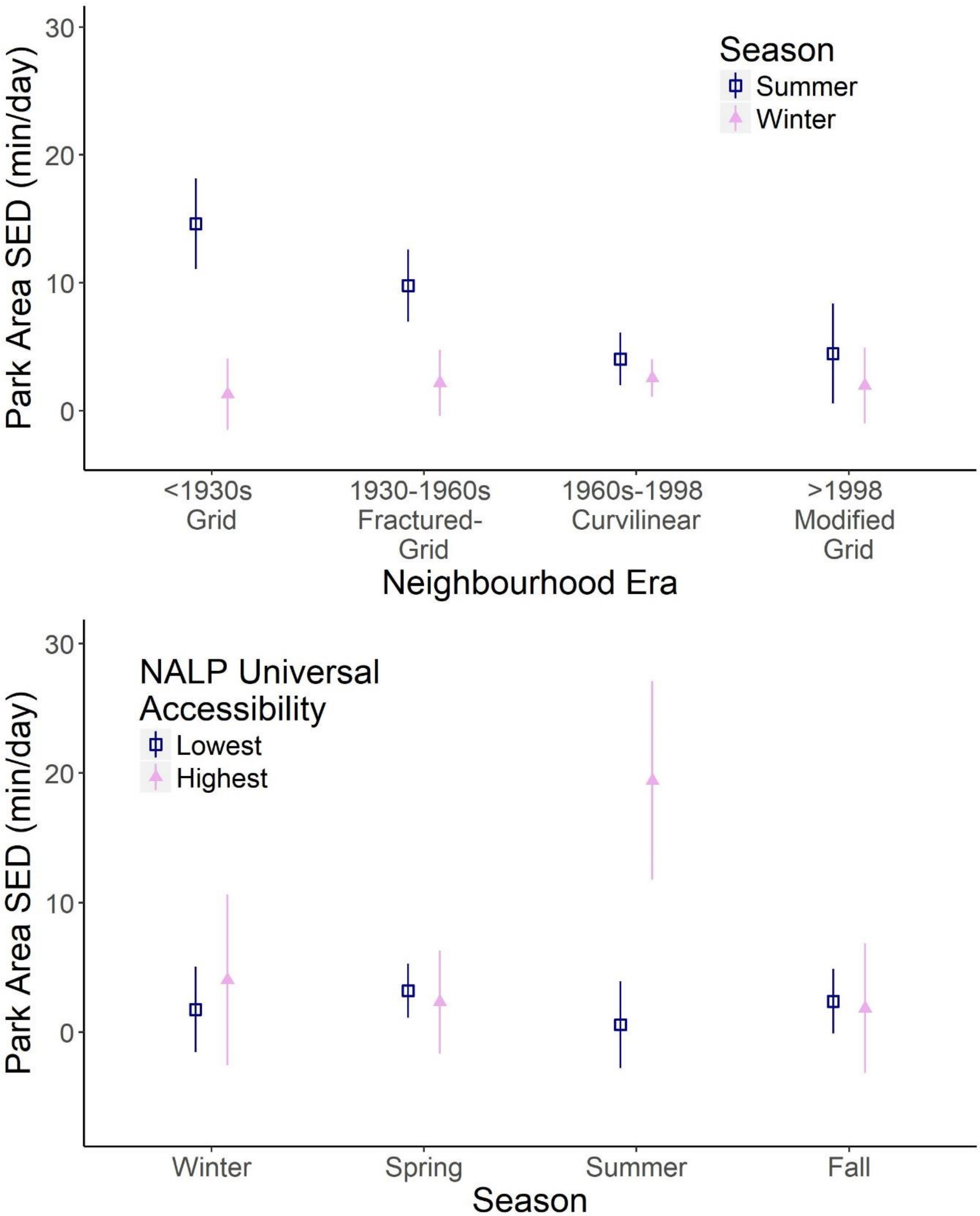


Figure 5.33 The predicted effects of season on park area sedentary behaviour are moderated by home neighbourhood build environment.

*Predicted effects presented are derived from physical activity inclusive multilevel models presented in **Table 5.17** (season*neighbourhood era, season*NALP universal accessibility). 95% CI are shown as vertical bars. Reference categories: season – winter, era - <1930 grid.*

To understand the level of concordance between parent and child dyads, paired questionnaire items were examined using Cohen's kappa coefficient. Two-thirds of parent-child paired questionnaire items demonstrated a fair agreement. Parental encouragement of outdoor play during extreme winter conditions, parental limits on screen time during both extreme winter weather conditions and pleasant summer weather conditions, and perceptions of outdoor play safety during average winter conditions questionnaire dyads demonstrated a moderate level of agreement (**Table B.8**).

In order to understand if both parent and child perceptions of weather-specific outdoor play held an association with children's activity outcomes, ANOVA was performed to examine the relationship between SED, LPA and MVPA and all questionnaire items. Post-hoc ANOVA, Tukey's HSD was used to examine relative differences in activity outcomes between perceptions supporting and discouraging active lifestyles. Children whose parents reported limiting screen time in their children (i.e. not allowing unlimited access to TV/videos or play video/computer games) in all weather conditions were significantly less sedentary and significantly more active. Children whose parents perceived regulating screen time during extreme winter weather (≤-27°C or colder with the windchill), average winter weather (-10 to -15°C) and pleasant summer weather (≥10°C with little or no rain) experienced 28.5 (95% CI 3.44, 53.5), 31.9 (95% CI 5.59, 58.3), and 33.0 (95% CI 5.54, 60.5) fewer SED minutes per day, respectively (**Figure 5.34**). None of the parental perceptions examined were associated with differences in children's LPA (**Figure 5.35**). In contrast to SED accumulation, children's parents who perceived regulating screen time during extreme winter conditions, average winter temperatures and pleasant summer weather had children who accumulated 30.9 (95% CI 15.1, 46.8), 31.4 (95% CI 14.6, 48.3) and 24.8 (95% CI 6.7, 42.8) *additional* MVPA minutes per day, respectively. Children whose parents discouraged indoor play, through encouragement of outdoor play, during average winter temperatures experienced 17.4 (95% CI 0.44, 34.4) additional MVPA minutes per day (**Figure 5.36**).

Children who perceived discouragement of indoor play during average winter weather and pleasant summer weather were significantly less sedentary (28.1 minutes/day, 95% CI 2.47, 53.7; 32.8 minutes/day, 95% CI 1.96, 63.7, respectively) than their counterparts. Children who perceived screen time regulation during average winter weather experienced 27.2 (95% CI 1.03, 53.5) fewer sedentary minutes/day (**Figure 5.37**).

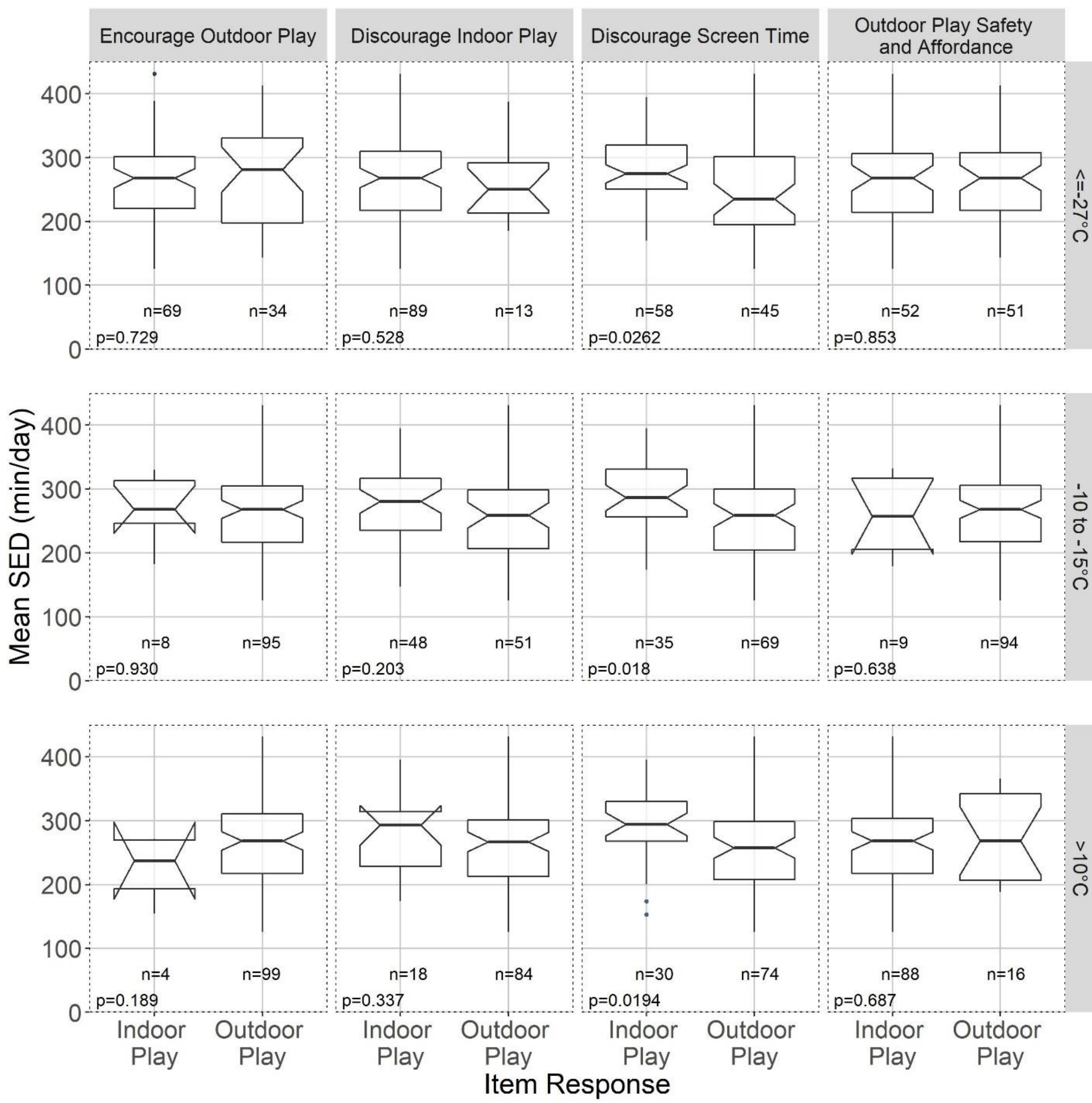


Figure 5.34 Mean SED outcomes stratified by parent perception questionnaire items.

Box bar and upper and lower hinges represent the median and interquartile range (25th and 75th centile), respectively. Notches represent upper and lower 95% confidence interval limits. Outliers are shown as dots. Item responses are coded as either favouring indoor play or outdoor play and stratified by temperature (>-27°C or colder with the windchill: items 1-4; -10 to -15°C: items 5-8; ≥10°C with little or no rain: items 9-12), and by (3) theme (parental practices - encouragement of outdoor play: items 1, 5, and 9; encouragement of indoor play (reverse coded): items 2, 6, and 10; encouragement of screen time (reverse coded): items 3, 7, and 11; cold weather safety: items 4 and 8; seasonal affordance: item 12). Post-hoc ANOVA Tukey's HSD p-values are shown (p<0.05).

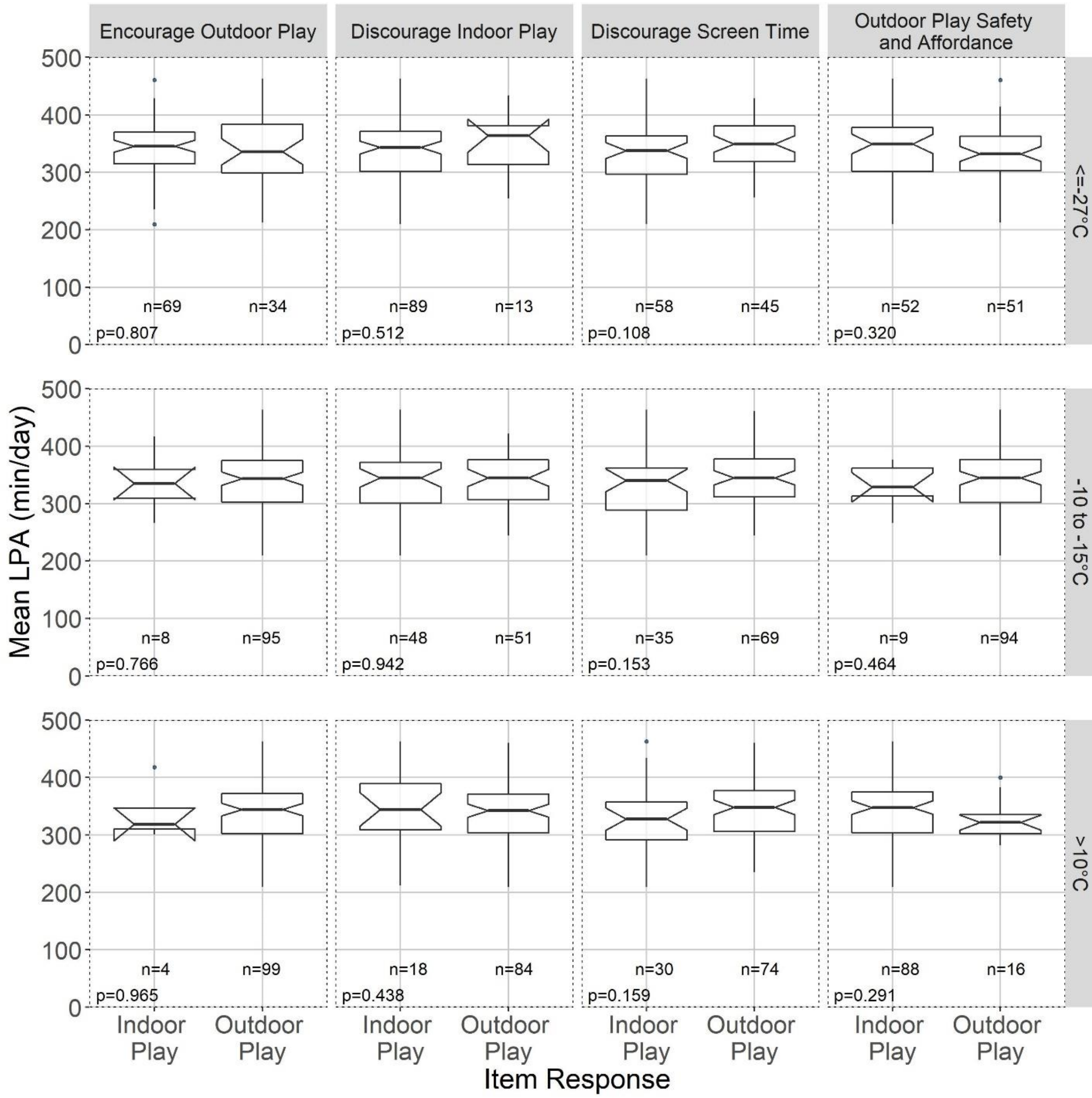


Figure 5.35 Mean LPA outcomes stratified by parent perception questionnaire items.

Box bar and upper and lower hinges represent the median and interquartile range (25th and 75th centile), respectively. Notches represent upper and lower 95% confidence interval limits. Outliers are shown as dots. Item responses are coded as either favouring indoor play or outdoor play and stratified by temperature (>-27°C or colder with the windchill: items 1-4; -10 to -15°C: items 5-8; ≥10°C with little or no rain: items 9-12), and by (3) theme (parental practices - encouragement of outdoor play: items 1, 5, and 9; encouragement of indoor play (reverse coded): items 2, 6, and 10; encouragement of screen time (reverse coded): items 3, 7, and 11; cold weather safety: items 4 and 8; seasonal affordance: item 12). Post-hoc ANOVA Tukey's HSD p-values are shown ($p<0.05$).

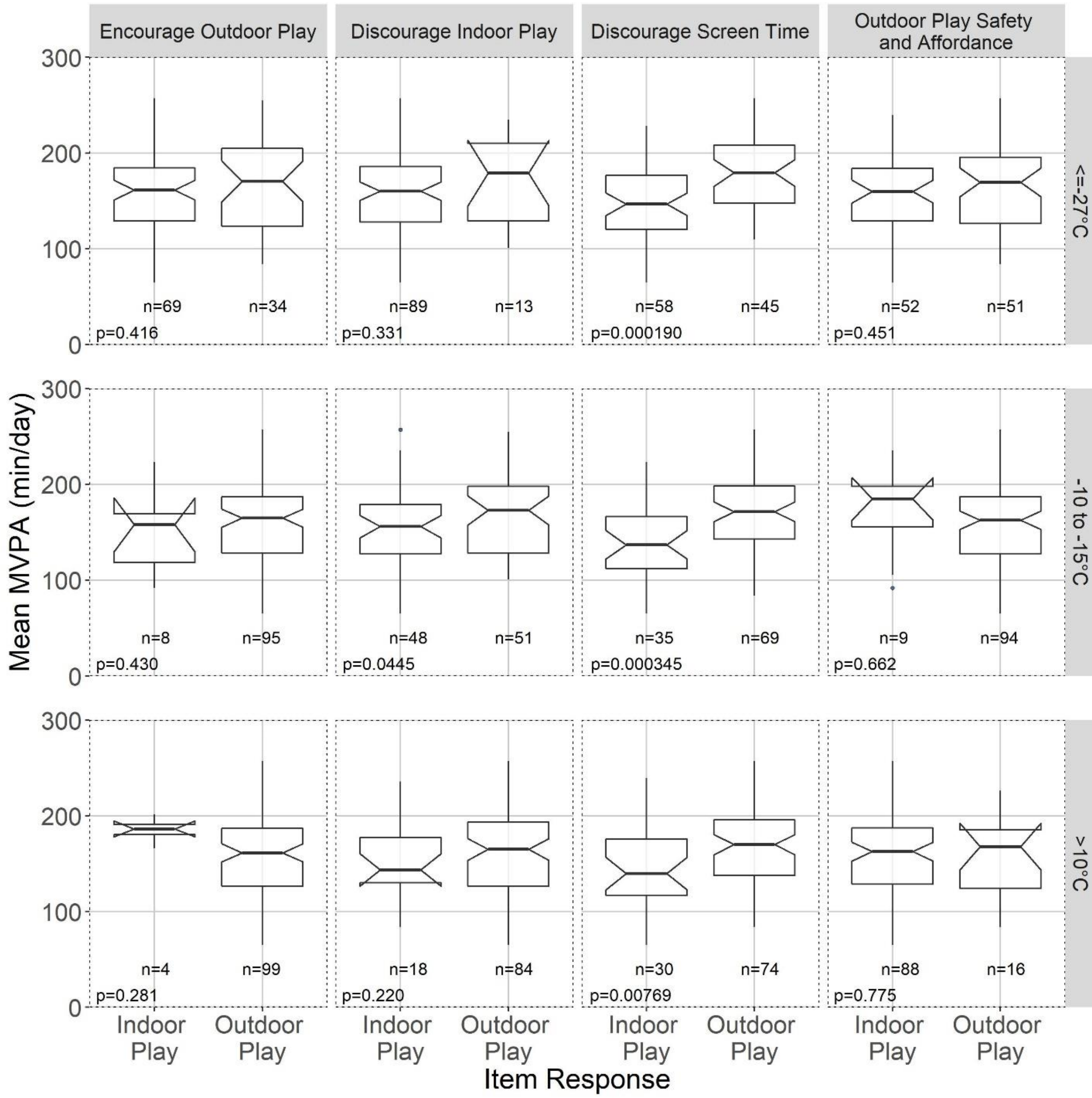


Figure 5.36 Mean MVPA outcomes stratified by parent perception questionnaire items.

Box bar and upper and lower hinges represent the median and interquartile range (25th and 75th centile), respectively. Notches represent upper and lower 95% confidence interval limits. Outliers are shown as dots. Item responses are coded as either favouring indoor play or outdoor play and stratified by temperature (>-27°C or colder with the windchill: items 1-4; -10 to -15°C: items 5-8; ≥10°C with little or no rain: items 9-12), and by (3) theme (parental practices - encouragement of outdoor play: items 1, 5, and 9; encouragement of indoor play (reverse coded): items 2, 6, and 10; encouragement of screen time (reverse coded): items 3, 7, and 11; cold weather safety: items 4 and 8; seasonal affordance: item 12). Post-hoc ANOVA Tukey's HSD p-values are shown (p<0.05).

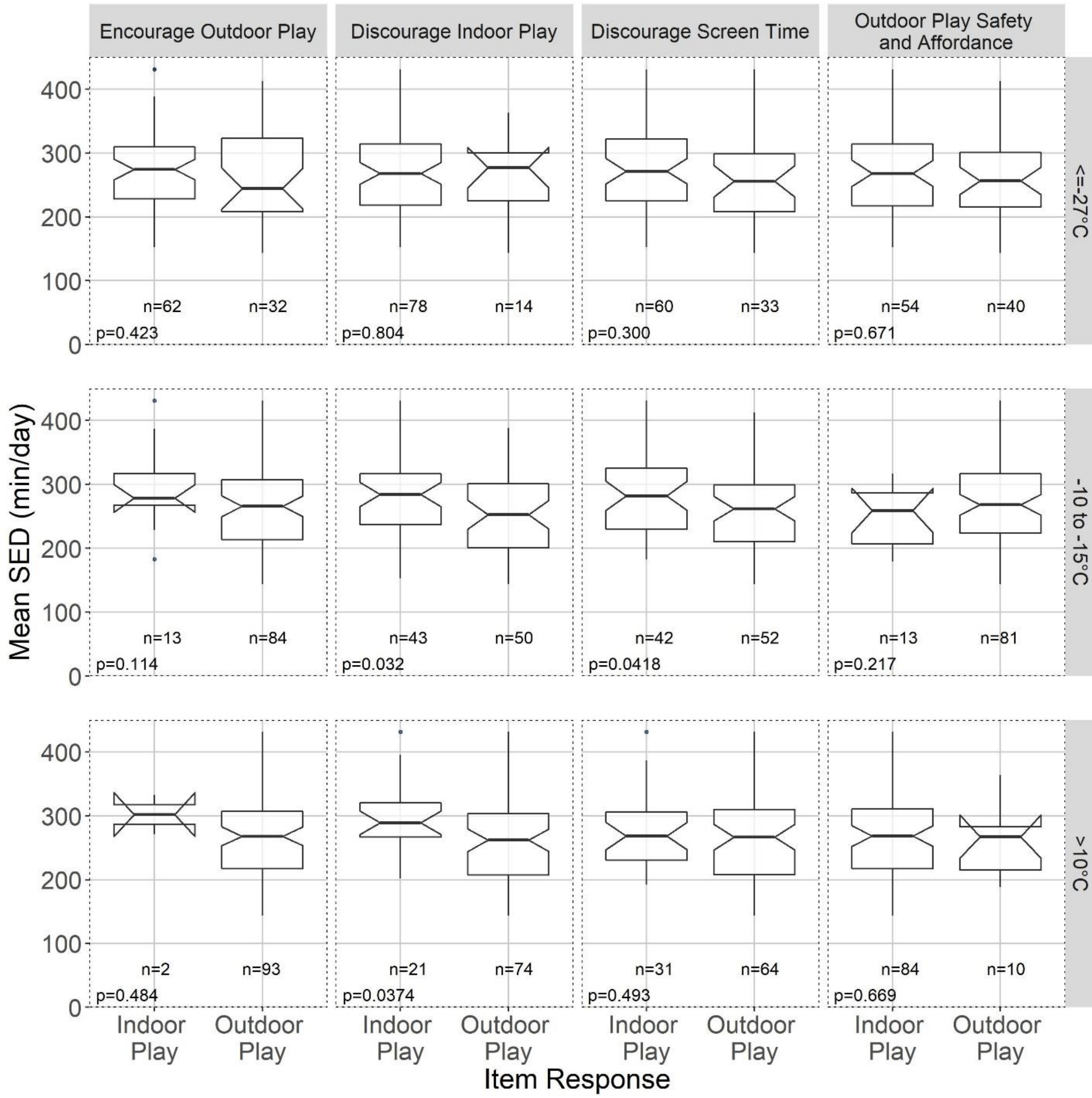


Figure 5.37 Mean SED outcomes stratified by child perception questionnaire items.

Box bar and upper and lower hinges represent the median and interquartile range (25th and 75th centile), respectively. Notches represent upper and lower 95% confidence interval limits. Outliers are shown as dots. Item responses are coded as either favouring indoor play or outdoor play and stratified by temperature (>-27°C or colder with the windchill: items 1-4; -10 to -15°C: items 5-8; ≥10°C with little or no rain: items 9-12), and by (3) theme (parental practices - encouragement of outdoor play: items 1, 5, and 9; encouragement of indoor play (reverse coded): items 2, 6, and 10; encouragement of screen time (reverse coded): items 3, 7, and 11; cold weather safety: items 4 and 8; seasonal affordance: item 12). Post-hoc ANOVA Tukey's HSD p-values are shown (p<0.05).

Daily LPA was significantly greater in children who perceive encouragement of outdoor play and discouragement of indoor play during pleasant summer weather (72.5 minutes, 95% CI 2.9, 141; 27.2 minutes, 95% CI 3.85, 50.6, respectively) (**Figure 5.38**). Children who perceived discouragement of indoor play during pleasant summer weather accumulated 21.1 (95% CI 0.49, 41.6) additional minutes of MVPA per day. Children who perceived parental regulation of screen time during extreme winter conditions, average winter conditions and pleasant summer conditions accumulated significantly greater levels of MVPA per day (30.9, 91%CI 15.1, 46.8; 31.4, 95% CI 14.6, 48.4; and 24.8, 95% CI 6.70, 42.8, respectively) (**Figure 5.39**).

To better understand if overarching relationships in perceptions of outdoor play existed between specific weather conditions and activity outcomes, composite perception scores were created. Positive parental perceptions of outdoor play in all weather conditions were significantly negatively correlated with SED and positively correlated with MVPA in children. Composite perception scores, stratified by extreme weather conditions, average weather conditions and mild summer conditions, showed no significant correlation with either SED or LPA. Positive parental perceptions of outdoor play during extreme weather and average winter weather was significantly correlated with increased MVPA in children. Children who perceived postive support of outdoor play in average winter conditions demonstrated significantly greater levels of mean daily MVPA (**Table 5.18**).

The relationship between all questionnaire items (i.e. both parent and child responses) was examined using a correlation matrix. The most apparent correlation cluster existed between questionnaire items relating to screen time. Both parent and child perceptions of screen time regulation demonstrated a positive correlation between one another, with the exception of parental perceptions of screen time regulation during pleasant summer weather conditions. To a lesser extent, parental discouragement out outdoor play, and children's perceived discouragement of outdoor play and screen time regulation demonstrated positive correlations between one another in a average winter and pleasant summer weather condition context. In a third correlation group, all items exploring parent support and children's perceptions of this support in an extreme winter weather context were positively associated with one another. The use of Likert scales and a small population sample sizes resulted in non-gaussian distributions, preventing further exploratory factor analysis (**Figure 5.40**).

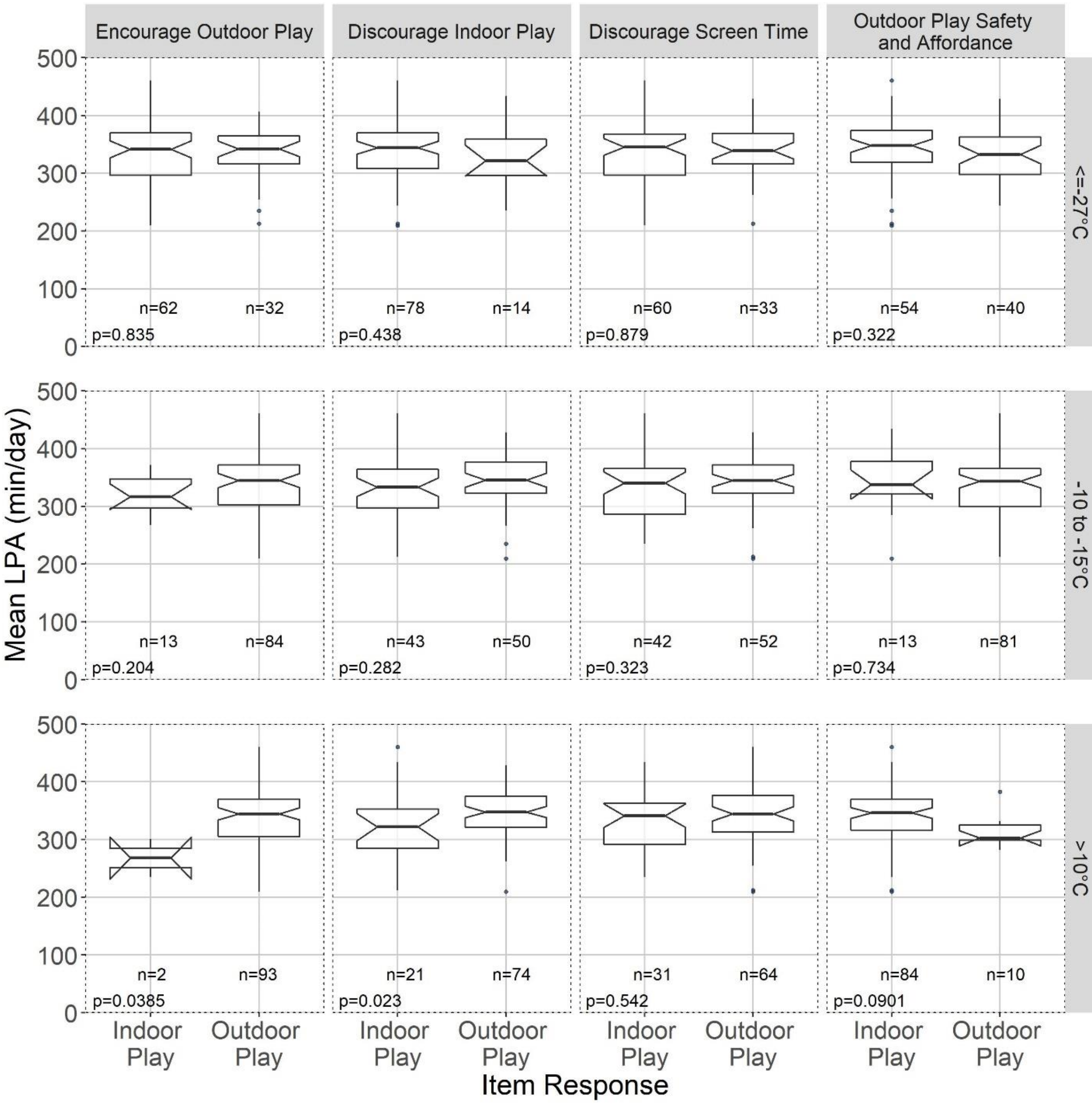


Figure 5.38 Mean LPA outcomes stratified by child perception questionnaire items.

Box bar and upper and lower hinges represent the median and interquartile range (25th and 75th centile), respectively. Notches represent upper and lower 95% confidence interval limits. Outliers are shown as dots. Item responses are coded as either favouring indoor play or outdoor play and stratified by temperature (>-27°C or colder with the windchill: items 1-4; -10 to -15°C: items 5-8; ≥10°C with little or no rain: items 9-12), and by (3) theme (parental practices - encouragement of outdoor play: items 1, 5, and 9; encouragement of indoor play (reverse coded): items 2, 6, and 10; encouragement of screen time (reverse coded): items 3, 7, and 11; cold weather safety: items 4 and 8; seasonal affordance: item 12). Post-hoc ANOVA Tukey's HSD p-values are shown (p<0.05).

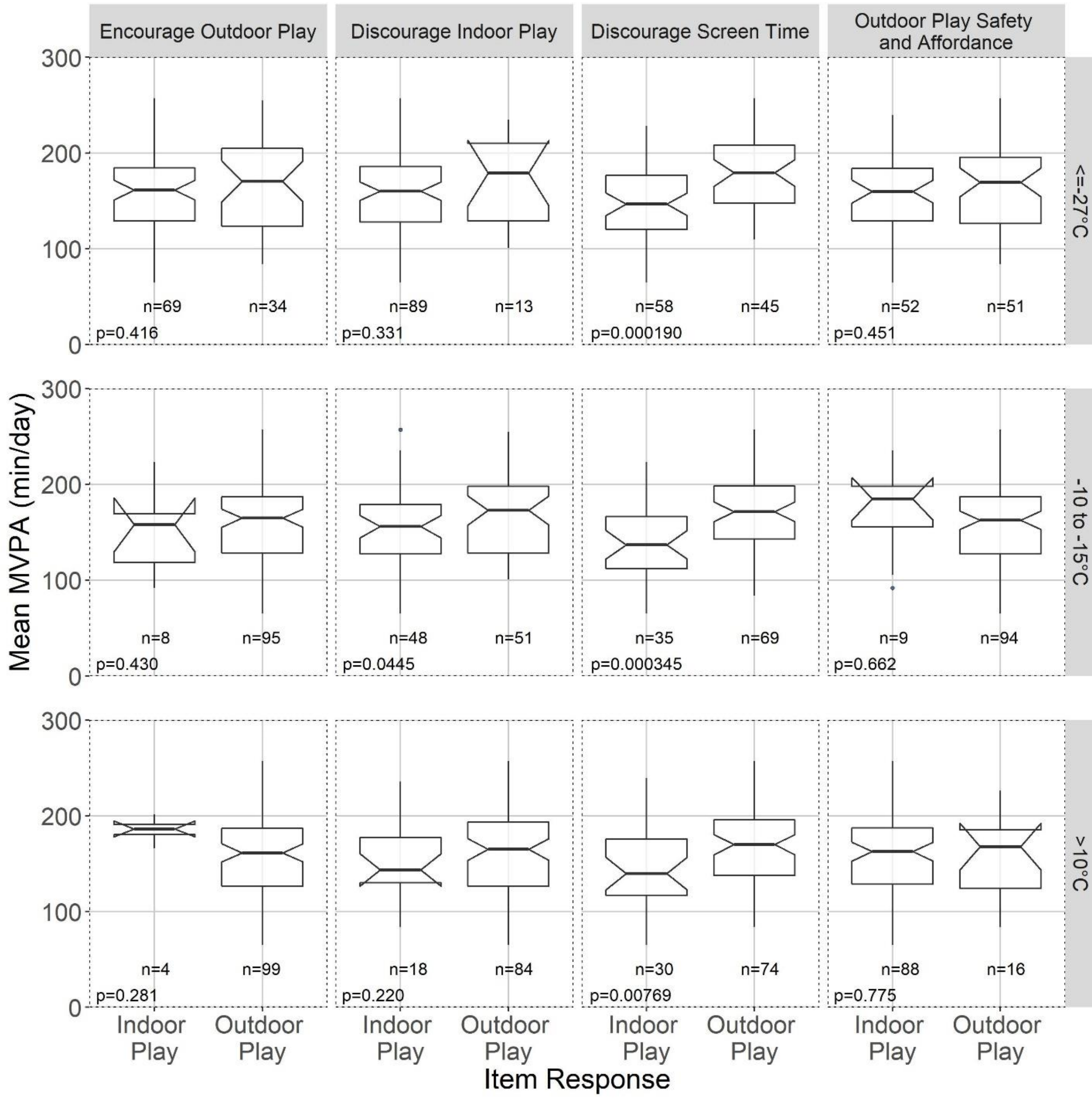


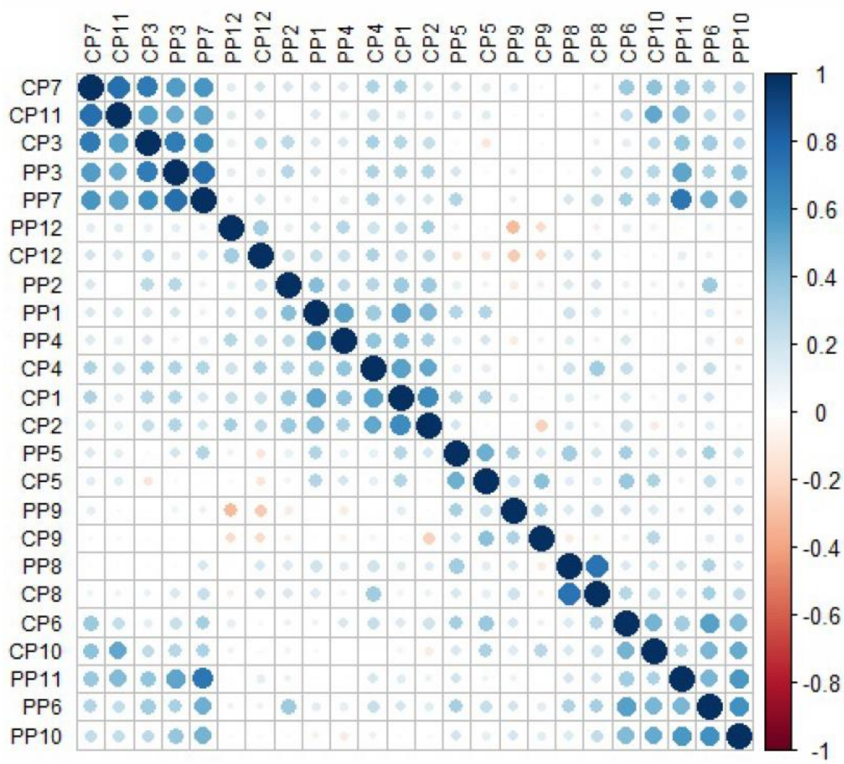
Figure 5.39 Mean MVPA outcomes stratified by child perception questionnaire items.

Box bar and upper and lower hinges represent the median and interquartile range (25^{th} and 75^{th} centile), respectively. Notches represent upper and lower 95% confidence interval limits. Outliers are shown as dots. Item responses are coded as either favouring indoor play or outdoor play and stratified by temperature (>-27°C or colder with the windchill: items 1-4; -10 to -15°C: items 5-8; ≥10°C with little or no rain: items 9-12), and by (3) theme (parental practices - encouragement of outdoor play: items 1, 5, and 9; encouragement of indoor play (reverse coded): items 2, 6, and 10; encouragement of screen time (reverse coded): items 3, 7, and 11; cold weather safety: items 4 and 8; seasonal affordance: item 12). Post-hoc ANOVA Tukey's HSD p-values are shown (p<0.05).

Table 5.18 Correlations between perceptions of outdoor play composite scores and activity outcomes.

		Parental Perception		Child's Perception of Parental Support	
		Kendell's τ	p-value	Kendell's τ	p-value
Sedentary Behaviour	Composite Score	*-0.149*	*0.0309*	-0.126	0.0882
	Composite Score Stratified by Temperature Grouping				
	-27°C or colder with the windchill	-0.106	0.126	-0.0703	0.327
	-10 to -15°C	-0.138	0.0511	-0.109	0.144
	10°C with little or no rain	-0.132	0.0607	-0.143	0.0550
Light Physical Acitvity	Composite Score	0.0322	0.641	0.0380	0.608
	Composite Score Stratified by Temperature Grouping				
	-27°C or colder with the windchill	0.0157	0.821	-0.00314	0.965
	-10 to -15°C	0.0689	0.331	0.0689	0.358
	10°C with little or no rain	0.0595	0.400	0.0354	0.636
Moderate to Vigorous Physical Acitvity	Composite Score	*0.201*	*0.00352*	*0.183*	*0.0138*
	Composite Score Stratified by Temperature Grouping				
	-27°C or colder with the windchill	*0.163*	*0.0190*	0.122	0.0877
	-10 to -15°C	*0.191*	*0.00710*	*0.157*	*0.0361*
	10°C with little or no rain	0.137	0.0526	0.0354	0.636

Italicized values represent statistically significant correlations ($p<0.05$).



Parent Item	Child Item	Temperature Scenario	Item Description
PP1	CP1	When it is very cold outside (-27°C with the wind chill or colder)	Encouraged to play outdoors
PP2	CP2		Encouraged to play indoors
PP3	CP3		Unlimited screen time
PP4	CP4		Belief outdoor play is unsafe
PP5	CP5	When it is around -10 to -15°C	Encouraged to play outdoors
PP6	CP6		Encouraged to play indoors
PP7	CP7		Unlimited screen time
PP8	CP8		Belief outdoor play is unsafe
PP9	CP9	When the weather is warmer (at least 10°C with little or no rain)	Encouraged to play outdoors
PP10	CP10		Encouraged to play indoors
PP11	CP11		Unlimited screen time
PP12	CP12		Belief that there are more activities to participate in

Figure 5.40 Correlation matrix of all perceptions of PA and SED in different weather conditions questionnaire item responses.

n=91. Incomplete case responses were excluded from analysis (n=27). Questionnaire items are coded by (1) parent (PP) and child (CP) perception items, (2) weather condition specific items (>-27°C or colder with the windchill: items 1-4; -10 to -15°C: items 5-8; ≥10°C with little or no rain: items 9-12), and by (3) theme (parental practices - encouragement and permissiveness regarding indoor/outdoor activity: items 1-3,5-7,9-11; Cold weather safety; items 4 and 8; Seasonal affordance: item 12). Post-hoc ANOVA Tukey's HSD p-values are shown (p<0.05).

These findings highlight that both parent self-reported screen limitation and encouragement of outdoor play demonstrate an association with decreased SED and increased MVPA of children year round. Similarly, children who perceived screen time limitations by parents and encouragement of outdoor play accumulated less SED, but greater levels of MVPA year round.

Chapter 6 Discussion

6.1 The Relationship Between a Child's Demographic Factors, Season and Neighbourhood Built Environment on Sedentary Behaviour Outcomes

This body of work was aimed at forming a better understanding of the determinants of childhood SED in the context of child characteristics, season and neighbourhood level BE characteristics over an entire year. Children's SED was examined both in terms of time (when in the day) and where the SED occurred, to examine if specific environments, such as the home or school social and physical environments of a child, result in different predictors of SED. The findings discussed in this section address Research Question A and Hypothesis A (**Section 1.3**).

6.1.1 Seasonal Changes in Children's Sedentary Behaviour

It was hypothesized that winter months would be associated with the greatest levels of SED in children in comparison to other seasons. While significant seasonal differences in SED emerged, no consistent patterns appeared within all models presented. As hypothesized, children accumulated significantly lower levels of SED during fall (vs winter) months while in their home or school areas. In contrast, children accumulated significantly greater levels of SED in spring (vs winter) months over their entire day, or while in their home or school area. Summer months were associated with significantly greater levels of school hour, school park and park area SED in children. In MLMs examining leisure hour and school hour SED, SED did not differ significantly between winter and any other season. The unexpected seasonal differences in children's SED demonstrates the nuanced nature of children's activity behaviours. The seasonal differences in children's SED accumulation is dependent on both the social and physical environments they are experiencing, whether it be within their home or school properties, within public parks, or during specific times of the day. What is not well understood is why children's seasonal patterns in SED are divergent between these domains, prompting the need for further in-depth studies that explore these differences.

SED data collection occurred three times over four months, within a one year period. Summer months had the fewest valid accelerometry participant days (n=646) vs winter (n=2028), spring (n=1988) and fall (2750), but likely not low enough to warrant caution in the interpretation of the presented results. While the majority of participants provided accelerometry at all three data collection points, 175 individuals only provided 1 or 2 valid time points of data.

As each individual provided at least one to three time points of seasonal SED data, this makes it difficult to delineate if subgroups existed within the primary cohort. That is, it is possible that while some children adopt more sedentary lifestyles in warmer months, others may participate more frequently in SB-displacing activities during these same periods, and that their individual characteristics may differ significantly between groups. While speculative, it is possible that spring months may be associated with greater SED accumulation in children because of a lull in organized sport programming, or children are simply delayed in adopting outdoor play during spring months, after spending increased time indoors during colder winter months.

A key finding of this work was that seasonal differences in SED were moderated by children's PA levels, gender, age, and BMI and neighbourhood level characteristics. These relationships are discussed below within each section.

6.1.2 The Relationship Between Sedentary Behaviour and Physical Activity

In time- and location-dependent models increased levels of MVPA were consistently predictive of lower SED. In terms of location, school parks demonstrated the weakest association, where only a single minute of SED was predicted to be reduced for every 32 minutes of MVPA accumulated. However, in terms of time, school hour MVPA demonstrated the greatest negative association with SED, where almost every minute of additional MVPA was associated with an equivalent reduction in SED. Therefore, it is possible that children accumulated high levels of MVPA while on school grounds, during recess, lunch hours and curriculum-based physical education, thereby displacing school hour SED. In a study examining school day SED in a low-income community of England, 1 minute of MVPA was associated with a reduction of a child's school day SED by 2 minutes (201). However, in an intervention aiming to reduce screen-based SED by 25-50% in youth aged 8-16 years of age, PA levels remain unchanged (202). Further complicating matters, children's physical behaviour patterns may be categorized by the relative balance between SED and PA. For example, children can be categorized as those who perform prolonged bouts of SED or those who take frequent breaks from sedentary activity (51). Additionally, children who meet MVPA guideline targets are likely to engage in different forms of SB and accumulate less SED in comparison to those not meeting recommended targets (203). Unexpectedly, MVPA was not a significant predictor of SED when GPS-derived school-area SED was considered, yet it was a significant predictor of reduced school hour SED. This may be an indication that MVPA that occurred *near* the school area (during school hours), but not necessarily within the school boundaries, can contribute to reducing a child's SED, including active transportation to nearby recreation/parks and retail. While a small proportion of schools within the Public Division have explicit rules stating that children are only allowed to leave school grounds during recess and lunch hour with parental consent, almost all schools that participated in this study do not have this information publicly available or no clear indicators if such a rule exists. Many schools within Saskatoon's Public and Catholic school divisions are situated near parks, retail and other areas of interest. Children may be participating in active forms of mobility or transport or visiting nearby areas of interest, both through walking or biking, during periods where they may leave school properties (morning and afternoon recess and lunch hour).

In a random examination of participant GPS data points both immediately outside of schools areas and during morning or afternoon recesses, lunch hours or immediately after school, children accumulated substantial data points in retail destinations (*e.g.* corner stores, malls and mall food courts) and nearby public parks that were within walking distance of participating schools *(data not shown).* Neither activity spaces nor active travel was captured in this study, but these results suggest that children who are permitted to leave school grounds are likely to do so in an active manner (e.g. walking), displacing SED opportunities. Additionally, notable differences in predictors of school hour, school area and school park area SED outlined in this study suggest that non-curriculum school periods offer unique opportunities to improve children's activity-sedentary behaviour balance. Forming a better understanding of how school policies and enactment of these policies impact active-sedentary behaviour balance, including in the periods before and after schools and during school hours, are warranted.

In contrast to MVPA, LPA showed varying associations, and direction of associations, with SED, dependant on the timing or location of SED being examined. When a child's entire day or only school hours were considered, for every 3.6 and 1.2 minutes of LPA accumulated, respectively, the predicted reduction of SED was by 1 minute. In contrast, while children were in their home area, school or school-park or within a city park, LPA was associated with an increase in SED. To date, LPA is not commonly included in, "physical activity," research, therefore, its relationship between other physical behaviours and health outcomes remains largely unexplored. In a study examining compensatory PA and SED in children, SED or LPA accumulated on the previous day was not significantly associated with LPA or SED levels accumulated on the following day, respectively (204).

Studies examining how one physical behaviour intensity relates to another level of another physical behaviour intensity are quite limited. A unique aspect of this study was the examination of the SED-PA interrelationship in children in relation to where this happens and when. This study demonstrates that displacement of SED with the varying forms of PA is not constant throughout the day nor does it occur consistently between locations, yet MVPA consistently has the greatest predicted effect of reducing sedentariness in children. A meta-analysis broadly exploring the relationship between any domain of children and adolescents' PA and SED found a small, but negative, association between domains (205). In agreement, increasing SED in children was found to suppress PA behaviours (202). Taken together, these results suggest interventions aimed at reducing SED will be most effective through displacement of SED with MVPA. Interventions targeting non-curriculum school period SED during recesses and lunch hours may be most effective at reducing SED. Reduced SED and increased MVPA may be achieved by promoting active forms of transportation between home and school during before and after school periods and during lunch hours. Additionally, school policies allowing children to leave school grounds during school periods may further encourage active forms of mobility, thereby reducing SED and increasing MVPA.

In addition to varying magnitudes of association between SED and PA during different periods of the day or locations of activity, the effect of season on SED was moderated by PA levels. During leisure and school hours, children who accumulated the greatest levels of MVPA were significantly less sedentary in winter vs fall or summer months. Similarly, higher levels of LPA during school hours was associated with a greater reduction in SED in winter vs summer months. These findings suggest that during winter months, opportunities to participate in light to vigorous PA may provide greater opportunities to directly displace SED in comparison to other seasons. In a study examining seasonal differences in activity behaviour, Midwestern-USA-based youth accumulated significantly less MVPA during physical education, before and after school and on weekends in winter vs non-winter months (206). Taking our own findings into account, these results emphasize the need to prioritize both in-school and out-of-school PA opportunities in Canadian youth during winter months as a strategy to displace SBs.

6.1.3 Sedentary Behaviour, Gender and Age

SED did not differ by gender when a child's entire day was considered. Similarly, male and female children aged 11-14 years from the 2007 to 2009 Canadian Health Measures Survey cohort demonstrated no significant difference in mean daily SED (35). Yet, in comparison to males, females were more sedentary during school hours, but less sedentary during leisure hours and when in their home area. Additionally, males demonstrated a greater increase in leisure hour SED with increased LPA in comparison to females. In agreement with our findings, in a Canadian cohort of 8-11-year-old children, females accumulated significantly greater levels of SED during their entire school day, during regular class time, recess, and lunch hour, but not during physical education classes. In school environments, enjoyment of PA education decreases in females with age but not so in males (149). Furthermore, physical education can be biased towards supporting males to a greater extent than females. This is done so with physical education's frequent reward and praise of participants based on their physical ability (207) and, "patriarchal nature of sport-based physical education curriculum," (208), leading to the possibility that females may be accumulating greater levels of SED in physical education classes. Yet, a review examining PA outcomes in middle years students concluded that MVPA did not significantly vary by gender in a physical education context. Additionally, in two reviews examining MVPA in elementary (209) and middle to high school children (210), gender was not consistently associated with divergent levels of PA accumulation during physical education classes. SED was not considered in either of these physical education-based reviews. Taken together, these findings demonstrate how limited our understanding is of the types of SBs children accumulate during school hours, and why the degree of SED accumulation varies between genders.

While school policies regarding children leaving school grounds during recess and lunch hour could not be confirmed in this study, it is possible that female and male children may not have been permitted equally to leave school grounds, thereby reducing the activity space and physical movement opportunities during recess and lunch hour periods. Furthermore, in a Canadian cohort of 10-13-year-old children, males were recorded spending more time in curriculum-based PA in comparison to females (211). While these divergent characteristics between genders provide a possible explanation for higher school SED in females, they do not explain why females engaged in significantly less SED outside of school hours or within their home area. Gendered differences in free play, independent mobility and perceived physical literacy may be steering females to accumulate greater levels of SED during school hours. Outside of school, females are afforded lower levels of independent mobility by their caregivers (107). Further exploration of gendered differences in children's trip behaviours to and from school and during school hours is warranted. Examination of these trip behaviours should include a thorough understanding of the form of transportation children use to move between home and school and during school hours (*e.g.* active vs inactive), and if this varies by gender. Furthermore, additional research is needed to understand if children are permitted parent-consent to leave school grounds differentially based on their gender.

During school hours and when children were on school property, the increased difference in sedentariness between younger and older children was significantly diminished in summer and fall vs winter months. As explored both in this section and the introduction, greater levels of independent mobility are afforded to children of an older age. While speculative, the combination of greater levels of independent mobility (107,212) and more pleasant weather conditions may sway older, more sedentary, children to leave school properties allowing them to accumulate greater levels of PA, while displacing SED.

Screen time is the most commonly reported form of SB (40,61). Screen time can involve multiple types of devices (televisions, tablets, computers, gaming consoles, or smartphones) and can involve multiple types of media (television shows, streaming video, offline and online gaming, social media platforms, internet browsing, *etc.*). In this study, in comparison to males, females were significantly less sedentary during leisure hours and while in their home area. Yet, the female participants of this study reported watching television and using their phone for longer durations than male participants. Conversely, male participants reported playing video games on a gaming console, computer, tablet or smartphone for longer durations than their female counterparts (*data not shown*). Studies examining specific SBs have shown that the use of specific forms of screen time can vary by gender. Three studies based in Canada (n=403 children in grades 5 and 6) (213), the USA (n>33,000 6-17-year-olds) (214) and Taiwan (n=8640 13-16-year-olds) (215) found that males were significantly more likely to engage in ≥2 hours of screen time per day or multiple screen time behaviours in comparison females. Furthermore, in a large Canadian study examining school PA policies and screen time behaviours of youth over their entire day, females were more likely to engage in, "communication based," SB and internet surfing in comparison to males. Similarly, males reported significantly more time playing video games than any other SB (216). It is possible that while female participants of this study reported longer durations of television viewing and phone use, screen time behaviours reported by males, such as video gaming, may result in longer bouts of uninterrupted SED. Unlike television viewing, where programmes have a finite length of time, non-physically active video games can offer uninterrupted experiences that can be played continuously for hours without a definitive, 'end.' Additionally, communication-based SBs, such as texting using a smartphone, likely provide greater opportunities for LPA. Evidence supporting this notion is lacking and largely speculative but provides one possible explanation of why females accumulate less SED in leisure hours and within their home area. Studies examining the relationship between gender and the accumulation of different forms of SB, including the use of media devices, within home and school environments are needed.

This study found that with every year of increase in age, children accumulated between 8 and 22 additional sedentary minutes/day, with the exception of SED during school hours and in school park. The phenomenon of decreased PA (69,76–78,217), and increased sedentariness (82,218), with increased chronologic age and biological maturation has been reported elsewhere and emphasizes the importance of understanding what contributes to this notable change in PA-SED balance during this critical period within the life course. In addition to accumulating greater level of SED, older children's sedentary bouts are greater in length (219). While increased age was a consistent predictor of SED in all models presented, its estimated association on SED was notably lower during school hours or when children were within school or school park properties, where each year of age was only associated with 0.4-2 additional sedentary minutes/day.

When children's entire days or leisure hours were considered, this study's youngest females (age 9) were less sedentary than their male counterparts, yet the oldest female participants (age 14) were more sedentary than their male counterparts. This finding indicates that females are likely to increase sedentariness at a greater rate than males during the transition to adolescence. These differential trajectories may be partially driven by timing of biological maturation, physical literacy and independent mobility differences experienced between genders. In a Southern Ontario longitudinal cohort of grade 5-9 children, the effect of age and sex on increased SED were completely attenuated when biological maturation was taken into account (measured using years from attainment of peak height velocity). Yet, in the same group of adolescents, males were significantly more likely to participate in organized sports outside of school curriculum, regardless of their degree of maturation, in comparison to females (217), indicating social mechanisms may also be at play. From research examining children's independent mobility, it has been established that males and females are afforded different levels of freedom to explore the world outside of the confines of their homes without adult supervision. Children's independent mobility is consistently associated with increased PA, but associations with reduced SED are mixed (138). Males are afforded greater levels of independent mobility in comparison to females, and this only increases as they age (107,212).

In this cohort, male children experienced greater levels of leisure hour SED with increased LPA in comparison to females. This suggests that the form and intensity of activities a child participates may be shaped by one's social environment, through different interests and opportunities provided to children based on their gender, resulting in a difference in PA states between the genders. Yet, during school hour SED analysis, males were significantly less sedentary than females in all seasons, except during fall months. This phenomenon remains unexplained, as existing studies have yet to explore the deeply nuanced relationship between activity behaviours, gender and the physical (climate/seasonal) environments of Canadian children.

6.1.4 Body Composition and Sedentary Behaviour

The relationship between SED and overweight and obesity is potentially reciprocal, in that SED is associated with increased BMI (52) and in turn, overweight and obesity status can further promote SB. In almost all models presented, body composition was a significant predictor of SED, but notable differences occurred while children were within school, school park, and park areas. During a child's entire day, during school and leisure hours, and when a child was within their home area, children who were overweight or obese accumulated significantly greater levels of SED. While children were within their school or school park properties, obesity, but not overweight status, significantly predicted SED. While schools may offer mandatory physical education and regular opportunities for reduced sedentariness during morning and afternoon recess and lunch hour, in its current state, children with obesity are still likely experiencing obstacles which prevent them from meeting the lower sedentary levels of their peers. Children with overweight or obesity are faced with challenges, such as greater likelihood of limited physical ability, not finding pleasure in PA, and experiencing prejudice and discrimination in comparison to their normal weight counterparts (220). Additionally, the stigmatization of children with obesity can be received from both peers and educators in school settings. While school peers are likely to engage in bullying, teasing and victimization (221), both general and health- and education-specialist teachers were found to have, “anti-fat,” biased views of children with obesity (222). The associated risk of sedentariness with weight status and potential barriers to achieving reduced SED in those with overweight and obesity is especially problematic as over 13% of this study’s population had an obese weight status.

With increased leisure hour MVPA, children who were overweight or obese demonstrated a greater associated reduction in SED in comparison to children with healthy weight. However, in their leisure hours, children with obesity demonstrated significantly greater levels of SED in winter vs summer months. This suggests that interventions aimed at displacing SED with MVPA may demonstrate a greater effect in the highest risk populations, such as children with overweight or obesity, and especially so if activity behaviours during winter months are targeted.

6.1.5 Socioeconomic Status and Sedentary Behaviour

In comparison to households earning <$20,000, children living in homes with an annual household income of $20-40,000 and $40-80,000 (leisure hours only) were significantly less sedentary during leisure hours and while in their home environment (that is, income was a main effect in models predicting leisure hour and home area SED). In previous work examining the relationship between SES and activity behaviour, results have been mixed, which may be a product of the varying nature of SB. While some SBs may be a sign of affluence, such as family car ownership (driving), access to mobile media devices, and economic availability of extracurricular sport enrollment, others may be an indicator of barriers experienced by those living with low income. Screen time and indoor play during leisure hours may be welcomed alternatives to unsupervised outdoor play by parents with limited financial resources or social support or those living within neighbourhoods with higher crime and social disorder (89). Yet, youth are more likely to engage in greater levels of commuting, and subsequently MVPA, with increased level of urbanicity (223).

Families who reported annual household incomes >$40,000 had children who were significantly more sedentary during school hours. Yet, income was not a significant predictor of school *area* SED. These finding suggests that city-wide publicly funded schools with similar curricula and school grounds likely offer equal opportunities of SED and PA for attending children. School-neighbourhood level characteristics, as defined by the NALP and IMI dimension scores, did not vary significantly between children of different SES, with the exception of IMI safety from crime. While neighbourhood safety from crime significantly varied between groups of children by annual household income (ANOVA $p<0.05$), pair-wise comparisons showed no significant differences (Tukey's HSD, *data not shown*). This suggests that a child's household income may be indicative of social or physical environment characteristics not captured here, which in turn can steer children towards divergent outcomes of SED.

6.1.6 Sedentary Behaviour Patterns of Children on Weekdays vs Weekends, and During Summer Months

Within the SASK study cohort, children accumulated less SED on weekdays than on weekends. Time series plots of activity behaviour throughout the day revealed that children are predictably less sedentary and more active during the period immediately before school, during recess periods, during lunch periods, and in the period immediately after school dismissal, a pattern reported elsewhere in Australian children aged 10-17 years (224). This consistent pattern describing lower energy expenditure on the weekend has been described as the, "structured day hypothesis." While traditional indoor school environments provide opportunity for sitting, routine breaks throughout the day disrupt this SED. Unlike weekday school days, weekends do not consistently provide children with structured activities throughout the day. Also, later wake times on the weekend days displace PA opportunities, and at the same time provide greater freedom surrounding diet and screen time access (225). In a cohort of 2,296 Australian children, those who *did not* meet the minimum of 60 minutes of *daily* PA were achieving higher levels of weekly PA in comparison to children who obtained at least 60 minutes of PA daily. The authors theorized that these children, who were more active on weekdays, were so because of dynamic factors, such as participation in organized sports or family preferences for weekday PA (226).

In this study population, accelerometry wear time (*i.e.* time that did not include sleep and non-wear time) began substantially later in the day on weekends vs weekdays, with peak accelerometry wear occurring at 1200h (vs 0830h on weekdays). On weekdays, outside of school hours, a greater proportion of a child's time is spent sedentary. On weekdays, study participants accumulated most of their SED outside of school hours. Furthermore, the most prevalent self-reported SB on both weekdays and weekends was television viewing followed by video games. Both television viewing and video gaming were reported at a frequency three times that of all other SBs (*data not shown*). Similar to these findings, a systematic review examining children's after-school SBs found that the largest contributor to sedentariness in children was television viewing (20.4%), homework (20.3%) and other screen-based SBs (18.2%) (227). These findings indicate that while the highly structured environment of elementary schools may offer an effective intervention route to reduce sedentariness, altering the behaviour of children (and their families) during their personal time may offer the greatest benefit. In particular, interventions targeting the period immediately after school dismissal have the potential to significantly impact children's leisure hour SED outcomes. A systematic review of children's after-school periods revealed that 41-51% of this period is spent sedentary, and this only increases with age. Of this after-school period SED, 12% is spent utilizing motorized transport (227). By shifting children's modal choice to active forms of transport for the purpose of commuting between school and home, SED could be reduced.

As with leisure hours (evenings and weekends), non-school summer months provide greater opportunity for SED gains and MVPA losses. Within an intervention designed to counter this out-of-school period drop off in energy expenditure, children with the highest degree of participation had significantly reduced BMI scores (228). While this study occurred over a one-year period, only a small proportion of study participants contributed activity data during non-school summer months. Forty-eight participants had their final collection point during non-school summer months, but only 25 of these participants provided valid accelerometry data included in all analyses. Therefore, meaningful analyses regarding the non-structured environment of summer months were not pursued.

6.1.7 Sedentary Behaviour and the Built Environment

No single feature of the BE consistently predicted SED across all time- and location-dependent scenarios examined. Additionally, BE variables were generally not significant predictors on their own (as main effects), with a few exceptions. When a child's entire day and leisure hours were considered, home neighbourhood design era was a significant predictor of SED. Children living in fractured grid and curvilinear style neighbourhoods were statistically more sedentary than those living in grid style neighbourhoods when a child's entire day or leisure hours were considered (fractured grid only). In a previous cohort of 10-13-year-old children living in Saskatoon, those living in grid style neighbourhoods established before 1930 were significantly more active (MVPA) than children living in fractured grid neighbourhoods. In contrast to our findings, SED did not differ significantly between grid and fractured grid or curvilinear neighbourhoods in a previous cross-sectional cohort of children living in Saskatoon (229). Models predicting total daily and leisure hour SED demonstrated a strong negative association between MVPA and SED outcomes. While it is possible that the collinearity between MVPA and SED amplified the association between SED and neighbourhood era design, both PA inclusive and exclusive models demonstrated a significant association between neighbourhood era design and SED. These results show the possibility of identifying detailed and more varied sets of results when using a longitudinal cohort across all seasons, and when examining SED and PA in relation to context and time in the day of these activities.

Children living in neighbourhoods with more things to see and do (NALP density of destinations) and greater (IMI) activity friendliness were significantly less sedentary while they were in their home area. In contrast, children living in neighbourhoods with the highest level of safety from crime and overall activity friendliness measured (by combining all NALP and IMI scores) were significantly more sedentary. Home area captured by GPS-paired accelerometry only included physical behaviours that occurred within a 20m radius of a child's home. While NALP and IMI dimension scores examine broad features of a neighbourhood's BE, they also consider individual aspects of the style of housing and housing developments within a neighbourhood. For example, the IMI includes individual items that capture sidewalk width, grade and condition, the presence of a buffer between a sidewalk and the roadway, the dominance of garage-fronted housing with little passive surveillance, the presence of loose/unsupervised/barking dogs, *etc.* (230), all of which may alter the likelihood of a child utilizing the outdoor space within their own home property. While the NALP items exploring density of destinations specifically explore the number and variety of destinations in a neighbourhood (231), there may be unmeasured features of homes in neighbourhoods with a high degree of destinations that are more conducive to reduced sedentariness of children while in their home environment (*e.g.* yard size, home size, average room size, *etc.*). In a review by Maitland *et al.* examining home attributes and SB outcomes (232), yard size was the only home attribute measured across all studies examine. The association between yard size and SB outcomes were mixed, resulting in the call for more thorough investigations of home area attributes and SB outcomes (232). The role of neighbourhood self-selection and home environment social influences that have been found in other studies (233) as alternate explanations cannot be ruled out. Adults who prefer walking are more likely to live in highly walkable neighbourhoods. Furthermore, residents who preferred living within a walkable distance to shopping destinations were more likely to walk than their neighbours (234). While neighbourhood self-selection may be partially responsible for more active families, in and outside of the home, perceptions of the BE have been shown to significantly predict walking in adults after self-selection has been accounted for (235). Therefore, parents of children who are less sedentary (meaning more active) may have chosen to live in neighbourhoods with greater activity friendliness to help support a more active lifestyle, explaining reductions in home area SED.

Almost all BE variables examined were not significant predictors (i.e. main effects) of time- and location-dependent SED, yet many demonstrated moderating effects on seasonal SED patterns. In some cases, children living or attending school in neighbourhoods with specific BE characteristics, such as higher levels of safety from crime or traffic, overall activity friendliness, universal accessibility demonstrated no difference in winter SED, yet showed significantly increased summer SED accumulation in comparison to children living in opposing neighbourhoods. Conversely, other home and school neighbourhoods with specific attributes, such as increased levels of pedestrian accessibility and activity friendliness were associated with increased levels of winter SED in comparison to children living in opposing neighbourhoods, but this pattern did not occur in other seasons of the year.

Findings from this study and elsewhere elucidate the complicated relationships that the BE can have on children’s year-round activity behaviours. In existing research examining the association between the BE and children's activity outcomes, season is rarely included in analyses. Most often when season is included, it is used to correct for timing of data collection, either through the inclusion of weather conditions on the date of data collection (133) or by controlling for season (236). In the limited studies simultaneously considering season and the BE, moderating effects have been noted. In a cohort of children aged 11-12 years living in Cyprus, seasonal differences in step-counts were moderated by residents of urban vs rural environments (237). Similarly, in a Kingston, ON based study of 10-to-13-year-old youth, objectively measured neighbourhood walkability was associated with greater levels of active transport. The difference in active transport trips between the least and most walkable neighbourhoods was greatest in spring months and diminished in winter months (238).

Both the home and school neighbourhood BEs of children moderated the association of LPA on SED outcomes. The moderating effects of the BE on LPA were highly variable, including changes in the direction of association. Interestingly, the association between MVPA and SED was not moderated by a child's home or school neighbourhood BE attributes in all scenarios examined. As discussed in **Section 6.1.2**, MVPA was consistently predictive of SED across all models tested except that of predicting school area SED. Where LPA describes activities that are limited to tasks such as walking slowly, MVPAs can encompass a broader range of activities involving movement within one's physical environment (*e.g.* brisk walking, cycling, running, using a scooter or skate board, *etc*.). These results suggest that while lower energy movements may be altered by a child's BE exposure, those controlling the relationship between displacing healthful MVPA with SED may be driven by factors not accounted for in the models presented. Children's natural dispositions towards movement and play may also be attenuated by a combination of the social and physical environment that they experience. In an intervention targeting 5-7-year-old children's free play during school recess, teachers reported children who were previously inclined to SED as being more physically active when presented with free play objects (239).

SED in relation to leisure hours or within children's home area, home neighbourhood BE significantly moderated the effect of some demographic factors on SED. Children living in households earning <$20,000 and in neighbourhoods with low levels of crime safety and general activity friendliness (IMI cumulative score) were more sedentary than their counterparts in neighbourhoods with higher crime safety and lower activity friendliness. Conversely, children living with higher income were more likely to be sedentary if their neighbourhoods were safer or had higher general activity friendliness in comparison to children living in households earning less than $20,000 annually. Similar findings have been described by Gauvin *et al.* (124) but in a population of Canadian adults. Higher levels of NALP safety, in comparison to average safety, were associated with a lower likelihood of walking in adults. However, caution should be used when comparing effects of the BE on children and adult's walking and cycling patterns, as substantive differences in BE barriers and promoters have been noted between these populations (129). While the perception of neighbourhood safety is a common barrier expressed by both children and parents on achieving outdoor play, the role of family income has not been examined in this relationship (240,241). Additionally, perceived levels and objective measures of crime demonstrate poor agreement (242). SED outcomes of children living in Saskatoon's safest neighbourhoods seem unaffected by their level of household income. It is plausible that children living with lower incomes may have limited social and physical resources to remain active (*i.e.* avoid SBs) while living in neighbourhoods with higher levels of crime and social disorder. In a mapping of Australian children's PA locations, children residing in the least deprived neighbourhoods lived significantly closer to a public park vs those living in the most deprived areas of Victoria, Australia. Conversely, children living in the lowest SES areas were allowed to walk or bike significantly greater distances on their own (243) and accumulated the greatest levels of MVPA (244) in comparison to their counterparts. Similarly, children living in low-income neighbourhoods of Toronto, Ontario were afforded greater levels of independent mobility, even after parental attitudes towards independent mobility were adjusted for (212). Collectively, these results demonstrate how both individual and area-level deprivation can shape activity behaviour.

As discussed in **Section 6.1.3**, children increase their levels of sedentariness with age. Remarkably, children attending schools in the least (IMI) attractive neighbourhoods did not demonstrate this pattern when they were in their school area. In contrast, children attending schools in neighbourhoods with the highest level of (NALP) activity friendliness also did not experience an increased sedentariness with age while in their school park areas. A systematic review examining the association between PA and school playground markings and design and access to sports equipment found no long term improvements in PA outcomes of children (245). In contrast, multiple urban green space interventions have shown a positive association with both the number of individuals visiting these areas and the amount of PA accumulated in them (246). Taken together, these results demonstrate the need to form a deeper understanding if school proximity to public parks or public park amenities are predictive of physical behaviour in children.

The majority of children's time was spent in their school and home environments on weekdays and weekends, respectively. Even though all participants lived within walking distances of public parks, they were the least frequented location of interest in terms of PA or SED, both on weekdays and weekends. In an Australian study examining play area preferences of 5-12-year-olds, more children described their home or a friend's home as their preferred place to play, rather than parks or streets. Yet, when asked what they would like to do on a sunny day, the majority of children chose outdoor activities which could have taken place in bushland, parks and beaches (247). When parents of children in grades one through six were asked to describe barriers of allowing play outside of the home, the safety of their children was a primary inhibiting factor, including travel to and play within parks. As one parent aptly described the sentiment of others within the study and elsewhere, "The way the world is today, you don't let them play out in the street. It would be nice to let them just run around as we used to do, but you can't anymore." Within the same study, parents described the presence of older adolescence as a deterrent, yet also described playground equipment as being "boring" because they felt it was intended for children of a younger age (248). Similarly, in a scoping review summarizing the role of neighbourhood safety and PA, both parents and children reported the home as a safe alternative to public spaces. In these same families, 'stranger danger' and road and crime safety were the most common forms of safety concerns reported by parents (249). However, another scoping review examining the association between crime and PA outcomes found that when objectively measured reported crime was considered, PA outcomes only demonstrate a weak association with crime (250).

In contrast to all other multilevel models presented, neither BMI, gender nor age predicted park area SED. Only LPA and summer (vs winter) months were associated with increased, and MVPA was associated with decreased park area SED in children. Second to school parks, city parks also offered children minimal sedentary opportunities. Children accumulated significantly greater levels of SED during summer (vs winter) months when in public park areas. Public parks in the city of Saskatoon offer multiple uses for patrons, including play structures, wooded areas, splash pads, paddling pools, sporting fields, and sloped terrain conducive to winter sledding/tobogganing in the presence of snow ground cover (251). Public parks may offer a variety of opportunities for PA throughout the year, but the timing and dynamics of play (free vs organized) may be the underlying reason for differences in park area SED between seasons. Park activities only available in winter, such as sledding or ice skating, may be more conducive to higher energy expenditure overall but may be performed less frequently due to reduced park visits during cold weather months. Park area SED differed significantly by children's home neighbourhood universal accessibility, but only in summer months, indicating that home area neighbourhoods and their surrounding parks may offer different opportunities for activities that may vary by season.

6.1.8 Differences in Models Predicting Sedentary Behaviour Inclusive and Exclusive of Physical Activity

When a single physical behaviour is examined, other behaviours must be considered in concert. Dumuid *et al.* (50) described studies examining only a single activity expenditure as, "failing," to account for the, "subsequent and equal," change in other behaviour domains, such as PA, SED or sleep. Additionally, the result of the exclusion of other behaviours makes delineating the, "health and economic burden of physical inactivity," challenging (50).

The association between PA and SED outcomes can vary both in magnitude and direction depending on the time or locational context of the activity behaviours in question. Both PA inclusive and exclusive MLMs predicting total daily, leisure hour and school hour SED were presented in **Sections 5.4-5.6**, none of which demonstrated identical predictors of SED. The variance of significant predictors between PA inclusive and exclusive models highlights the importance of this finding for both future research and when comparisons between previous studies are being made. For example, neighbourhood era design was predictive of total daily SED in PAEM, but not in PAIM. Similarly, gender was predictive of PAEM school hour and PAIM leisure hour SED, but not in time-specific models predicting SED. While studies described above (in **Section 6.1.2**) have included SED in their prediction of PA, no studies to date have made direct comparisons between models predicting SED inclusive and exclusive of PA. These results suggest that both the amplitude and significance of physical behaviour predictors may be diminished and entirely abrogated with the inclusion of compensatory physical behaviour in MLMs.

6.2 Perceptions of Year-Round Outdoor Play

The relationship between perceptions of parent support of year-round active play and activity behaviour outcomes are discussed in this section.

CSEP's 24 Hour Movement Guidelines for youth have been published by news media outlets (252) and adopted by influential organizations, such as the Canadian Pediatric Society (253) and ParticipACTION (254). Yet, 29-56% of parents reported that they did not limit screen time in their children, and 33-65% of children did not perceive screen time limitations by their parent(s). These findings are similar to those reported in an Ontario, Canada study of children in grades 5 and 6. On weekdays, 50, 55, 30, and 63% of children perceived parental rules limiting television, video games, computer use for homework and computer use for non-homework, respectively. Perceived screen time limits were even lower on weekends, with 22-52% of children reporting screen time limits, depending on the type of screen time examined (213). In a Lebanese cohort of 7-11-year-old children, only 14.7% of males' parents and 16.4% of females' parents reported limiting screen time (255).

Children of parents who did not perceive regulating screen time in their children accumulated significantly greater levels of SED and significantly lower levels of MVPA. As sleep was not accounted for, a direct displacement of MVPA by SED cannot be confirmed in these children, yet the gain in SED was roughly equivalent to the associated reduction in MVPA (~30 minutes/day). Additionally, parents who encourage indoor play of their children in average winter conditions had children with significantly lower levels of daily MVPA. A recent report by Roberts *et al.* (33) showed that 5-17-year-old Canadian children's average daily MVPA and screen time was 53.8 minutes (95% CI 50.6, 57.0) and 3.1 hours (95% CI 2.9, 3.2). While limiting screen time may not have swayed this national study population below screen time limit recommendations (<2 hours/day), a theoretical 30 minute increase in MVPA would have allowed these children to achieve the minimum recommended daily duration of MVPA (≥60 minutes/day).

Children with overweight or obesity are significantly more likely to exceed the CSEP screen time recommended limits of 2 hours (203). Therefore, interventions aimed at reducing phone and other media device ‘ownership’ by young children, parent-driven limitation of media devices, and the removal of media device access as a disciplinary tool may have healthful impacts related to both body composition (BMI) and SED outcomes.

In this study, children who perceive their parents as encouraging indoor play were significantly more sedentary and significantly less active (LPA and MVPA) than their counterparts. The rampant use of media devices in and outside of the home may also cause children, normally inclined to participate in outdoor PA, to be labelled as a person preferring the indoors, when media device access is unlimited or when play environments are not ideal. Several studies demonstrate that parents frequently perceive their child as preferring media-related entertainment vs outdoor play, and therefore label them as an “indoor” child, or simply allow little time for outdoor free play. In a qualitative study examining parent perceptions of influences on their child’s play behaviours, some parents described their children as preferring to, “watch tv all the time,” and not being their child’s, “preference, even on a nice day, to be outdoors,” (248). Likewise, in a qualitative study exploring children’s use of urban spaces in Amsterdam, Netherlands, a subset of children were described as, “indoor children.” These children rarely played outside, and if so, it was only done so for very short periods. Indoor ‘play’ was often allocated to television viewing and the child did not participate in many other types of activities. A second type of child described was the, “backseat child,” who’s outdoor time was often extremely restricted as a result of their highly scheduled life, in and outside of school (256).

Increased outdoor play can provide benefit to a child’s activity behaviour balance. A systematic review by Gray *et al.* (257) provided convincing evidence that children’s outdoor play is associated with a significant increase in PA across different ages and genders. SED is also reduced when children are outdoors, but evidence of this is substantially limited in comparison to PA. Nonetheless, the duration of time children spend outdoors over the past few generations has declined (247,256). As described in **Section 6.1.7,** parent and child fears of safety, from crime, strangers and traffic are commonly reported barriers to outdoor play, independent mobility of children and free play. In an Australian cohort of adolescents, children of parents who reported restricting or highly supervising outdoor play reported significantly lower levels of active transport (258). Taken together, these results suggest that interventions targeting screen time regulation and outdoor play restriction may provide positive benefit by reducing SED and increasing MVPA.

6.3 Revisiting the Proposed Theoretical Framework and Models

In **Chapter 3**, a theoretical framework exploring the factors that influence a child's activity behaviours was proposed (**Figure 3.1**). Of the individual factors proposed, annual household income and new immigrant to Canada status demonstrated limited utility in predicting time- and location-specific SED. In contrast, child age, body composition, and gender were significant predictors of children's SED outcomes across multiple SED-specific-domains.

The physical environment, as defined by both the seasonal climate and neighbourhood-scale BE, were significant predictors of children's SED outcomes, but in surprising ways. While SED was hypothesized to be the lowest in non-winter months, only fall months were associated with reduced SED outcomes in children. Despite seasonal differences in SED results contradicting those hypothesized, season remained a significant predictor of SED in almost all SED domains examined.

Interestingly, in almost all SED-domains examined, neighbourhood scale BE domains were not significant predictors of SED on their own. Yet, as proposed in the model outlining the role of children's demographic factors, climate and season and the BE in shaping SED outcomes of children (**Figure 3.2**), neighbourhood-scale BE features moderated the effect of season on SED outcomes.

As shown in **Figure 3.3**, a model proposing the relationship between parent support and beliefs and a child's own perceptions of these supports and beliefs surrounding year round outdoor-play and children's activity behaviours was outlined. Encouragement of indoor play was associated with increased levels of SED and decreased levels of MVPA, but only in a limited number of weather scenarios presented. Parent limitations of screen time were associated with significantly greater levels of MVPA and lower levels of SED in children in almost all weather scenarios presented. In contrast, encouragement of outdoor play, perceived seasonal affordance of outdoor play, and perceived safety of playing outdoors in cold weather conditions demonstrated no utility in predicting activity behaviour outcomes of children.

In the proposed theoretical framework (**Figure 3.1**) all SBs were presented as a single outcome. Throughout this thesis, SB was examined using SED as it occurred within either temporal or spatial domains. This study's findings suggest that the predictors of SED differ by time and space, and this should be acknowledged within future frameworks.

6.4 Study Strengths and Limitations

This study is unique in its inclusion of device-based measures of children's physical behaviour, geographic location of physical behaviours, survey data exploring multiple demographic factors, climate and weather data, neighbourhood level BE characteristic data, and parent-child dyad perceptions of year-round indoor and outdoor play. Through the use of MLM, individual-, social- and environment-level characteristics were considered simultaneously, adding to the strength of the analyses presented here. Additionally, with the inclusion of compensatory PA, models presented throughout took into consideration the displacement hypothesis, but also with the simultaneous consideration of physical behaviours as they occur in time and place.

A major strength of this study was its year-long longitudinal design, with three collection time points occurring over four seasons. This study utilized objective measures of children's activity behaviours, activity behaviour location, and neighbourhood level attributes. Participants provided up to 21 days of device-based activity data over an entire year, allowing seasonal context to be included in our analyses, all of which provided novel insights into what predicts SED in children. Furthermore, this study provides an understanding of both time and location-specific SED, an aspect absent in much of existing activity behaviour research (259).

The accelerometry units used in this study were designed to capture movement in three planes. The ActiGraph GT3X is designed with no power switch and has a battery life capable of recording 14-21 continuous days of data, a period longer than our collection period of seven days. Integrated device software allowed researcher-controlled start and stop data recording times. These features were critical for promoting participant compliance and deriving non-wear time criteria. Additionally, participants were instructed to wear their accelerometry equipped belts during all waking and sleeping hours and to only remove the device when entering water. The instruction to wear accelerometers during all hours of the day (vs only during waking hours) may have improved wear time compliance (260). While some study participants expressed difficulties wearing their devices during high-energy expenditure sports, such as ice hockey (due to sports equipment around the hip area) and dancing, it is likely that losses to all activity outcomes occurred during non-wear time periods.

This study's population wear time and non-sleep activity peaked from 0830h until 1900h on weekdays and diminished thereafter. It is possible that during the period of 1900-2300h, participants were awake, but accelerometry devices had been removed (i.e. non-wear time). Similarly, it is impossible to know if participants were awake but not wearing their devices on weekend mornings or if they were sleeping until much later periods in the day, as the steady increase in wear time occurred during the entire morning and only peaked at 1200h. In a similarly aged cohort from the same geographic location, accelerometry wear time was consistently lower on weekends and was associated with significantly lower levels of SED on days with reduced wear time (36).

At the time of this study's methodological development Kozey-Keadle et al. (166) publication on the validation of wearable monitors for assessing SB was the most comprehensive validation of SBs using the GT3X accelerometer device. Therefore, despite this validation study using only an adult population, the SB cut-point of <150 cpm was used for all analyses. Additionally, LPA and MVPA cut-points derived from an adult population were used for PA analyses (167). Children have higher metabolic rates in comparison to adults, resulting in higher thresholds of METs for equivalent physical behaviours in adults (261). By using adult PA cut-points this study overestimated MVPA in the child population analyzed. This notion was confirmed by comparing SED, LPA and MVPA outcomes using physical behaviour cut-points used in this study (167) to those derived from child populations and vector magnitude accelerometry outputs (*data not shown*) (66,262). Additionally, the low-frequency extension, developed to increase low-intensity sensitivity in accelerometer models such as the GT3X, was not applied during post-hoc accelerometry data processing (263). Using the cut-points employed in this study, a sensitivity analysis was performed on SED and MVPA outcomes using all valid participant data. A shift of 10% in SED cut-points and 5% in MVPA cut-points resulted in significant differences in the measured physical behaviour outcomes (*data not shown*).

When defining valid wear time criteria, a minimum of 10 hours/day over a minimum of 4 days was chosen for all accelerometry data analyses. Herrmann *et al.* (264) demonstrated that selecting a daily minimum wear time of 10 hours/day (vs 14 hours/day) resulted in a 28% increase in absolute percentage error. In contrast, Rich *et al.* (265) has demonstrated that increasing minimum daily wear time beyond 10 hours showed no benefit to data reliability but increasing the minimum number of days from 4 to this study's possible maximum of 7, improves reliability from 0.93 to 0.96. Within the study population, LPA experienced the greatest loss with reduced wear time, followed by SED and MVPA. In two studies examining the effect of accelerometry wear time on activity outcomes, longer wear times resulted in significantly greater amounts of SED, LPA and MPA (264,266). As Herrmann *et al.* (266) has similarly argued elsewhere, the more relaxed accelerometry validation criteria used in this study resulted in a high degree of participant compliance, but estimated outcomes, and their quality were likely diminished as a result of higher error.

The GPS devices utilized in this study had a limited battery life of approximately 48 hours. During the first collection time point, participants were instructed to turn off the GPS device and charge it during sleeping hours. It is likely that many children failed to turn their devices back on the following morning, resulting in data loss despite attempted compliance. This protocol, which was altered in subsequent collection periods, is the likely cause of reduced valid GPS data points present during the first collection period. To prevent GPS data loss during the second and third collection period, children were instructed to plug in their GPS devices each night but to never turn off their devices. Unlike the ActiGraph GT3X accelerometer, which remains fixed to a belt worn by participants, the Qstarz BT-1000XT Travel Recorder GPS logger sat in a pouch allowing easy removal for charging. Furthermore, the GPS logger was approximately twice the size of the accelerometer used by study participants. The requirement of daily charging, ability to remove the GPS device and bulkier nature of the device may have all contributed to reduced wear time compliance of the GPS device.

For the purpose of developing GPS wear time criteria for this study, any data point acquired during the collection period, regardless of location, was considered wear time. Because study participants were able to separate their two devices, it is impossible to tell if atypical behaviour (*e.g.* GPS data points not entering a school polygon on a weekday) is the result of compliance issues or a participant simply not attending school on a school day. To date, research dedicated to the effect of wear time on GPS data relative to activity outcomes is rare. Studies have primarily taken an approach of adopting accelerometry wear time criteria to GPS data either before or after accelerometry-GPS data merging has taken place (267–269), or failing to report any GPS wear time criteria at all (270–272). The GIS analysis presented in this study utilized the former approach, but required a more relaxed GPS wear time validation criterion (vs that used for accelerometry analysis), to retain an adequate sample size. As with accelerometry wear time, more relaxed criteria likely results in greater error within the sample. Furthermore, because of our limited understanding of GPS wear time patterns, it is unknown if systemic patterns arise during non-wear time periods. Validation studies exploring the effects of GPS-device wear time criterion are warranted to better understand the minimum number of hours per day over the minimum days per week needed to reliably understand children's activity spaces.

When valid accelerometry data points were paired with valid GPS data points at each participant minute, participant minutes classified as SED lacked accompanying GPS data points more than any other physical behaviours (i.e. because no valid GPS data was available to accompany it). The initial requirement to power off and charge the GPS devices each evening likely resulted in home area SED being unaccounted for during these charging periods when children were awake, wearing the accelerometry device and within the home. Timestamps of accelerometry data points with no accompanying GPS data points were not thoroughly examined, which may have indicated if these data points were likely accumulated within the home (i.e. occurring immediately before or after home area-paired physical behaviours).

IMI and NALP measures were included in all MLMs presented in an effort to capture neighbourhood-scale BE features children are exposed to on a daily basis. As children's daily activity spaces were not explored in this study, it is impossible to know if participants were exposed to the neighbourhood-level attributes within their home or school neighbourhoods. A study of 9-13-year-old children residing in London, Ontario revealed that activity spaces are highly variable between children. In this same study population, children with the largest independent mobility domains were afforded greater levels of independent mobility and had unstructured schedules, low screen time levels and low time spent in vehicles (273). Therefore, by considering neither children's activity spaces nor their degree of BE feature exposure, it is probable that the effects of BE features were diminished within our findings.

Items developed in the perceptions of year-round outdoor play questionnaire were not validated, nor was the relationship between items explored beyond simple correlation analysis. The most popular forms of exploratory factor analysis, maximum likelihood method and principal component analysis, both assume data is normally distributed and on an interval scale. Item responses were on an ordinal 4-point Likert scale that demonstrated a non-normal distribution, even after data was centered. Therefore, factor analysis could not be performed.

Neighbourhood-level audits utilizing the NALP and IMI audit tools were conducted over two periods. The majority of neighbourhoods were assessed in 2010, prior to the commencement of the Smart Cities Healthy Kids project. Neighbourhoods undergoing construction and development at the time of the Smart Cities Healthy Kids project or that underwent major changes between 2011 and 2015, were audited between July and August in 2015. All audits occurred during summer months during pleasant weather conditions with no ground cover. While the city of Saskatoon's Sidewalk Clearing Bylaw (no. 8463) states that the owner or occupant of an adjoining property must clear snow, ice or debris from the sidewalk within 48 hours (274), this bylaw was generally enforced through a complaint-driven system at the time of data collection (275). During the data collection period, snow ground cover was recorded during the months of December through February. While snow and ice can create additional hazards within neighbourhood BEs, shoulder seasons, where leaves or snowmelt are commonplace on streets, can create issues of water drainage citywide. While models found that daily snow ground cover did not significantly predict SED in children, daily precipitation was associated with increased SED (*data not shown*). Furthermore, daylight duration was not considered in any of the models presented predicting SED in children. While light exposure, as measured by ambient light sensor-equipped accelerometers, has shown an associated reduction in SED in children (276), it is unclear if SED is a physiological result of reduced light exposure, or more likely an indicator of prolonged time spent indoors, where light is reduced. Using a combination of sunrise, sunset, and cloud cover data, future studies could explore the effects of light exposure on physical behaviour outcomes.

The participants of this study were subject to age-period-cohort effects. While biological age was included in analyses, maturation onset (measured by peak height velocity) was not. In models presented, an increased age of one-year was associated with up to 22 additional minutes of SED/day. It is probable that over the one year of data collection, younger children significantly increased their SED. Although period and cohort effects were not accounted for, the 2012 cross-sectional study, Saskatoon-based Smart Cities Healthy Kids, involving similarly aged children exhibited similar findings in children's activity behaviours on a neighbourhood scale (36,133). It is possible that children in our and the Smart Cities Healthy Kids studies could be classified into the same period as the participants of this study, as study commencement occurred only four years apart.

While we included the IMI safety from crime dimension score to examine the role of social and physical disorder on SED, area-level deprivation was not accounted for nor were actual crime statistics included in these analyses. The cancellation of the Canadian government issued long-form census between 2007 and 2015 did not allow area-level deprivation to be measured in newly developed neighbourhoods of Saskatoon (277).

Location-specific activity behaviour analyses included all public city parks within Saskatoon. City of Saskatoon parks offer a variety of amenities and vary greatly in size, topography and landscape features (251). While parks 'use' was measured, the attributes of individual parks were not. Furthermore, the city of Saskatoon uses multiple zoning designations for public open spaces and adjacent indoor and outdoor facilities. This mixed use of zoning designations within single park area spaces makes conclusions difficult to draw regarding the relationship between park amenities and SED outcomes. Where some parks include city-run outdoor public pools, indoor pools immediately adjacent to parks were not included. Similarly, as described above in **Section 6.1.7**, school ground attributes were not accounted for, all of which may have influenced activity behaviour outcomes between children attending different schools. Additionally, school policies surrounding recess and lunch hour length and policies surrounding mandatory outdoor play were not explored. For example, lunch hour break length can significantly reduce 9-11-year-old children's school hour SED (278).

A major limitation of this study was the small population size of families reporting an annual household income of less than $20,000. When included in analyses presented here, less than 2% of the study population reported an annual household income below $20,000, resulting in predicted effects with large confidence intervals. It is unknown if comparisons made between those living with annual household incomes below and above $20,000 resulted in Type I error, because of the underpowered reference category of an annual household income of <$20,000. At the time of writing, the Government of Canada had no official measure of poverty or a clear definition of the poverty line. Additionally, between October 15, 2018 and January 31, 2019, Statistics Canada was conducting a review of the Market Basket Measure, a tool used to measure poverty (279). The aggregation of study participants with annual household incomes below $40,000 would have improved the power of the reference category, but the theoretical implication of this change remains unclear.

This study sought to understand a broader context of what may influence health (or unhealthy) behaviours in children by examining demographic factors, season and the BE simultaneously. From a population health perspective, the primary goal of this research was to reduce morbidities and mortality associated with what is often labeled as a 'westernized' lifestyle, rife with opportunities for sedentariness and high-caloric diets. While the goal of population health is to shift the levels of PA among targeted populations towards a more healthful state, this may also increase the likelihood of stigmatization of those who do not fall within the so-called ideal healthy lifestyle. The focus on individual and family level covariates increases the risk of further stigmatizing children, and their families, who participate in prolonged SED. Labelling any individual as sedentary is inappropriate, and individuals, "are increasingly advised about our freedom to opt and choose how to conduct our health and our lives, through the management of information about studied, measured and denominated risks," (280). Yet, little is known about how systemic social practices and physical environments, beyond the control of the individual, influence sedentariness. Similar to the stigmatization experienced by those living with obesity (281), sedentariness is viewed as a result of behavioural "choices" of an individual, rather than a complex characteristic of a modern society that does not affect all equally. While this examination of the determinants of SED included individual-level variables, it sought to delineate the role of the physical environment on a neighbourhood level scale.

Differences between the study population and children of a similar age living within Saskatoon and Canada are described in **Section 5.2.1**. The demographic factors which varied between our study population and the city of Saskatoon were included in all models, addressing possible issues of selection bias. Participating children and their parents, homeroom teachers and principals were recruited to the study on a voluntary basis. That is, the study sample (individual, classroom or school level) was not randomly drawn, nor was the study weighted based on Saskatoon population-level data. The study recruitment method makes the likelihood of representativeness unlikely. Given the findings of this study are not in stark contrast to previous publications focused on similar outcomes, it is possible that the results of this study are generalizable, even if the study sample was not representative. As Rothman 2013 argues (282), representativeness is not necessary, absolutely, for a study to be useful, but rather specific knowledge, derived from careful testing of hypotheses and accumulation of statistical inference, are required to achieve study usefulness or generalizability.

Datasets utilized throughout this thesis were not assess for randomness of missing data. Missing data may compromise the, "interpretation, reliability, and generalizability," of findings, leading to the introduction of bias in the study's findings. Missing accelerometry data is additionally problematic in that non-random periods of the day or specific days may be missing entirely (283), yet the data is still considered valid and incorporated into analyses presented, as it was here. Low wear time patterns on weekday and weekend evenings and weekday mornings noted in this study were discussed above. Further, a comparison between participants contributing no valid accelerometry data or incomplete accelerometry data at specific time points were made. Participants only contributing a single time point were made up of a greater proportion of those who did not report their annual household income and those living in fractured-grid neighbourhoods. To better understand if those only contributing one or two valid accelerometry time points (vs all three) introduced error into this study's findings univariate and level 1 main effect models were recreated for all SED domain outcomes analyzed using only participants with three valid accelerometry time points. With the exception of total daily SED, the relative magnitude and direction of beta estimates for the season variable remained unchanged in models predicting leisure and school hour SED and school, school park, and park area SED. In constrast to the models presented in this thesis, fall, but not other seasons, was associated with a significant reduction in total daily SED (univariate model). In a model including level 1 main effects, total daily SED did not differ significantly between seasons (*data not shown*).

6.5 Study Significance and Implications

This study sought to better understand the complex relationship between SED and PA, demographic factors and the social and physical environments, including seasons, that children 9-14 years of age experience year-round. Understanding clearly how SED and PA inter-relate and how this is shaped by time and context in children's day to day lives, is necessary for the development of successful interventions capable of shifting children's health through physical behaviour change. Study participants accumulated, on average, 183 minutes of SED (inclusive of all possible SBs) in their leisure hours per day *(data not shown)*, approximately 1 hour longer than the recommended screen time limits proposed by the CSEP (8). While it is unlikely that a single intervention proposed in this section and above would result in a dramatic 1 hour reduction of children's leisure hour SED, the cumulative effect of both home- and school-environment and neighbourhood-level BE interventions have the potential to dramatically improve our population's health during this critical period of development through the reduction of SED.

A major contribution of this study was the inclusion of compensatory PA behaviours in all time and location-specific SED domain analyses. In its entirety, this study's findings present a new understanding of the physical behaviour displacement hypothesis, but as it occurs in time and place. Furthermore, notable differences in significant predictors between models inclusive and exclusive of PA were discussed in **Section 6.1.8**. Therefore, caution should be used when attempting to draw definitive conclusions between models exclusive and inclusive of other physical behaviours as independent variables.

One of the most striking findings from this study was the associated reduction of SED and increase in MVPA of children whose parents reported limiting screen time. In this study, it is impossible to know if the almost associated equivalent ~30 minutes/day loss in SED was replaced with MVPA in children who experienced screen time limits, but the lack of LPA's association creates a compelling argument to limit screen time use in children within their home environments.

In this study, specific BE features were associated with small, but discernible, changes in SED outcomes of children. For example, children living in neighbourhoods with the highest density of destinations accumulated six fewer minutes of SED/day while in their home area in comparison to their counterparts. Alteration to the BE, such as increasing retail and recreational destinations through infill development, can shift an entire population's health through the reduction of SED. By altering neighbourhood level BEs to improve children's daily activity behaviour patterns, an entire population's activity behaviours, rather than only those deemed as 'high risk' (i.e. those not meeting CSEP's SED and MVPA targets), could be altered, resulting in tangible and quantifiable long-term health benefits.

Many of the BE features examined in this study moderated the effect of season on children's sedentary outcomes. In the majority of these cases, the BEs features were associated with pronounced SED outcome difference in warmer seasons vs winter months. These results suggest that alterations to the BE will result in greater physical behaviour change in the warmest months of the year. Yet, it is unclear if policy-driven interventions specifically targeting BE features in winter conditions could improve our population's energy expenditure in colder months of the year (*e.g.* improved snow and ice clearing, wind reduction, public warming shelters, *etc.*).

Chapter 7 Conclusion

SB research is no longer in its infancy. There is yet much to be done – conceptually, methodologically - in this field to generate reliable and valid evidence that is actionable at the local level. The simultaneous examination of both season and the BE in a one-year longitudinal setting is unique to this study. Focus on SED and taking into account light and moderate-to-vigorous PA, are also not commonly done in previous research. This study highlights the significant increase in sedentariness as children age, emphasizing critical need to understand the determinants of children's physical behaviour during this critical period of development. Knowledge gained from this project will meet the call to understand better what factors drive SED in children (284). Forming a clearer understanding of SED in children is necessary for future successful intervention implementation. Secondly, findings presented here will provide members of the community with an increased awareness of the activity state of Saskatoon's children through knowledge dissemination projects. Finally, this new-found understanding of children's activity behaviours in the context neighbourhood scale BE and seasonality will shape infill and new urban development projects by providing necessary information to relevant public health policy architects, driving urban transformation and healthier cities.

REFERENCES

1. Chen CK, Bruce M, Tyler L, Brown C, Garrett A, Goggins S, et al. Analysis of an environmental exposure health questionnaire in a metropolitan minority population utilizing logistic regression and Support Vector Machines. J Health Care Poor Underserved. 2013 Feb;24(1 Suppl):153–71.

2. WHO | BMI-for-age (5-19 years) [Internet]. WHO. [cited 2017 Oct 5]. Available from: http://www.who.int/growthref/who2007_bmi_for_age/en/

3. de Onis áM, Lobstein T. Defining obesity risk status in the general childhood population: which cut-offs should we use? Int J Pediatr Obes. 2010;5(6):458–460.

4. Windsor U of. What does the term “built environment” mean? Vol. 2014. 2010.

5. Grewal MS, Weill LR, Andrews AP. Global positioning systems, inertial navigation, and integration. John Wiley & Sons; 2007.

6. Martindale J. Research Guides: Mapping and Geographic Information Systems (GIS): What is GIS? [Internet]. University of Wisconsin-Madison Libraries. [cited 2018 Jun 29]. Available from: https://researchguides.library.wisc.edu/c.php?g=178144&p=1169699

7. Boarnet MG, Day K, Alfonzo M, Forsyth A, Oakes M. The Irvine–Minnesota inventory to measure built environments: reliability tests. Am J Prev Med. 2006;30(2):153-159. e43.

8. Canadian Society for Exercise Physiology. Canadian 24-hour movement guidelines: glossary of terms [Internet]. Canadian 24-Hour Movement Guidelines: Glossary of Terms. [cited 2018 Jun 26]. Available from: http://www.csep.ca/en/guidelines/glossary-2017

9. Jette M, Sidney K, Blümchen G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. Clin Cardiol. 1990;13(8):555–565.

10. Hurkmans E, Matthys C, Bogaerts A, Scheys L, Devloo K, Seghers J. Face-to-face versus mobile versus blended weight loss program: randomized clinical trial. JMIR MHealth UHealth. 2018;6(1):e14.

11. Puyau MR, Adolph AL, Vohra FA, Zakeri I, Butte NF. Prediction of activity energy expenditure using accelerometers in children. Med Sci Sports Exerc. 2004;36(9):1625–1631.

12. World Health Organization. NCDs | Physical activity [Internet]. WHO. 2018 [cited 2018 Aug 14]. Available from: http://www.who.int/ncds/prevention/physical-activity/en/

13. Tremblay MS, Aubert S, Barnes JD, Saunders TJ, Carson V, Latimer-Cheung AE, et al. Sedentary Behavior Research Network (SBRN) – Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act. 2017 Jun 10;14(1):75.

14. Pate RR, O'neill JR, Lobelo F. The evolving definition of "sedentary." Exerc Sport Sci Rev. 2008;36(4):173–178.

15. Whitehead M. The concept of physical literacy. In: Physical literacy: throughout the lifecourse. New York, NY: Routledge; 2010. p. 10–20.

16. Consensus Statement [Internet]. Physical Literacy. [cited 2018 Sep 10]. Available from: http://physicalliteracy.ca/physical-literacy/consensus-statement/

17. Shearer C, Goss HR, Edwards LC, Keegan RJ, Knowles ZR, Boddy LM, et al. How is physical literacy defined? A contemporary update. J Teach Phys Educ. 2018 Jul 1;37(3):237–45.

18. Mansoubi M, Pearson N, Clemes SA, Biddle SJ, Bodicoat DH, Tolfrey K, et al. Energy expenditure during common sitting and standing tasks: examining the 1.5 MET definition of sedentary behaviour. BMC Public Health. 2015 May 29;15:516.

19. Barnes J, Behrens TK, Benden ME, Biddle S, Bond D, Brassard P, et al. Letter to the editor: standardized use of the terms "sedentary" and "sedentary behaviours." Appl Physiol Nutr Metab-Physiol Appl Nutr Metab. 2012;37(3):540–542.

20. American Psychology Association. Socioeconomic status [Internet]. http://www.apa.org. [cited 2018 Jun 29]. Available from: http://www.apa.org/topics/socioeconomic-status/index.aspx

21. Biddle SJ, Gorely T, Marshall SJ, Murdey I, Cameron N. Physical activity and sedentary behaviours in youth: issues and controversies. J R Soc Promot Health. 2004 Jan;124(1):29–33.

22. Egger G, Swinburn B. An "ecological" approach to the obesity pandemic. BMJ. 1997 Aug 23;315(7106):477–80.

23. Kohl HW, Craig CL, Lambert EV, Inoue S, Alkandari JR, Leetongin G, et al. The pandemic of physical inactivity: global action for public health. The Lancet. 2012;380(9838):294–305.

24. World Health Organization. Physical inactivity: a global public health problem [Internet]. WHO. [cited 2017 Jun 21]. Available from: http://www.who.int/dietphysicalactivity/factsheet_inactivity/en/

25. Kamath CC, Vickers KS, Ehrlich A, McGovern L, Johnson J, Singhal V, et al. Behavioral interventions to prevent childhood obesity: a systematic review and meta analyses of randomized trials. J Clin Endocrinol Metab. 2008;93(12):4606–15.

26. Canadian Society for Exercise Physiology. Canadian 24-hour movement guidelines and children and youth: an integration of physical activity, sedentary behaviour, and sleep [Internet]. 2016 [cited 2018 Jun 26] p. 2. Available from: http://csepguidelines.ca/wp-content/themes/csep2017/pdf/Canadian24HourMovementGuidelines2016_2.pdf

27. Canadian Paediatric Society. Physical activity and sedentary behaviour in children and youth: a guide for physicians [Internet]. Canadian Paediatric Society. 2018 [cited 2018 Jun 26]. Available from: https://www.cps.ca/uploads/active/AKHK_Guide_Physicians.pdf

28. Department of Health, Australian Government. Australia's physical activity and sedentary behaviour guidelines [Internet]. 2017. Available from: http://www.health.gov.au/internet/main/publishing.nsf/content/health-pubhlth-strateg-phys-act-guidelines#apa512

29. Council on Communications and Media. Children, adolescents, and the media. Pediatrics. 2013 Oct 28;peds.2013-2656.

30. Tremblay MS, Barnes JD, Gonzalez SA, Katzmarzyk PT, Onywera VO, Reilly JJ, et al. Global matrix 2.0: report card grades on the physical activity of children and youth comparing 38 countries. J Phys Act Health. 2016 Nov;13(11 Suppl 2):S343–66.

31. Canadian 24-hour movement guidelines for children and youth [Internet]. [cited 2017 Jul 1]. Available from: https://indd.adobe.com/view/b82b4a90-6e46-4b1a-b628-d53805688baf

32. Tremblay MS, Willms JD. Secular trends in the body mass index of Canadian children. CMAJ Can Med Assoc J J Assoc Medicale Can. 2000 Nov 28;163(11):1429–33.

33. Roberts KC, Yao X, Carson V, Chaput J-P, Janssen I, Tremblay MS. Meeting the Canadian 24-hour movement guidelines for children and youth. Health Rep. 2017;28(10):3–7.

34. Esliger DW, Sherar LB, Muhajarine N. Smart cities, healthy kids: the association between neighbourhood design and children's physical activity and time spent sedentary. Can J Public Health Rev Can Sante Publique. 2012 Jul 26;103(9 Suppl 3):eS22-8.

35. Colley RC, Garriguet D, Janssen I, Craig CL, Clarke J, Tremblay MS. Physical activity of Canadian children and youth: accelerometer results from the 2007 to 2009 Canadian Health Measures Survey. Health Rep. 2011 Mar;22(1):15–23.

36. Katapally TR, Muhajarine N. Towards uniform accelerometry analysis: a standardization methodology to minimize measurement bias due to systematic accelerometer wear-time variation. J Sports Sci Med. 2014;13(2):379.

37. Basterfield L, Adamson AJ, Frary JK, Parkinson KN, Pearce MS, Reilly JJ, et al. Longitudinal study of physical activity and sedentary behavior in children. Pediatrics. 2011 Jan;127(1):e24-30.

38. Santos DA, Júdice PB, Magalhães JP, Correia IR, Silva AM, Baptista F, et al. Patterns of accelerometer-derived sedentary time across the lifespan. J Sports Sci. 2018 May 10;0(0):1–9.

39. Barnes JD, Cameron C, Carson V, Chaput J-P, Colley RC, Faulkner GE, et al. Results from Canada's 2018 report card on physical activity for children and youth. J Phys Act Health. 2018;15(Supplement 2):S328–S330.

40. Gray CE, Barnes JD, Bonne JC, Cameron C, Chaput JP, Faulkner G, et al. Results from Canada's 2014 report card on physical activity for children and youth. J Phys Act Health. 2014 May;11(4 Suppl 1):S26-32.

41. Barnes JD, Cameron C, Carson V, Chaput J-P, Faulkner GEJ, Janson K, et al. Results from Canada's 2016 ParticipACTION report card on physical activity for children and youth. J Phys Act Health. 2016;13(11 Suppl 2):S110–6.

42. Hamilton MT, Healy GN, Dunstan DW, Zderic TW, Owen N. Too little exercise and too much sitting: inactivity physiology and the need for new recommendations on sedentary behavior. Curr Cardiovasc Risk Rep. 2008;2(4):292–8.

43. Dohrn I-M, Kwak L, Oja P, Sjöström M, Hagströmer M. Replacing sedentary time with physical activity: a 15-year follow-up of mortality in a national cohort. Clin Epidemiol. 2018 Jan 25;10:179–86.

44. Stamatakis E, Rogers K, Ding D, Berrigan D, Chau J, Hamer M, et al. All-cause mortality effects of replacing sedentary time with physical activity and sleeping using an isotemporal substitution model: a prospective study of 201,129 mid-aged and older adults. Int J Behav Nutr Phys Act. 2015 Sep 30;12:121.

45. Spanier PA, Marshall SJ, Faulkner GE. Tackling the obesity pandemic: a call for sedentary behaviour research. Can J Public Heal Can Santee Publique. 2006;255–7.

46. van Sluijs EMF, McMinn AM, Griffin SJ. Effectiveness of interventions to promote physical activity in children and adolescents: systematic review of controlled trials. BMJ. 2007 Oct 6;335(7622):703.

47. Azevedo LB, Ling J, Soos I, Robalino S, Ells L. The effectiveness of sedentary behaviour interventions for reducing body mass index in children and adolescents: systematic review and meta-analysis. Obes Rev. 2016;17(7):623–635.

48. Mutz DC, Roberts DF, Vuuren D van. Reconsidering the displacement hypothesis: television's influence on children's time use. Commun Res. 1993;20(1):51–75.

49. Pedišić Ž. Measurement issues and poor adjustments for physical activity and sleep undermine sedentary behaviour research—the focus should shift to the balance between sleep, sedentary behaviour, standing and activity. Kinesiol Int J Fundam Appl Kinesiol. 2014;46(1):135–146.

50. Dumuid D, Stanford TE, Martin-Fernández J-A, Pedišić Ž, Maher CA, Lewis LK, et al. Compositional data analysis for physical activity, sedentary time and sleep research. Stat Methods Med Res. 2018;27(12):3726–3738.

51. Tremblay MS, Colley RC, Saunders TJ, Healy GN, Owen N. Physiological and health implications of a sedentary lifestyle. Appl Physiol Nutr Metab. 2010;35(6):725–40.

52. Tremblay MS, LeBlanc AG, Kho ME, Saunders TJ, Larouche R, Colley RC, et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. Int J Behav Nutr Phys Act. 2011;8(1):98.

53. Pate RR, Wang C-Y, Dowda M, Farrell SW, O'Neill JR. Cardiorespiratory fitness levels among US youth 12 to 19 years of age: findings from the 1999-2002 national health and nutrition examination survey. Arch Pediatr Adolesc Med. 2006 Oct 1;160(10):1005–12.

54. Colley RC, Garriguet D, Janssen I, Wong SL, Saunders TJ, Carson V, et al. The association between accelerometer-measured patterns of sedentary time and health risk in children and youth: results from the Canadian Health Measures Survey. BMC Public Health. 2013 Mar 7;13:200-2458-13–200.

55. Ekelund U, Luan J, Sherar LB, Esliger DW, Griew P, Cooper A, et al. Moderate to vigorous physical activity and sedentary time and cardiometabolic risk factors in children and adolescents. Jama. 2012;307(7):704–12.

56. Proper KI, Singh AS, Mechelen WV, Chinapaw MJ. Sedentary behaviors and health outcomes among adults: a systematic review of prospective studies. Am J Prev Med. 2011;40(2):174–82.

57. Katzmarzyk PT, Church TS, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. Med Sci Sports Exerc. 2009 May;41(5):998–1005.

58. Dunstan DW, Barr EL, Healy GN, Salmon J, Shaw JE, Balkau B, et al. Television viewing time and mortality: the Australian Diabetes, Obesity and Lifestyle Study (AusDiab). Circulation. 2010 Jan 26;121(3):384–91.

59. Utter J, Neumark-Sztainer D, Jeffery R, Story M. Couch potatoes or French fries: are sedentary behaviors associated with body mass index, physical activity, and dietary behaviors among adolescents? J Am Diet Assoc. 2003;103(10):1298–1305.

60. Hamilton MT. The role of skeletal muscle contractile duration throughout the whole day: reducing sedentary time and promoting universal physical activity in all people. J Physiol. 2018;596(8):1331–1340.

61. Lubans DR, Hesketh K, Cliff DP, Barnett LM, Salmon J, Dollman J, et al. A systematic review of the validity and reliability of sedentary behaviour measures used with children and adolescents. Obes Rev. 2011;12(10):781–99.

62. Brodersen NH, Steptoe A, Boniface DR, Wardle J. Trends in physical activity and sedentary behaviour in adolescence: ethnic and socioeconomic differences. Br J Sports Med. 2007 Mar;41(3):140–4.

63. Masse LC, Fuemmeler BF, Anderson CB, Matthews CE, Trost SG, Catellier DJ, et al. Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables. Med Sci Sports Exerc. 2005;37(11):S544.

64. Evenson KR, Jr JWT. Assessment of differing definitions of accelerometer nonwear time. Res Q Exerc Sport. 2009;80(2):355–62.

65. Migueles JH, Cadenas-Sanchez C, Ekelund U, Nyström CD, Mora-Gonzalez J, Löf M, et al. Accelerometer Data Collection and Processing Criteria to Assess Physical Activity and Other Outcomes: A Systematic Review and Practical Considerations. Sports Med. 2017 Mar 16;1–25.

66. Romanzini M, Petroski EL, Ohara D, Dourado AC, Reichert FF. Calibration of ActiGraph GT3X, Actical and RT3 accelerometers in adolescents. Eur J Sport Sci. 2014;14(1):91–99.

67. Healy GN, Matthews CE, Dunstan DW, Winkler EA, Owen N. Sedentary time and cardio-metabolic biomarkers in US adults: NHANES 2003-06. Eur Heart J. 2011 Mar;32(5):590–7.

68. Thorp AA, Owen N, Neuhaus M, Dunstan DW. Sedentary behaviors and subsequent health outcomes in adults: a systematic review of longitudinal studies, 1996–2011. Am J Prev Med. 2011;41(2):207–15.

69. Dumith SC, Gigante DP, Domingues MR, 3rd HWK. Physical activity change during adolescence: a systematic review and a pooled analysis. Int J Epidemiol. 2011 Jun;40(3):685–98.

70. Sleddens EF, Kremers SP, Hughes SO, Cross MB, Thijs C, Vries NKD, et al. Physical activity parenting: a systematic review of questionnaires and their associations with child activity levels. Obes Rev Off J Int Assoc Study Obes. 2012 Nov;13(11):1015–33.

71. Sawka KJ, McCormack GR, Nettel-Aguirre A, Hawe P, Doyle-Baker PK. Friendship networks and physical activity and sedentary behavior among youth: a systematized review. Int J Behav Nutr Phys Act. 2013 Dec 1;10:130-5868-10–130.

72. Roh E, Kim MS. Brain regulation of energy metabolism. Endocrinol Metab Seoul Korea. 2016 Dec;31(4):519–24.

73. Waterland RA. Epigenetic mechanisms affecting regulation of energy balance: many questions, few answers. Annu Rev Nutr. 2014;34:337–55.

74. Rosenbaum M, Knight R, Leibel RL. The gut microbiota in human energy homeostasis and obesity. Trends Endocrinol Metab. 2015;26(9):493–501.

75. Moraes AD, Guerra PH, Menezes PR. The worldwide prevalence of insufficient physical activity in adolescents; a systematic review. Nutr Hosp. 2013;28(3):575–84.

76. Sallis JF, Prochaska JJ, Taylor WC. A review of correlates of physical activity of children and adolescents. Med Sci Sports Exerc. 2000;32(5):963–75.

77. Sallis JF, Taylor WC, Dowda M, Freedson PS, Pate RR. Correlates of vigorous physical activity for children in grades 1 through 12: comparing parent-reported and objectively measured physical activity. Pediatr Exerc Sci. 2002;14(1):30.

78. Sallis JF. Age-related decline in physical activity: a synthesis of human and animal studies. Med Sci Sports Exerc. 2000 Sep;32(9):1598–600.

79. Fakhouri TH, Hughes JP, Brody DJ, Kit BK, Ogden CL. Physical activity and screen-time viewing among elementary school–aged children in the United States from 2009 to 2010. JAMA Pediatr. 2013;167(3):223–9.

80. Hjorth MF, Chaput JP, Michaelsen K, Astrup A, Tetens I, Sjodin A. Seasonal variation in objectively measured physical activity, sedentary time, cardio-respiratory fitness and sleep duration among 8-11 year-old Danish children: a repeated-measures study. BMC Public Health. 2013 Sep 8;13:808-2458-13–808.

81. Brodersen NH, Steptoe A, Williamson S, Wardle J. Sociodemographic, developmental, environmental, and psychological correlates of physical activity and sedentary behavior at age 11 to 12. Ann Behav Med. 2005;29(1):2–11.

82. Kristjansdottir G, Vilhjálmsson R. Sociodemographic differences in patterns of sedentary and physically active behavior in older children and adolescents. Acta Paediatr. 2001;90(4):429–35.

83. Pate RR, Mitchell JA, Byun W, Dowda M. Sedentary behaviour in youth. Br J Sports Med. 2011 Sep;45(11):906–13.

84. Melkevik O, Torsheim T, Iannotti RJ, Wold B. Research Is spending time in screen-based sedentary behaviors associated with less physical activity: a cross national investigation. 2010;

85. Finne E, Bucksch J, Lampert T, Kolip P. Age, puberty, body dissatisfaction, and physical activity decline in adolescents. Results of the German Health Interview and Examination Survey (KiGGS). Int J Behav Nutr Phys Act. 2011;8:119.

86. Jago R. Commentary: Age-related decline in physical activity during adolescence - an opportunity to reflect on intervention design and key research gaps. Int J Epidemiol. 2011 Jun;40(3):699–700.

87. Kukaswadia A, Pickett W, Janssen I. Time since immigration and ethnicity as predictors of physical activity among Canadian youth: a cross-sectional study. PloS One. 2014 Feb 21;9(2):e89509.

88. Shea JM, Beausoleil N. Breaking down 'healthism': barriers to health and fitness as identified by immigrant youth in St. John's, NL, Canada. Sport Educ Soc. 2012;17(1):97–112.

89. Lindsay AC, Sussner KM, Greaney ML, Peterson KE. Influence of social context on eating, physical activity, and sedentary behaviors of Latina mothers and their preschool-age children. Health Educ Behav Off Publ Soc Public Health Educ. 2009 Feb;36(1):81–96.

90. Crossley N. Habit and habitus. Body Soc. 2013;19(2–3):136–61.

91. Ergler CR, Kearns RA, Witten K. Seasonal and locational variations in children's play: implications for wellbeing. Soc Sci Med 1982. 2013 Aug;91:178–85.

92. Jamone L, Ugur E, Cangelosi A, Fadiga L, Bernardino A, Piater J, et al. Affordances in psychology, neuroscience and robotics: a survey. IEEE Trans Cogn Dev Syst. 2016;

93. Bouma AJ, Wilgen P van, Dijkstra A. The barrier-belief approach in the counseling of physical activity. Patient Educ Couns. 2015 Feb;98(2):129–36.

94. Olander EK, Fletcher H, Williams S, Atkinson L, Turner A, French DP. What are the most effective techniques in changing obese individuals' physical activity self-efficacy and behaviour: a systematic review and meta-analysis. Int J Behav Nutr Phys Act. 2013;10(1):1.

95. Puglisi LM, Okely AD, Pearson P, Vialle W. Barriers to increasing physical activity and limiting small screen recreation among obese children. Obes Res Clin Pract. 2010;4(1):e33–40.

96. Drenowatz C, Eisenmann JC, Pfeiffer KA, Welk G, Heelan K, Gentile D, et al. Influence of socio-economic status on habitual physical activity and sedentary behavior in 8- to 11-year old children. BMC Public Health. 2010 Apr 27;10:214-2458-10–214.

97. Ball K, Cleland VJ, Timperio AF, Salmon J, Crawford DA. Socioeconomic position and children's physical activity and sedentary behaviors: longitudinal findings from the CLAN study. J Phys Act Health. 2009 May;6(3):289–98.

98. Hanson MD, Chen E. Socioeconomic status and health behaviors in adolescence: a review of the literature. J Behav Med. 2007;30(3):263–85.

99. Tandon PS, Zhou C, Sallis JF, Cain KL, Frank LD, Saelens BE. Home environment relationships with children's physical activity, sedentary time, and screen time by socioeconomic status. Int J Behav Nutr Phys Act. 2012;9:88.

100. Moore LL, Lombardi DA, White MJ, Campbell JL, Oliveria SA, Ellison RC. Influence of parents' physical activity levels on activity levels of young children. J Pediatr. 1991;118(2):215–9.

101. Beets MW, Cardinal BJ, Alderman BL. Parental social support and the physical activity-related behaviors of youth: a review. Health Educ Behav Off Publ Soc Public Health Educ. 2010 Oct;37(5):621–44.

102. Carson V, Clark M, Berry T, Holt NL, Latimer-Cheung AE. A qualitative examination of the perceptions of parents on the Canadian Sedentary Behaviour Guidelines for the early years. Int J Behav Nutr Phys Act. 2014 May 17;11:65-5868-11–65.

103. Davison K, Cutting TM, Birch LL. Parent's activity-related parenting practices predict girls' physical activity. Psychobiology and behavioral strategies. Med Sci Sports Exerc. 2003;35(9):1589–95.

104. Brunet J, Sabiston CM, O'Loughlin J, Mathieu ME, Tremblay A, Barnett TA, et al. Perceived parental social support and moderate-to-vigorous physical activity in children at risk of obesity. Res Q Exerc Sport. 2014 Jun;85(2):198–207.

105. Marzi I, Demetriou Y, Reimers AK. Social and physical environmental correlates of independent mobility in children: a systematic review taking sex/gender differences into account. Int J Health Geogr. 2018 Jul 3;17(1):24.

106. Aggio D, Gardner B, Roberts J, Johnstone J, Stubbs B, Williams G, et al. Correlates of children's independent outdoor play: Cross-sectional analyses from the Millennium Cohort Study. Prev Med Rep. 2017 Dec 1;8:10–4.

107. Stone MR, Faulkner GE, Mitra R, Buliung RN. The freedom to explore: examining the influence of independent mobility on weekday, weekend and after-school physical activity behaviour in children living in urban and inner-suburban neighbourhoods of varying socioeconomic status. Int J Behav Nutr Phys Act. 2014 Jan 22;11:5-5868-11–5.

108. Encyclopedia Britannica. Season | meteorological division [Internet]. Encyclopedia Britannica. [cited 2019 May 27]. Available from: https://www.britannica.com/science/season

109. Fisher A, Reilly JJ, Montgomery C, Kelly LA, Williamson A, Jackson DM, et al. Seasonality in physical activity and sedentary behavior in young children. Pediatr Exerc Sci. 2005;17(1).

110. Shen B, Alexander G, Milberger S, Jen K-LC. An exploratory study of seasonality and preschoolers' physical activity engagement. J Phys Act Health. 2013;10(7).

111. King AC, Parkinson KN, Adamson AJ, Murray L, Besson H, Reilly JJ, et al. Correlates of objectively measured physical activity and sedentary behaviour in English children. Eur J Public Health. 2011 Aug;21(4):424–31.

112. Pearce MS, Basterfield L, Mann KD, Parkinson KN, Adamson AJ, Reilly JJ, et al. Early predictors of objectively measured physical activity and sedentary behaviour in 8-10 year old children: the Gateshead Millennium Study. PloS One. 2012;7(6):e37975.

113. Silva P, Santos R, Welk G, Mota J. Seasonal differences in physical activity and sedentary patterns: the relevance of the PA context. J Sports Sci Med. 2011;10(1):66.

114. Chan CB, Ryan DA. Assessing the effects of weather conditions on physical activity participation using objective measures. Int J Environ Res Public Health. 2009;6(10):2639–54.

115. Gordon-Larsen P, McMurray RG, Popkin BM. Determinants of adolescent physical activity and inactivity patterns. Pediatrics. 2000 Jun;105(6):E83.

116. Nilsson A, Anderssen SA, Andersen LB, Froberg K, Riddoch C, Sardinha LB, et al. Between-and within-day variability in physical activity and inactivity in 9-and 15-year-old European children. Scand J Med Sci Sports. 2009;19(1):10–8.

117. Goodman A, Paskins J, Mackett R. Day length and weather effects on children's physical activity and participation in play, sports, and active travel. J Phys Act Health. 2012 Nov;9(8):1105–16.

118. Belanger M, Gray-Donald K, O'Loughlin J, Paradis G, Hanley J. Influence of weather conditions and season on physical activity in adolescents. Ann Epidemiol. 2009 Mar;19(3):180–6.

119. Yildirim M, Schoeni A, Singh AS, Altenburg TM, Brug J, Bourdeaudhuij ID, et al. Daily Variations in Weather and the Relationship With Physical Activity and Sedentary Time in European 10- to 12-Year-Olds: The ENERGY-Project. J Phys Act Health. 2014 Feb;11(2):419–25.

120. Harrison F, Goodman A, van Sluijs EM, Andersen LB, Cardon G, Davey R, et al. Weather and children's physical activity; how and why do relationships vary between countries? Int J Behav Nutr Phys Act. 2017;14(1):74.

121. Sallis JF. Measuring physical activity environments: a brief history. Am J Prev Med. 2009 Apr;36(4 Suppl):S86-92.

122. McCormack GR, Shiell A. In search of causality: a systematic review of the relationship between the built environment and physical activity among adults. Int J Behav Nutr Phys Act. 2011 Nov 13;8:125-5868-8–125.

123. Trudel M, Cragg S. Neighbourhood active living potential measurement tool. Canadian Fitness and Lifestyle Research Institute; 2008. Report No.: Version 1.1.

124. Gauvin L, Riva M, Barnett T, Richard L, Craig CL, Spivock M, et al. Association between neighborhood active living potential and walking. Am J Epidemiol. 2008 Apr 15;167(8):944–53.

125. Boarnet MG, Forsyth A, Day K, Oakes JM. The street level built environment and physical activity and walking: results of a predictive validity study for the Irvine Minnesota Inventory. Environ Behav. 2011;0013916510379760.

126. Kirtland KA, Porter DE, Addy CL, Neet MJ, Williams JE, Sharpe PA, et al. Environmental measures of physical activity supports: perception versus reality. Am J Prev Med. 2003;24(4):323–31.

127. Gebel K, Bauman AE, Sugiyama T, Owen N. Mismatch between perceived and objectively assessed neighborhood walkability attributes: prospective relationships with walking and weight gain. Health Place. 2011 Mar;17(2):519–24.

128. Ball K, Jeffery RW, Crawford DA, Roberts RJ, Salmon J, Timperio AF. Mismatch between perceived and objective measures of physical activity environments. Prev Med. 2008 Sep;47(3):294–8.

129. Villanueva K, Pereira G, Knuiman M, Bull F, Wood L, Christian H, et al. The impact of the built environment on health across the life course: design of a cross-sectional data linkage study. BMJ Open. 2013 Jan 16;3(1):10.1136/bmjopen-2012–002482.

130. Giles-Corti B, Wood G, Pikora T, Learnihan V, Bulsara M, VanNiel K, et al. School site and the potential to walk to school: the impact of street connectivity and traffic exposure in school neighborhoods. Health Place. 2011;17(2):545–50.

131. Veitch J, Timperio A, Crawford D, Abbott G, Giles-Corti B, Salmon J. Is the neighbourhood environment associated with sedentary behaviour outside of school hours among children? Ann Behav Med. 2011;41(3):333–41.

132. Roemmich JN, Epstein LH, Raja S, Yin L. The neighborhood and home environments: disparate relationships with physical activity and sedentary behaviors in youth. Ann Behav Med. 2007;33(1):29–38.

133. Katapally TR, Rainham D, Muhajarine N. Factoring in weather variation to capture the influence of urban design and built environment on globally recommended levels of moderate to vigorous physical activity in children. BMJ Open. 2015 Nov 30;5(11):e009045-2015–009045.

134. Lachowycz K, Jones AP, Page AS, Wheeler BW, Cooper AR. What can global positioning systems tell us about the contribution of different types of urban greenspace to children's physical activity? Health Place. 2012 May;18(3):586–94.

135. Schaefer L, Plotnikoff RC, Majumdar SR, Mollard R, Woo M, Sadman R, et al. Outdoor time is associated with physical activity, sedentary time, and cardiorespiratory fitness in youth. J Pediatr. 2014 Sep;165(3):516–21.

136. Stone MR, Faulkner GE. Outdoor play in children: associations with objectively-measured physical activity, sedentary behavior and weight status. Prev Med. 2014 Aug;65:122–7.

137. Carson V, Kuhle S, Spence JC, Veugelers PJ. Parents' perception of neighbourhood environment as a determinant of screen time, physical activity and active transport. Can J Public Heal Can Santee Publique. 2010;124–7.

138. Schoeppe S, Duncan MJ, Badland H, Oliver M, Curtis C. Associations of children's independent mobility and active travel with physical activity, sedentary behaviour and weight status: A systematic review. J Sci Med Sport. 2013;16(4):312–9.

139. Panter JR, Jones AP, Sluijs EM van. Environmental determinants of active travel in youth: a review and framework for future research. Int J Behav Nutr Phys Act. 2008 Jun 23;5:34-5868-5–34.

140. O'Connor J, Brown A. A qualitative study of "fear" as a regulator of children's independent physical activity in the suburbs. Health Place. 2013;24 No:157–64.

141. Giblin S, Collins D, Button C. Physical literacy: importance, assessment and future directions. Sports Med. 2014;44(9):1177–1184.

142. Webber J. What is existentialism? In: Rethinking Existentialism. Oxford University Press; 2018. p. 1–16.

143. Smith DW. Phenomenology. In: Zalta EN, editor. The Stanford Encyclopedia of Philosophy [Internet]. Summer 2018. Metaphysics Research Lab, Stanford University; 2018 [cited 2018 Sep 10]. Available from: https://plato.stanford.edu/archives/sum2018/entries/phenomenology/

144. Rhodes RE, Stearns J, Berry T, Faulkner G, Latimer-Cheung AE, O'Reilly N, et al. Predicting parental support and parental perceptions of child and youth movement behaviors. Psychol Sport Exerc. 2019 Mar 1;41:80–90.

145. Chastin SFM, De Craemer M, Lien N, Bernaards C, Buck C, Oppert J-M, et al. The SOS-framework (Systems of Sedentary behaviours): an international transdisciplinary consensus framework for the study of determinants, research priorities and policy on sedentary behaviour across the life course: a DEDIPAC-study. Int J Behav Nutr Phys Act. 2016 Jul 15;13(1):83.

146. Edgerton JD, Roberts LW. Cultural capital or habitus? Bourdieu and beyond in the explanation of enduring educational inequality. Sch Field. 2014 Jul 1;12(2):193–220.

147. Weinstein N. Human Motivation and Interpersonal Relationships : Theory, Research, and Applications. Springer; 2014.

148. Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJ, Martin BW. Correlates of physical activity: why are some people physically active and others not? The Lancet. 2012;380(9838):258–71.

149. Cairney J, Kwan MY, Velduizen S, Hay J, Bray SR, Faught BE. Gender, perceived competence and the enjoyment of physical education in children: a longitudinal examination. Int J Behav Nutr Phys Act. 2012 Mar 6;9:26.

150. Stockie ML. The Relationship Between Socioeconomic Status and Physical Activity Among Adolescents [Internet]. 2009. Available from: http://scholars.wlu.ca/cgi/viewcontent.cgi?article=1951&context=etd

151. Ferreira I, Horst KVD, Wendel-Vos W, Kremers S, Lenthe FJV, Brug J. Environmental correlates of physical activity in youth–a review and update. Obes Rev. 2007;8(2):129–54.

152. Government of Canada SC. Census Profile, 2016 Census - Saskatoon [Census metropolitan area], Saskatchewan and Ontario [Province] [Internet]. 2017 [cited 2017 Sep 18]. Available from: http://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/details/page.cfm?Lang=E&Geo1=CMACA&Code1=725&Geo2=PR&Code2=35&Data=Count&SearchText=Saskatoon&SearchType=Begins&SearchPR=01&B1=All&TABID=1

153. Paul AH. Chapter 3: Climate and Weather. In: Thraves BD, Lewry ML, Dale JE, Schlichtmann H, editors. Saskatchewan: Geographic Perspective. Regina: Canadian Plains Research Center; 2007. p. 37-38–44.

154. Canada E. Canadian Climate Normals 1971-2000 Station Data (Saskatoon Diefenbacker International Airport, Saskatchewan). 2014.

155. Ross NA, Tremblay S, Khan S, Crouse D, Tremblay M, Berthelot JM. Body mass index in urban Canada: neighborhood and metropolitan area effects. Am J Public Health. 2007 Mar;97(3):500–8.

156. Muhajarine N, Smart Cities HKRT. Planning for growth in Saskatoon: past, present and future. Vol. 2014. 2012.

157. Galston R. The accidental beauty of Winnipeg's street system. Spectator Tribune [Internet]. 2012 Dec 18 [cited 2019 May 31]; Available from: https://www.spectatortribune.com/the-accidental-beauty-of-winnipegs-street-system/

158. Querengesser T. Street repairs. Canadian Geographic. 2019 Jun;56 – +62.

159. Southworth M, Owens PM. The evolving metropolis: studies of community, neighborhood, and street form at the urban edge. J Am Plann Assoc. 1993;59(3):271–287.

160. Wheeler SM. Built Landscapes of Metropolitan Regions: An International Typology. J Am Plann Assoc. 2015 Jul 3;81(3):167–90.

161. Canada Mortgage and Housing Corporation. Residential street pattern design fused grid applications. 2004. Report No.: NA9053.S7 R47.

162. Canada Mortgage and Housing Corporation. Policy and Research Division. Breaking ground : a fused grid neighbourhood in Calgary [Internet]. 2008. Report No.: CA1 MH113 08H020. Available from: ftp://ftp.cmhc-schl.gc.ca/chic-ccdh/RHSE-PenRSE/66337.pdf

163. SPHERU. Smart Cities, Healthy Kids (Working upstream: effecting healthy children through neighbourhood design). Vol. 2014. 2013.

164. Heil DP. Predicting activity energy expenditure using the Actical® activity monitor. Res Q Exerc Sport. 2006;77(1):64–80.

165. Chinapaw MJ, Niet M de, Verloigne M, Bourdeaudhuij ID, Brug J, Altenburg TM. From sedentary time to sedentary patterns: accelerometer data reduction decisions in youth. PloS One. 2014 Nov 4;9(11):e111205.

166. Kozey-Keadle S, Libertine A, Lyden K, Staudenmayer J, Freedson PS. Validation of wearable monitors for assessing sedentary behavior. Med Sci Sports Exerc. 2011;43(8):1561–7.

167. Vanhelst J, Mikulovic J, Bui-Xuan G, Dieu O, Blondeau T, Fardy P, et al. Comparison of two ActiGraph accelerometer generations in the assessment of physical activity in free living conditions. BMC Res Notes. 2012;5(1):187.

168. QGIS Development Team. QGIS Geographic Information System [Internet]. Open Source Geospatial Foundation Project; Available from: http://qgis.osgeo.org

169. R Core Team. R: A language and environment for statistical computing [Internet]. Vienna, Austria: R Foundation for Statistical Computing; 2018. Available from: https://www.R-project.org/

170. RStudio Team. RStudio: Integrated Development Environment for R [Internet]. Boston, MA: RStudio, Inc.; 2016. Available from: http://www.rstudio.com/

171. Pebesma EJ, Bivand RS. Classes and methods for spatial data in R. R News. 2005 Nov;5(2):9–13.

172. Pebesma E. Simple Features for R: Standardized Support for Spatial Vector Data. R J [Internet]. 2018; Available from: https://journal.r-project.org/archive/2018/RJ-2018-009/index.html

173. Rebholz CE, Chinapaw MJ, Stralen MM van, Bere E, Bringolf B, Bourdeaudhuij ID, et al. Agreement between parent and child report on parental practices regarding dietary, physical activity and sedentary behaviours: the ENERGY cross-sectional survey. BMC Public Health. 2014;14(1):918.

174. Saelens BE, Sallis JF, Black JB, Chen D. Neighborhood-based differences in physical activity: an environment scale evaluation. Am J Public Health. 2003 Sep;93(9):1552–8.

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

176. Research AL. Irvine Minnesota Inventory. 2015.

177. Fuller DL, Muhajarine N. Replication of the neighborhood active living potential measure in Saskatoon, Canada. Am J Prev Med. 2010;39(4):364–7.

178. Canada E and CC. Historical Climate Data - Climate - Environment and Climate Change Canada [Internet]. 2011 [cited 2017 Sep 28]. Available from: http://climate.weather.gc.ca/

179. Government of Canada. Canadian Climate Normals 1981-2010 Station Data [Internet]. 2013 [cited 2017 Sep 30]. Available from: http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=saskatoon&searchMethod=contains&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=3328&dispBack=0

180. Canada E and CC. Monthly Climate Summaries - Climate - Environment and Climate Change Canada [Internet]. 2011 [cited 2017 Sep 30]. Available from: http://climate.weather.gc.ca/prods_servs/cdn_climate_summary_e.html

181. Defining Seasons [Internet]. [cited 2017 Sep 28]. Available from: https://www.timeanddate.com/calendar/aboutseasons.html

182. Wickham H, Francois R, Henry L, Müller K. dplyr: A Grammar of Data Manipulation [Internet]. 2017. Available from: https://CRAN.R-project.org/package=dplyr

183. Wickham H. tidyr: Easily Tidy Data with “spread()” and “gather()” Functions [Internet]. Available from: https://CRAN.R-project.org/package=tidyr

184. Grolemund G, Wickham H. Dates and Times Made Easy with {lubridate}. J Stat Softw. 2011;40(3):1–25.

185. Knowles JE. eeptools: Convenience Functions for Education Data [Internet]. 2016. Available from: https://CRAN.R-project.org/package=eeptoolshttps://CRAN.R-project.org/package=eeptools

186. Fox J, Hong J. Effect Displays in R for Multinomial and Proportional-Odds Logit Models: Extensions to the effects Package. J Stat Softw. 2009;32(1):1–24.

187. Hlavac M. stargazer: Well-Formatted Regression and Summary Statistics Tables [Internet]. Cambridge, USA: Harvard University; 2015. Available from: http://CRAN.R-project.org/package=stargazer

188. Pinheiro J, Bates D, DebRoy S, Sarkar D. {nlme}: Linear and Nonlinear Mixed Effects Models [Internet]. 2017. Available from: https://CRAN.R-project.org/package=nlme

189. Allaire JJ, Horner J, Marti V, Porte N. markdown: “Markdown” Rendering for R [Internet]. 2015. Available from: https://CRAN.R-project.org/package=markdown

190. Revelle W. psych: Procedures for Psychological, Psychometric, and Personality Research [Internet]. Evanston, Illinois: Northwestern University; 2017. Available from: https://CRAN.R-project.org/package=psych

191. Ooms J, James D, DebRoy S, Wickham H, Horner J. RMySQL: Database Interface and "MySQL" Driver for R [Internet]. 2017. Available from: https://CRAN.R-project.org/package=RMySQL

192. Wickham H. stringr: Simple, Consistent Wrappers for Common String Operations [Internet]. 2017. Available from: https://CRAN.R-project.org/package=stringr

193. Dragulescu AA. xlsx: Read, write, format Excel 2007 and Excel 97/2000/XP/2003 files [Internet]. 2014. Available from: {https://CRAN.R-project.org/package=xlsx

194. Wickham H. ggplot2: Elegant Graphics for Data Analysis [Internet]. New York, NY: Springer-Verlag; 2009. Available from: http://ggplot2.org

195. WHO | Application tools [Internet]. WHO. [cited 2017 Oct 5]. Available from: http://www.who.int/growthref/tools/en/

196. Colley RC, Michaud I, Garriguet D. Reallocating time between sleep, sedentary and active behaviours: Associations with obesity and health in Canadian adults. Health Rep. 2018;29(4):3–13.

197. Statistics Canada. Canada [Country] and Saskatoon, CY [Census subdivision], Saskatchewan (table). Census Profile. 2016 Census. [Internet]. Ottawa, Ontario; 2017 Nov. Report No.: Statistics Canada Catalogue no. 98-316-X2016001. Available from: https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/prof/index.cfm?Lang=E

198. Modupalli K, Cushon J, Neudorf C. 2010/2011 Student Health Survey: Evidence for Action [Internet]. Saskatoon, Canada: Saskatoon: Saskatoon Health Region; 2013 [cited 2018 Oct 17]. (Student Health Survey: Evidence for Action). Available from: https://www.saskatoonhealthregion.ca/locations_services/Services/Health-Observatory/Documents/Reports-Publications/studenthealthsurveyReportFINAL.pdf

199. Statistics Canada. Table 13-10-0797-01 Measured children and youth body mass index (BMI) (Cole classification), by age group and sex, Canada and provinces, Canadian Community Health Survey - Nutrition [Internet]. Available from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1310079701

200. Statistics Canada. Immigrant Status and Period of Immigration (11), Place of Birth (272), Age (7A) and Sex (3) for the Population in Private Households of Canada, Provinces and Territories, Census Divisions and Census Subdivisions, 2016 Census - 25% Sample Data. Ottawa, Ontario; 2017 Oct. Report No.: 98-400-X2016185.

201. Taylor S, Curry W, Knowles Z, Noonan R, McGrane B, Fairclough S, et al. Predictors of Segmented School Day Physical Activity and Sedentary Time in Children from a Northwest England Low-Income Community. Int J Environ Res Public Health. 2017 May 16;14(5):534.

202. Epstein LH, Roemmich JN, Paluch RA, Raynor HA. Physical activity as a substitute for sedentary behavior in youth. Ann Behav Med. 2005 Jun 1;29(3):200–9.

203. Herman KM, Sabiston CM, Mathieu ME, Tremblay A, Paradis G. Sedentary behavior in a cohort of 8- to 10-year-old children at elevated risk of obesity. Prev Med. 2014 Mar;60:115–20.

204. Ridgers ND, Timperio A, Cerin E, Salmon J. Compensation of Physical Activity and Sedentary Time in Primary School Children: Med Sci Sports Exerc. 2014 Aug;46(8):1564–9.

205. Pearson N, Braithwaite RE, Biddle SJ, Van ES, Atkin AJ. Associations between sedentary behaviour and physical activity in children and adolescents: a meta-analysis., Associations between sedentary behaviour and physical activity in children and adolescents: a meta-analysis. Obes Rev Off J Int Assoc Study Obes Obes Rev. 2014 Aug;15, 15(8, 8):666, 666–75.

206. Saint-Maurice P, Bai Y, Vazou S, Welk G. Youth Physical Activity Patterns During School and Out-of-School Time. Children. 2018;5(9):118.

207. Croston A, Hills LA. The challenges of widening ‘legitimate’ understandings of ability within physical education. Sport Educ Soc. 2017 Jul 4;22(5):618–34.

208. Azzarito L, Solomon MA. A reconceptualization of physical education: The intersection of gender/race/social class. Sport Educ Soc. 2005 Mar 1;10(1):25–47.

209. Fairclough SJ, Stratton G. A Review of Physical Activity Levels during Elementary School Physical Education. J Teach Phys Educ. 2006 Apr;25(2):240–58.

210. Fairclough S, Stratton G. Physical Activity Levels in Middle and High School Physical Education: A Review. Pediatr Exerc Sci. 2005 Aug;17(3):217–36.

211. Borghese MM, Janssen I. Duration and intensity of different types of physical activity among 10-13 year olds. Can J Public Health. 2018;1–9.

212. Mitra R, Faulkner GE, Buliung RN, Stone MR. Do parental perceptions of the neighbourhood environment influence children’s independent mobility? Evidence from Toronto, Canada. Urban Stud. 2014;51(16):3401–3419.

213. He M, Piché L, Beynon C, Harris S. Screen-related sedentary behaviours: Children’s and parents’ attitudes, motivations, and practices. J Nutr Educ Behav. 2010;42(1):17–25.

214. Sisson SB, Broyles ST, Baker BL, Katzmarzyk PT. Television, reading, and computer time: correlates of school-day leisure-time sedentary behavior and relationship with overweight in children in the U.S. J Phys Act Health. 2011 Sep;8(s2):S188–97.

215. Liou YM, Liou T-H, Chang L-C. Obesity among adolescents: sedentary leisure time and sleeping as determinants. J Adv Nurs. 2010 Jun 1;66(6):1246–56.

216. Katapally TR, Laxer RE, Qian W, Leatherdale ST. Do school physical activity policies and programs have a role in decreasing multiple screen time behaviours among youth? Prev Med. 2018 May 1;110:106–13.

217. Cairney J, Veldhuizen S, Kwan M, Hay J, Faught BE. Biological age and sex-related declines in physical activity during adolescence. Med Sci Sports Exerc. 2014 Apr;46(4):730–5.

218. Bacil EDA, Piola TS, Watanabe PI, Silva MP da, Legnani RFS, Campos W de, et al. Biological maturation and sedentary behaviour in children and adolescents: a systematic review. J Phys Educ [Internet]. 2016 [cited 2018 Mar 16];27. Available from: http://www.scielo.br/scielo.php?script=sci_abstract&pid=S2448-24552016000100204&lng=en&nrm=iso&tlng=en

219. Mooses K, Mägi K, Riso E-M, Kalma M, Kaasik P, Kull M. Objectively measured sedentary behaviour and moderate and vigorous physical activity in different school subjects: a cross-sectional study. BMC Public Health. 2017 Dec;17(1):108.

220. Gately P. Physical literacy and obesity. In: Physical Literacy. Routledge; 2010. p. 103–119.

221. Pont SJ, Puhl R, Cook SR, Slusser W, Obesity SO, Society TO. Stigma Experienced by Children and Adolescents With Obesity. Pediatrics. 2017 Dec 1;140(6):e20173034.

222. Lynagh M, Cliff K, Morgan PJ. Attitudes and Beliefs of Nonspecialist and Specialist Trainee Health and Physical Education Teachers Toward Obese Children: Evidence for “Anti-Fat” Bias. J Sch Health. 2015;85(9):595–603.

223. Rainham DG, Bates CJ, Blanchard CM, Dummer TJ, Kirk SF, Shearer CL. Spatial classification of youth physical activity patterns. Am J Prev Med. 2012 May;42(5):e87-96.

224. Olds T, Wake M, Patton G, Ridley K, Waters E, Williams J, et al. How do school-day activity patterns differ with age and gender across adolescence? J Adolesc Health. 2009;44(1):64–72.

225. Brazendale K, Beets MW, Weaver RG, Pate RR, Turner-McGrievy GM, Kaczynski AT, et al. Understanding differences between summer vs. school obesogenic behaviors of children: the structured days hypothesis. Int J Behav Nutr Phys Act. 2017 Jul 26;14:100.

226. Clemens SL, Lincoln DJ. Where children play most: physical activity levels of school children across four settings and policy implications. Aust N Z J Public Health. 2018;

227. Arundell L, Fletcher E, Salmon J, Veitch J, Hinkley T. A systematic review of the prevalence of sedentary behavior during the after-school period among children aged 5-18 years. Int J Behav Nutr Phys Act. 2016 Aug 22;13:93.

228. Evans EW, Bond DS, Pierre DF, Howie WC, Wing RR, Jelalian E. Promoting health and activity in the summer trial: Implementation and outcomes of a pilot study. Prev Med Rep. 2018 Jun 1;10:87–92.

229. Katapally TR, Muhajarine N. Capturing the interrelationship between objectively measured physical activity and sedentary behaviour in children in the context of diverse environmental exposures. Int J Environ Res Public Health. 2015;12(9):10995–11011.

230. Day K, Boarnet M, Alfonzo M. Irvine Minnesota Inventory for observation of physical environment features linked to physical activity. Codebook. [Internet]. Available from: https://webfiles.uci.edu/kday/public/Final_Codebook.2.pdf

231. Gauvin L, Richard L, Craig CL, Spivock M, Riva M, Forster M, et al. From walkability to active living potential: an "ecometric" validation study. Am J Prev Med. 2005;28(2):126–133.

232. Maitland C, Stratton G, Foster S, Braham R, Rosenberg M. A place for play? The influence of the home physical environment on children's physical activity and sedentary behaviour. Int J Behav Nutr Phys Act. 2013;10(1):99.

233. Boone-Heinonen J, Gordon-Larsen P, Guilkey DK, Jacobs DR, Popkin BM. Environment and Physical Activity Dynamics: The Role of Residential Self-selection. Psychol Sport Exerc. 2011 Jan 1;12(1):54–60.

234. Rodriguez DA. Active travel: the role of self-selection in explaining the effect of built environment on active travel [Internet]. Active Living Research; 2009. Available from: http://activelivingresearch.org/active-travel-role-self-selection-explaining-effect-built-environment-active-travel

235. Cao X, Handy SL, Mokhtarian PL. The influences of the built environment and residential self-selection on pedestrian behavior: evidence from Austin, TX. Transportation. 2006;33(1):1–20.

236. Colley RC, Carson V, Garriguet D, Janssen I, Roberts KC, Tremblay MS. Physical activity of Canadian children and youth, 2007 to 2015. Health Rep. 2017 Oct;28(10):8–16.

237. Loucaides CA, Chedzoy SM, Bennett N. Differences in physical activity levels between urban and rural school children in Cyprus. Health Educ Res. 2004 Apr 1;19(2):138–47.

238. Williams GC, Borghese MM, Janssen I. Neighborhood walkability and objectively measured active transportation among 10–13 year olds. J Transp Health. 2018 Mar 1;8:202–9.

239. Bundy AC, Luckett T, Tranter PJ, Naughton GA, Wyver SR, Ragen J, et al. The risk is that there is 'no risk': a simple, innovative intervention to increase children's activity levels. Int J Early Years Educ. 2009;17(1):33–45.

240. Weir LA, Etelson D, Brand DA. Parents’ perceptions of neighborhood safety and children’s physical activity. Prev Med. 2006;43(3):212–7.

241. Gómez JE, Johnson BA, Selva M, Sallis JF. Violent crime and outdoor physical activity among inner-city youth. Prev Med. 2004 Nov 1;39(5):876–81.

242. McGinn AP, Evenson KR, Herring AH, Huston SL, Rodriguez DA. The Association of Perceived and Objectively Measured Crime With Physical Activity: A Cross-Sectional Analysis. J Phys Act Health. 2008 Jan;5(1):117–31.

243. Veitch J, Salmon J, Ball K. Children’s active free play in local neighborhoods: a behavioral mapping study. Health Educ Res. 2008 Oct;23(5):870–9.

244. Shearer C, Blanchard C, Kirk S, Lyons R, Dummer T, Pitter R, et al. Physical activity and nutrition among youth in rural, suburban and urban neighbourhood types. Can J Public Health Rev Can Sante Publique. 2012 Jul 26;103(9 Suppl 3):eS55-60.

245. Escalante Y, García-Hermoso A, Backx K, Saavedra JM. Playground designs to increase physical activity levels during school recess: a systematic review. Health Educ Behav. 2014;41(2):138–144.

246. Hunter RF, Christian H, Veitch J, Astell-Burt T, Hipp JA, Schipperijn J. The impact of interventions to promote physical activity in urban green space: a systematic review and recommendations for future research. Soc Sci Med. 2015;124:246–256.

247. Tandy CA. Children’s Diminishing Play Space: a Study of Inter-generational Change in Children’s Use of their Neighbourhoods. Aust Geogr Stud. 1999;37(2):154–164.

248. Veitch J, Bagley S, Ball K, Salmon J. Where do children usually play? A qualitative study of parents’ perceptions of influences on children’s active free-play. Health Place. 2006 Dec 1;12(4):383–93.

249. Carver A, Timperio A, Crawford D. Playing it safe: The influence of neighbourhood safety on children’s physical activity—A review. Health Place. 2008 Jun 1;14(2):217–27.

250. Foster S, Giles-Corti B. The built environment, neighborhood crime and constrained physical activity: An exploration of inconsistent findings. Prev Med. 2008 Sep 1;47(3):241–51.

251. City of Saskatoon. Park Locations & Facilities [Internet]. Saskatoon.ca. 2018 [cited 2018 Oct 11]. Available from: https://www.saskatoon.ca/parks-recreation-attractions/parks/park-locations-facilities

252. Leung W. Limited screen time, adequate physical activity and sleep associated with improved cognition for kids: study - The Globe and Mail. The Globe and Mail [Internet]. 2018 Sep 26 [cited 2018 Oct 11]; Available from: https://www.theglobeandmail.com/canada/article-adequate-physical-activity-and-sleep-limited-screen-time-associated/

253. Canadian Paediatric Society. Screen time and young children: Promoting health and development in a digital world | Canadian Paediatric Society [Internet]. 2017 [cited 2018 Oct 11]. Available from: https://www.cps.ca/en/documents/position/screen-time-and-young-children

254. Follow the Guidelines, Reap the Rewards [Internet]. ParticipACTION. 2018 [cited 2018 Oct 11]. Available from: https://www.participaction.com/en-ca/thought-leadership/benefits-and-guidelines

255. Hawi NS, Rupert MS. Impact of e-Discipline on Children's Screen Time. Cyberpsychology Behav Soc Netw. 2015 Jun 1;18(6):337–42.

256. Karsten L. It all used to be better? Different generations on continuity and change in urban children's daily use of space. Child Geogr. 2005 Dec;3(3):275–90.

257. Gray C, Gibbons R, Larouche R, Sandseter EBH, Bienenstock A, Brussoni M, et al. What Is the Relationship between Outdoor Time and Physical Activity, Sedentary Behaviour, and Physical Fitness in Children? A Systematic Review. Int J Environ Res Public Health. 2015 Jun 8;12(6):6455–74.

258. Carver A, Timperio A, Hesketh K, Crawford D. Are children and adolescents less active if parents restrict their physical activity and active transport due to perceived risk? Soc Sci Med. 2010 Jun 1;70(11):1799–805.

259. Demant Klinker C, Schipperijn J, Toftager M, Kerr J, Troelsen J. When cities move children: Development of a new methodology to assess context-specific physical activity behaviour among children and adolescents using accelerometers and GPS. Health Place. 2015 Jan 1;31:90–9.

260. Tudor-Locke C, Barreira TV, Schuna JM, Mire EF, Chaput J-P, Fogelholm M, et al. Improving wear time compliance with a 24-hour waist-worn accelerometer protocol in the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE). Int J Behav Nutr Phys Act. 2015;12(1):1.

261. Ridley K, Olds T. Assigning energy costs to activities in children: a review and synthesis. Med Sci Sports Exerc. 2008;40(8):1439.

262. Hänggi JM, Phillips LRS, Rowlands AV. Validation of the GT3X ActiGraph in children and comparison with the GT1M ActiGraph. J Sci Med Sport. 2013 Jan 1;16(1):40–4.

263. Cain KL, Conway TL, Adams MA, Husak LE, Sallis JF. Comparison of older and newer generations of ActiGraph accelerometers with the normal filter and the low frequency extension. Int J Behav Nutr Phys Act. 2013;10(1):51.

264. Herrmann SD, Barreira TV, Kang M, Ainsworth BE. How many hours are enough? Accelerometer wear time may provide bias in daily activity estimates. J Phys Act Health. 2013;10(5):742–9.

265. Rich C, Geraci M, Griffiths L, Sera F, Dezateux C, Cortina-Borja M. Quality control methods in accelerometer data processing: defining minimum wear time. PloS One. 2013;8(6):e67206.

266. Herrmann SD, Barreira TV, Kang M, Ainsworth BE. Impact of accelerometer wear time on physical activity data: a NHANES semisimulation data approach. Br J Sports Med. 2014 Feb;48(3):278–82.

267. Almanza E, Jerrett M, Dunton G, Seto E, Ann Pentz M. A study of community design, greenness, and physical activity in children using satellite, GPS and accelerometer data. Health Place. 2012 Jan 1;18(1):46–54.

268. Klinker CDC, Schipperijn JJ, Kerr JJ, Ersbøll AKA, Troelsen JJ. Context-specific outdoor time and physical activity among school-children across gender and age: using accelerometers and GPS to advance methods. Front Public Health [Internet]. 2014 [cited 2018 Mar 14];2. Available from: https://www.frontiersin.org/articles/10.3389/fpubh.2014.00020/full

269. Carlson JA, Saelens BE, Kerr J, Schipperijn J, Conway TL, Frank LD, et al. Association between neighborhood walkability and GPS-measured walking, bicycling and vehicle time in adolescents. Health Place. 2015 Mar 1;32:1–7.

270. Kang B, Moudon AV, Hurvitz PM, Reichley L, Saelens BE. Walking objectively measured: classifying accelerometer data with GPS and travel diaries. Med Sci Sports Exerc. 2013;45(7):1419.

271. RodrÍguez DA, Brown AL, Troped PJ. Portable global positioning units to complement accelerometry-based physical activity monitors. Med Sci Sports Exerc. 2005;37(11):S572–S581.

272. Kerr J, Marshall S, Godbole S, Neukam S, Crist K, Wasilenko K, et al. The relationship between outdoor activity and health in older adults using GPS. Int J Environ Res Public Health. 2012 Dec 10;9(12):4615–25.

273. Loebach J, Gilliland J. Neighbourhood play on the endangered list: examining patterns in children’s local activity and mobility using GPS monitoring and qualitative GIS. Child Geogr. 2016;14(5):573–589.

274. Bylaw No. 8463, the sidewalk clearing bylaw, 2005 [Internet]. City of Saskatoon; 2014 [cited 2018 Oct 15]. Available from: https://www.saskatoon.ca/sites/default/files/documents/city-clerk/bylaws/8463.pdf

275. Hill A. City prepares to ticket sidewalk slackers | Saskatoon StarPhoenix. Saskatoon StarPhoenix [Internet]. 2015 Nov 8 [cited 2018 Oct 15]; Available from: https://thestarphoenix.com/news/local-news/city-prepares-to-ticket-sidewalk-slackers

276. Aggio D, Smith L, Fisher A, Hamer M, Aggio D, Smith L, et al. Association of light exposure on physical activity and sedentary time in young people. Int J Environ Res Public Health. 2015 Mar 10;12(3):2941–9.

277. Canadian Institute for Health Information. Deprivation In Canadian cities: an analytical tool [Internet]. 2017 [cited 2018 Oct 16]. Available from: https://www.cihi.ca/en/deprivation-in-canadian-cities-an-analytical-tool

278. Mantjes JA, Jones AP, Corder K, Jones NR, Harrison F, Griffin SJ, et al. School related factors and 1yr change in physical activity amongst 9–11 year old English schoolchildren. Int J Behav Nutr Phys Act. 2012 Dec 31;9:153.

279. Government of Canada SC. Measuring low income and Canada's Official Poverty Line [Internet]. 2018 [cited 2019 Jan 17]. Available from: https://www.statcan.gc.ca/eng/consultation/mbm

280. Bagrichevsky M, Santos DS dos. "Shameless" sedentarism: individual responsibility for health? Psychology. 2018 Apr 8;09(04):760.

281. Forhan M, Salas XR. Inequities in healthcare: a review of bias and discrimination in obesity treatment. Can J Diabetes. 2013 Jun 1;37(3):205–9.

282. Rothman KJ, Gallacher JE, Hatch EE. Why representativeness should be avoided. Int J Epidemiol. 2013 Aug 1;42(4):1012–4.

283. Stephens S, Beyene J, Tremblay MS, Faulkner G, Pullnayegum E, Feldman BM. Strategies for dealing with missing accelerometer data. Rheum Dis Clin. 2018;44(2):317–326.

284. Salmon J, Tremblay MS, Marshall SJ, Hume C. Health risks, correlates, and interventions to reduce sedentary behavior in young people. Am J Prev Med. 2011 Aug;41(2):197–206.

285. City of Saskatoon. Zoning bylaw no. 8770 of the city of Saskatoon [Internet]. Saskatoon, Canada: City of Saskatoon; 2017 Oct. Available from: https://www.saskatoon.ca/sites/default/files/documents/city-clerk/bylaws/8770.pdf

APPENDICES

APPENDIX A – Supplementary Materials

Table A.1 Referenced and adapted items for use in Perceptions of sedentary behaviour in different weather conditions parent-child questionnaire.

Questionnaire Item or Scale Description	Questionnaire Name	Reference	Adapted Parent Item	Adapted Child Item
Item: ”My parents encourage me to be physically active/do sports“/”I encourage my child to take part in physical activity/sports“	The EuropeaN Energy balance Research to prevent excessive weight Gain among Youth (ENERGY) project questionnaire	Rebholz et al. 2014	When it is very cold/ average winter weather/ pleasant summer weather outside I encourage my child to take part in physical activity/ sports OUTDOORS	My parents encourage me to play OUTDOORS when it is very cold /average winter weather/ pleasant summer weather outside
			When it is very cold/ average winter weather/ pleasant summer weather outside I encourage my child to take part in physical activity/ sports INDOORS	My parents encourage me to play INDOORS when it is very cold /average winter weather/ pleasant summer weather outside
Item: ”My parents allow me to watch television whenever I want“/”My child is allowed to watch TV/video/dvd whenever (s)he wants“	The EuropeaN Energy balance Research to prevent excessive weight Gain among Youth (ENERGY) project questionnaire	Rebholz et al. 2014	When it is very cold/ average winter weather/ pleasant summer weather outside my child is allowed to watch TV/videos or play video/computer games whenever (s)he wants.	My parents allow me to watch TV/videos or play video/computer games whenever I want when it is very cold when it is very cold/ average winter weather/ pleasant summer weather outside
Scale item description: High neighborhood crime rate, worried about being outside alone because of being taken or hurt by a stranger, worried about being in a park because of being taken or hurt by a stranger	Neighborhood Environment Walkability Scale for Youth (NEWS-Y) questionnaire	Rosenberg et al. 2009	Cold / average winter temperatures make it unsafe for my child to go for walks or play OUTSIDE	Very cold/ average winter temperatures make it unsafe for me to go for walks or play outside

Table A.2 City of Saskatoon property ownership zoning designations and descriptions.

Zoning Designation	**Uses or Description**
Commercial	**Adult day cares centres**, **art galleries**, **public libraries**, **museums**, bakeries, **banquet and public halls**, **catering halls, beauty parlours**, **barber shops**, **boarding apartments**, **boarding houses**, car washes, catering kitchens, **child care centres, pre-schools**, **commercial and public indoor and outdoor recreational uses and health clubs**, **community centres**, convenience stores, **custodial care facilities**, drug stores, **pharmacies**, dry cleaning pick up depots, **dry cleaners**, duplicating or copying centres, **educational institutions**, **financial institutions**, **funeral and wedding establishments**, **funeral homes**, **hotels and motels**, **medical clinics**, **medical**, **dental and optical laboratories**, **motion picture**, **radio**, **television and recording studios**, **multi-unit dwellings and dwelling groups**, neighbourhood recycling and collection depots, **office and office buildings, personal service trades**, **photography studios**, **places of worship**, **private clubs**, **private schools**, public garages, repair services (household and appliances), **restaurants**, **lounges and taverns**, **night clubs**, self-serve laundry, service stations, gas bars**, shopping centres**, **retail stores**, **special needs housing**, supermarkets, **theatres**, **two-unit dwellings**, **veterinary clinics**
Industrial	**Adult day cares centres**, adult mini-theatres, **arenas**, rinks, stadiums, **child care centres, pre-schools**, **commercial and public indoor and outdoor recreational uses and health clubs**, dwelling necessary for watchman or caretakers, **educational institutions**, **hotels and motels**, **places of worship**, **private clubs**, **private schools**, **public halls**, **catering halls**, **assembly halls**, **restaurants**, **lounges and taverns**, **night clubs**, **shopping centres**, **retail stores**, **theatres**
Institutional	**Adult day cares**, **ambulance stations**, **arenas**, **art galleries**, **public libraries**, **museums**, **banquet and public halls**, **bed and breakfast homes, boarding apartments**, **boarding houses**, **hostels**, **cemeteries**, commercial dwelling conversions (limited to **retail stores** or **restaurants**), **community centres**, **convents**, **monasteries**, converted dwellings, **custodial care facilities**, **child care centres, pre-schools**, **dry cleaners**, **educational institutions**, **elementary schools**, **financial institutions**, **funeral and wedding establishments**, **funeral homes**, **high schools**, **hospitals and special care homes**, hotels and motels, **medical clinics**, **medical**, **dental and optical laboratories**, **motion picture**, **radio**, **television and recording studios**, **multi-unit dwellings and dwelling groups**, offices and office buildings, one-unit dwellings, beauty parlours, confectionaries, newsstands, **office and office buildings, pharmacies**, optical dispensaries, **restaurants**, **lounges and taverns**, **personal service trades and health clubs**, **photography studios**, **places of worship**, **private clubs**, **private schools**, research laboratories, **residential care homes**, semi-detached dwellings, **special needs housing**, **two-unit dwellings**, **veterinary clinics**
Residential	One-unit dwellings, **adult day cares**, **ambulance stations**, **art galleries**, **public libraries**, **beauty parlours**, **barber shops**, confectionary accessory to

	multi-unit dwellings with ≥100 dwelling units, **boarding apartments**, **boarding houses**, **hostels**, **cemeteries**, **community centres**, **convents**, **monasteries**, **custodial care facilities**, **child care centres, pre-schools**, **elementary schools**, **high schools**, **hospitals and special care homes**, market gardens, nurseries, greenhouses with no retail sales, **multi-unit dwellings and dwelling groups**, **places of worship**, **private schools**, **residential care homes**, secondary suites, **special needs housing**, street townhouses
Unified Development	***Examples*** 1. Brighton Village Centre: Mixed use village, including pedestrian use and comfort, human-scale buildings 2. South Downtown Area: waterfront development of the South Downtown Area, with special interest in functional link development between the Downtown, South East Riversdale, the Gathercole site, Friendship Park and the South Saskatchewan River. 3. Retail development accommodating large-format retail stores 4. The Willows: The development of an integrated golf course community associated with the Willows Golf and Country Club 5. College Quarter: Academic and mixed land-use village develop including increased pedestrian use and comfort, human-scale buildings, architectural integrity, and environmental sustainability

Common uses between zoning designations are presented in **bold font**.
Zoning uses are derived from the Zoning Bylaw No. 8770 of the City of Saskatoon report (285).

APPENDIX B – Supplementary Results

Table B.1: Participants with Valid Accelerometry Data.
Values presented are total number of participants and % of total number of participants existing at each time point.

Time Point	**Total** (n)	**≥10 hours/day ≥4 days/time point** n (%)	**≥12 hours/day ≥4 days/time point** n (%)	**≥14 hours/day ≥4 days/time point** n (%)
1	745	519 (69.7%)	379 (50.9%)	39 (5.2%)
2	706	411 (58.2%)	216 (30.6%)	23 (3.3%)
3	592	301 (50.8%)	166 (28.0%)	12 (2.0%)

Table B.2: Factors predicting total daily sedentary behaviour in 9-14-year-old children: multilevel models exclusive of physical activity.

	Level 1-2 Main Effects		Level 1-3 Main Effects		Interaction Models: Model 1		Interaction Models: Model 2	
	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI	Estimate	95% CI
Population Size (n)	618		616		616		566	
Constant	8.64	(-40.6, 57.8)	-8.7	(-59.7, 42.2)	43.5	(-34.0, 121)	54.1	(-18.5, 127)
Level 1 Variables								
Season (reference - winter)								
Spring	4.00	(-1.87, 9.88)	3.93	(-1.95, 9.81)	16.6	(-0.386, 33.6)	-48.6	(-97.7, 0.447)
Summer	-0.696	(-9.53, 8.14)	-1.01	(-9.85, 7.82)	0.543	(-24.6, 25.7)	-31.4	(-97.8, 34.9)
Fall	-12.5	(-18.0, -7.06)	-12.8	(-18.3, -7.36)	-9.05	(-27.2, 9.09)	-27.2	(-72.3, 17.9)
Level 2 Variables								
Gender (reference - male)					-100	(-199, -2.09)		
Age	23.2	(18.8, 27.6)	22.9	(18.5, 27.3)	17.7	(11.0, 24.5)	23.5	(18.9, 28.0)
BMI (refence - normal weight)§								
Underweight	23.5	(-27.8, 74.8)	28	(-23.0, 79.0)	31.3	(-19.8, 82.4)	23.9	(-27.2, 75.0)
Overweight	20.5	(8.81, 32.1)	20.5	(8.98, 32.1)	20.0	(8.50, 31.6)	21.2	(9.08, 33.3)
Obese	51.1	(36.6, 65.6)	50.7	(36.3, 65.1)	49.9	(35.5, 64.3)	53.1	(38.2, 68.1)
Level 3 Variables								
Neighbourhood Era (reference - <1930 grid)								
1930-1960s fractured grid			31	(11.6, 50.4)	32.5	(9.56, 55.4)		
>1960s curvilinear			20.6	(3.48, 37.8)	26.7	(6.73, 46.6)		
rural			16.2	(-9.87, 42.3)	21.7	(-7.90, 51.3)		
NALP - Activity Friendliness							-12.9	(-26.4, 0.639)
*Age*Gender* ‡					9.35	(0.478, 18.2)		
*Season*Neighbourhood Era* ‡								
Spring<1930 grid*					-8.04	(-30.5, 14.4)		
Summer<1930 grid*					2.21	(-27.9, 32.3)		
Fall<1930 grid*					-1.68	(-23.5, 20.2)		
*Spring*1930-1960s fractured grid*					-15.8	(-34.3, 2.67)		
*Summer*1930-1960s fractured grid*					-9.53	(-37.5, 18.4)		
*Fall*1930-1960s fractured grid*					-4.91	(-24.3, 14.5)		
Spring>1960s curvilinear*					-16.3	(-45.7, 13.2)		
Summer>1960s curvilinear*					62.5	(17.3, 108)		
Fall>1960s curvilinear*					-13.4	(-42.2, 15.4)		
*Season*NALP Activity Friendliness* ‡								
*Spring*NALP Activity Friendliness*							14.2	(1.29, 27.1)
*Summer*NALP Activity Friendliness*							7.38	(-10.3, 25.0)
*Fall*NALP Activity Friendliness*							4.07	(-7.86, 16.0)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).
‡ Reference Categories: season – winter, gender – male, neighbourhood era - <1930 grid.
Abbreviations: BMI – body mass index, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, NALP – Neighbourhood Active Living Potential.

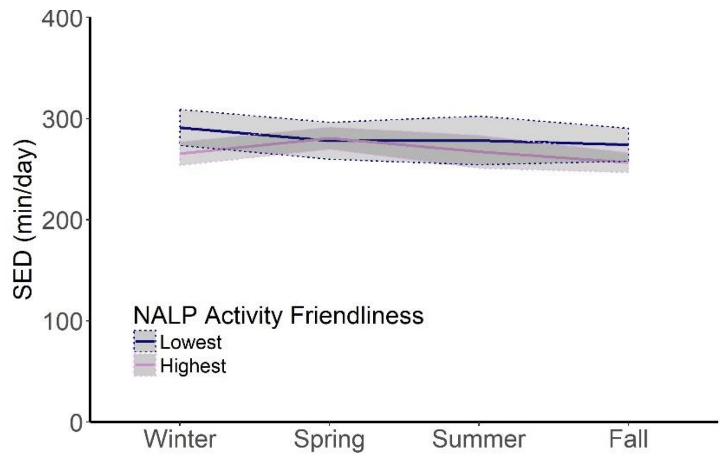


Figure B.1: Predicted effects of built environment and season on total daily sedentary behaviour in children.
Predicted effects presented are derived from multilevel models presented in ***Table B.2*** *(Model 2: season*NALP activity friendliness). 95% CIs are shown as grey ribbons. Reference categories: season – winter.*

Table B.3: Factors predicting leisure hour sedentary behaviour in 9-14-year-old children: main effects models exclusive of physical activity.

	Interaction Models			
	Level 2 Main Effects		Level 2 & 3 Main Effects	
	β Estimate	95% CI	β Estimate	95% CI
Population size (n)	616		616	
Constant	53.7	(17.8, 89.7)	43.8	(6.32, 81.3)
Level 2 Variables				
Age	11.3	(8.09, 14.6)	11.2	(7.99, 14.4)
BMI (refence - normal weight)§				
Underweight	16.7	(-22.1, 55.6)	19.5	(-19.2, 58.2)
Overweight	13.1	(4.56, 21.6)	13.0	(4.59, 21.5)
Obese	22.9	(12.2, 33.7)	22.8	(12.1, 33.5)
Level 3 Variables				
Neighbourhood Era (reference - <1930 grid)				
1930-1960s fractured grid			17.5	(2.08, 32.9)
>1960s curvilinear			11.1	(-2.62, 24.9)
rural			9.29	(-13.2, 31.7)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).
Abbreviations: BMI – body mass index, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity.

Table B.4 Factors predicting school hour sedentary behaviour in 9-14-year-old children: main effects and final multilevel models exclusive of physical activity.

	Level 1 & 2 Main Effects		Main Effects Models with Interactions: Model 1		Model 2		Model 3	
	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI	β Estimate	95% CI
Study Population (n)	616		616		616		616	
Constant	-54.8	(-96.4, -13.1)	-67.0	(-113, -21.5)	-87.4	(-157, -18.1)	-68.6	(-108, -28.9)
Level 1 Variables								
Season (reference - winter)								
Spring	2.73	(-0.254, 5.72)	4.31	(-26.4, 35.0)	-9.91	(-48.2, 28.4)	5.27	(1.68, 8.87)
Summer	-5.36	(-10.1, -0.608)	69.9	(19.8, 120)	-87.7	(-141, -34.6)	-5.72	(-10.6, -0.792)
Fall	-5.43	(-8.25, -2.61)	-0.999	(-30.0, 28.0)	19.4	(-19.3, 58.1)	-6.1	(-9.50, -2.71)
Level 2 Variables								
Gender (reference - male)	5.99	(0.878, 11.1)	8.38	(2.10, 14.7)	5.30	(-0.0595, 10.7)	4.9	(-0.491, 10.3)
Age	13.7	(11.4, 16.0)	13.7	(10.9, 16.6)	13.0	(10.6, 15.5)	12.9	(10.4, 15.3)
BMI (reference - normal weight)[§]								
Underweight	-12.2	(-38.8, 14.4)	-6.83	(-33.2, 19.5)				
Overweight	-2.19	(-29.1, 24.7)	2.08	(-24.6, 28.8)				
Obese	22.0	(-5.24, 49.3)	25.6	(-1.45, 52.7)				
Income (reference - <$20,000)								
$20,000 to $60,000	9.83	(-9.60, 29.32)			11.1	(-9.17, 31.5)	11.6	(-8.80, 32.0)
$60,000 to $100,000	9.25	(-9.97, 28.5)			9.24	(-11.0, 29.4)	9.69	(-10.5, 29.9)
>$100,000	19.1	(0.449, 37.8)			16.4	(-3.14, 36.0)	16.7	(-2.93, 36.3)
Unknown	8.68	(-10.2, 27.6)			8.30	(-11.5, 28.1)	8.56	(-11.2, 28.4)
Level 3 Variables								
Neighbourhood Era[‡]								
1930-1960s fractured grid			20.5	(1.56, 39.5)	20.9	(-2.03, 43.8)	21.3	(-0.263, 43.0)
>1960s curvilinear			18.6	(-0.213, 37.3)	16.4	(-8.30, 41.0)	19.2	(-4.88, 43.3)

NALP Dimension Scores								
Density of destinations					-6.44	(-15.0, 2.16)		
Activity Friendliness					7.32	(-3.27, 17.9)		
Safety					6.38	(-11.7, 24.4)		
Universal Accessibility					-5.36	(-13.9, 3.17)		
Combined Cumulative Score							-0.421	(-7.89, 7.05)
Interaction Terms								
Season*Age‡								
*Spring*Age*			-0.284	(-3.02, 2.45)				
*Summer*Age*			-6.89	(-11.3, -2.47)				
*Fall*Age*			-0.0266	(-2.61, 2.56)				
Season*Gender‡								
*Spring*Females*			2.53	(-3.54, 8.61)				
*Summer*Females*			-0.245	(-10.3, 9.78)				
*Fall*Females*			-7.89	(-13.6, -2.18)				
NALP Dimension Scores								
Season*Density of Destinations‡								
*Spring*Density of Destinations*					5.61	(-0.0109, 11.2)		
*Summer*Density of Destinations*					4.10	(-3.88, 12.1)		
*Fall*Density of Destinations*					6.57	(0.729, 12.4)		
Season*Activity Friendliness‡								
*Spring*Activity Friendliness*					-8.35	(-16.1, -0.609)		
*Summer*Activity Friendliness*					-17.5	(-32.4, -2.51)		
*Fall*Activity Friendliness*					-11.3	(-18.8, -3.81)		

Season*Safety‡								
*Spring*Safety*					7.68	(-5.66, 21.0)		
*Summer*Safety*					36.0	(12.5, 59.4)		
*Fall*Safety*					-6.12	(-18.7, 6.45)		
Season*Universal Accessibility‡								
*Spring*Universal Accessibility*					-2.84	(-9.19, 3.51)		
*Summer*Universal Accessibility*					-5.31	(-18.2, 7.56)		
*Fall*Universal Accessibility*					9.56	(2.79, 16.3)		
IMI and NALP Combined Scores								
Season*Cumulative Score‡								
*Spring*Cumulative Score*							6.21	(1.83, 10.6)
*Summer*Cumulative Score*							5.63	(-0.659, 11.9)
*Fall*Cumulative Score*							-0.742	(-5.04, 3.56)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).

‡ Reference Categories: season – winter, gender – male

Abbreviations: BMI – body mass index, IMI – Irvine Minnesota Inventory, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, NALP – Neighbourhood Active Living Potential.

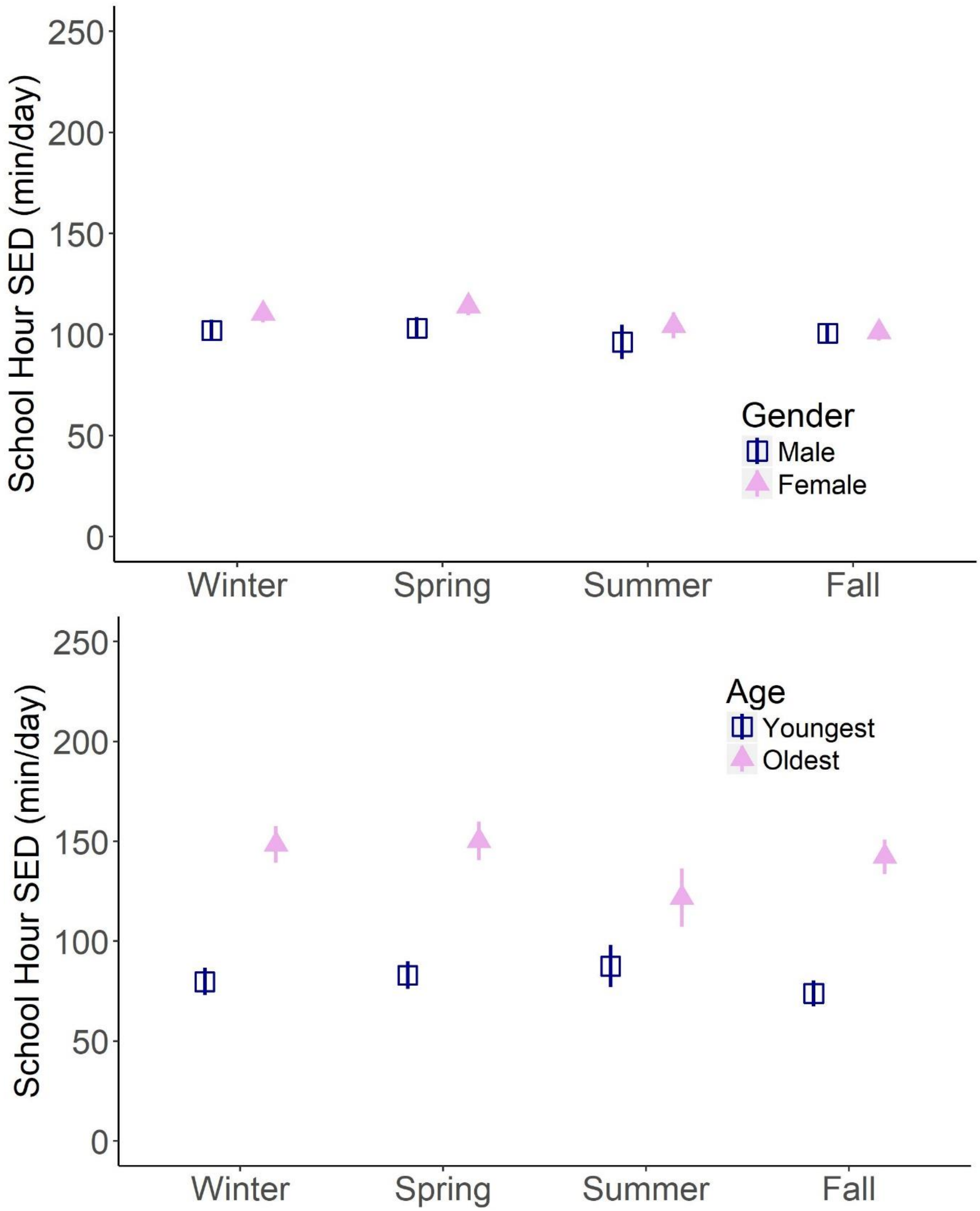


Figure B.2: Predicted moderating effects of age, gender and season on school hour sedentary behaviour in children.

*Predicted effects presented are derived from physical activity exclusionary multilevel model 1 presented in **Table B.4**. 95% CIs are shown as vertical bars. Reference category: gender – male, season - winter.*

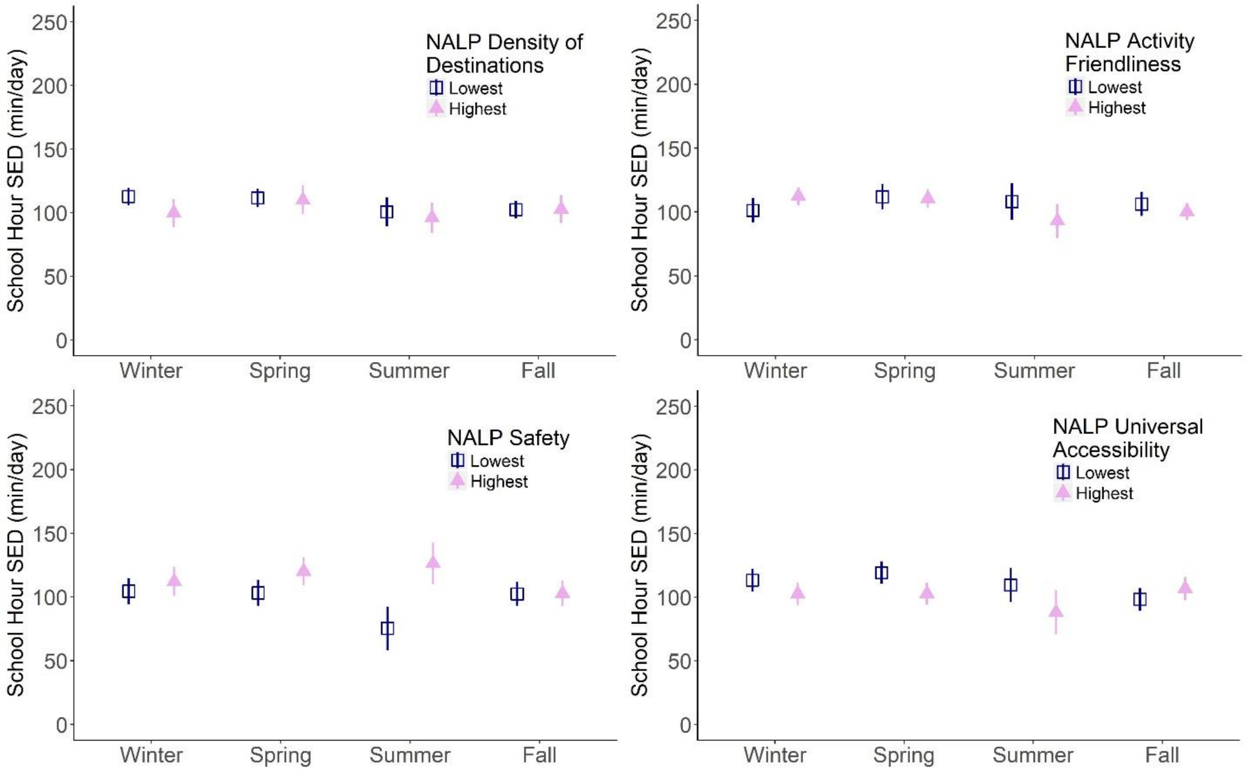


Figure B.3: Predicted moderating effects of built environment Neighbourhood Active Living Potential dimension scores on school hour sedentary behaviour in children. *Predicted effects presented are derived from physical activity exclusionary multilevel model 2 presented in **Table B.4**. 95% CIs are shown as vertical bars. Reference category: season - winter.*

Table B.5 Factors predicting school hour sedentary behaviour in 9-14-year-old children: final multilevel models exclusive of physical activity.

	Main Effects Models with Interactions			
	Model 4		Model 5	
	β Estimate	95% CI	β Estimate	95% CI
Study Population (n)	616		616	
Constant	-687	(-1060, -312)	-74.6	(-114, -34.8)
Level 1 Variables				
Season (reference - winter)				
Spring	120	(25.0, 215)	4.91	(1.19, 8.63)
Summer	66.4	(-85.2, 218)	-8.89	(-14.3, -3.51)
Fall	147	(52.4, 242)	-4.96	(-8.50, -1.43)
Level 2 Variables				
Gender (reference - male)	4.92	(-0.430, 10.3)	4.90	(-0.476, 10.3)
Age	58.5	(27.4, 89.6)	13.0	(10.6, 15.4)
Income (reference - <$20,000)				
$20,000 to $60,000	11.9	(-8.32, 32.1)	12.8	(-7.57, 33.1)
$60,000 to $100,000	11.4	(-8.73, 31.4)	10.5	(-9.67, 30.7)
>$100,000	18.4	(-1.04, 37.8)	17.9	(-1.71, 37.4)
Unknown	9.90	(-9.74, 29.5)	9.60	(-10.1, 29.4)
Level 3 Variables				
Neighbourhood Era‡				
1930-1960s fractured grid	27.7	(5.43, 50.0)	24.6	(2.66, 46.6)
>1960s curvilinear	25.1	(1.58, 48.6)	22.2	(-0.109, 44.5)
IMI Dimension Scores				
Pedestrian Access	112	(38.1, 185)		
Attractiveness	11.2	(-2.90, 25.3)		
Safety from Crime	0.0244	(-9.67, 9.72)		
Safety from Traffic	-2.22	(-16.3, 11.9)		
NALP Cumulative Score			1.07	(-5.52, 7.66)
IMI Cumulative Score			0.822	(-6.90, 8.55)
Interaction Terms				
IMI Dimension Scores				
Season*Attractiveness‡				
*Spring*Attractiveness*	-5.38	(-16.7, 5.96)		
*Summer*Attractiveness*	-13.6	(-39.9, 12.8)		
*Fall*Attractiveness*	-22.3	(-33.7, -10.9)		
*Age*Pedestrian Access*‡	-8.93	(-15.0, -2.82)		

Season*Pedestrian Access‡				
*Spring*Pedestrian Access*	-8.81	(-19.3, 1.65)		
*Summer*Pedestrian Access*	-26.0	(-42.9, -9.12)		
*Fall*Pedestrian Access*	-5.22	(-15.8, 5.39)		
Season*Safety from Crime‡				
*Spring*Safety from Crime*	-9.18	(-15.8, -2.59)		
*Summer*Safety from Crime*	-8.30	(-18.9, 2.26)		
*Fall*Safety from Crime*	0.670	(-6.87, 8.21)		
Season*Safety from Traffic‡				
*Spring*Safety from Traffic*	5.84	(-4.07, 15.7)		
*Summer*Safety from Traffic*	33.7	(18.6, 48.9)		
*Fall*Safety from Traffic*	-3.73	(-15.4, 7.90)		
Stratified Cumulative Scores				
Season*NALP‡				
*Spring*NALP*			2.76	(-2.05, 7.57)
*Summer*NALP*			12.0	(5.50, 18.5)
*Fall*NALP*			-2.10	(-6.88, 2.69)
Season*IMI‡				
*Spring*IMI*			-9.07	(-14.4, -3.73)
*Summer*IMI*			-7.85	(-18.7, 2.98)
*Fall*IMI*			-0.342	(-5.47, 4.79)

‡ Reference Categories: season – winter
Abbreviations: BMI – body mass index, IMI – Irvine Minnesota Inventory, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, NALP – Neighbourhood Active Living Potential.

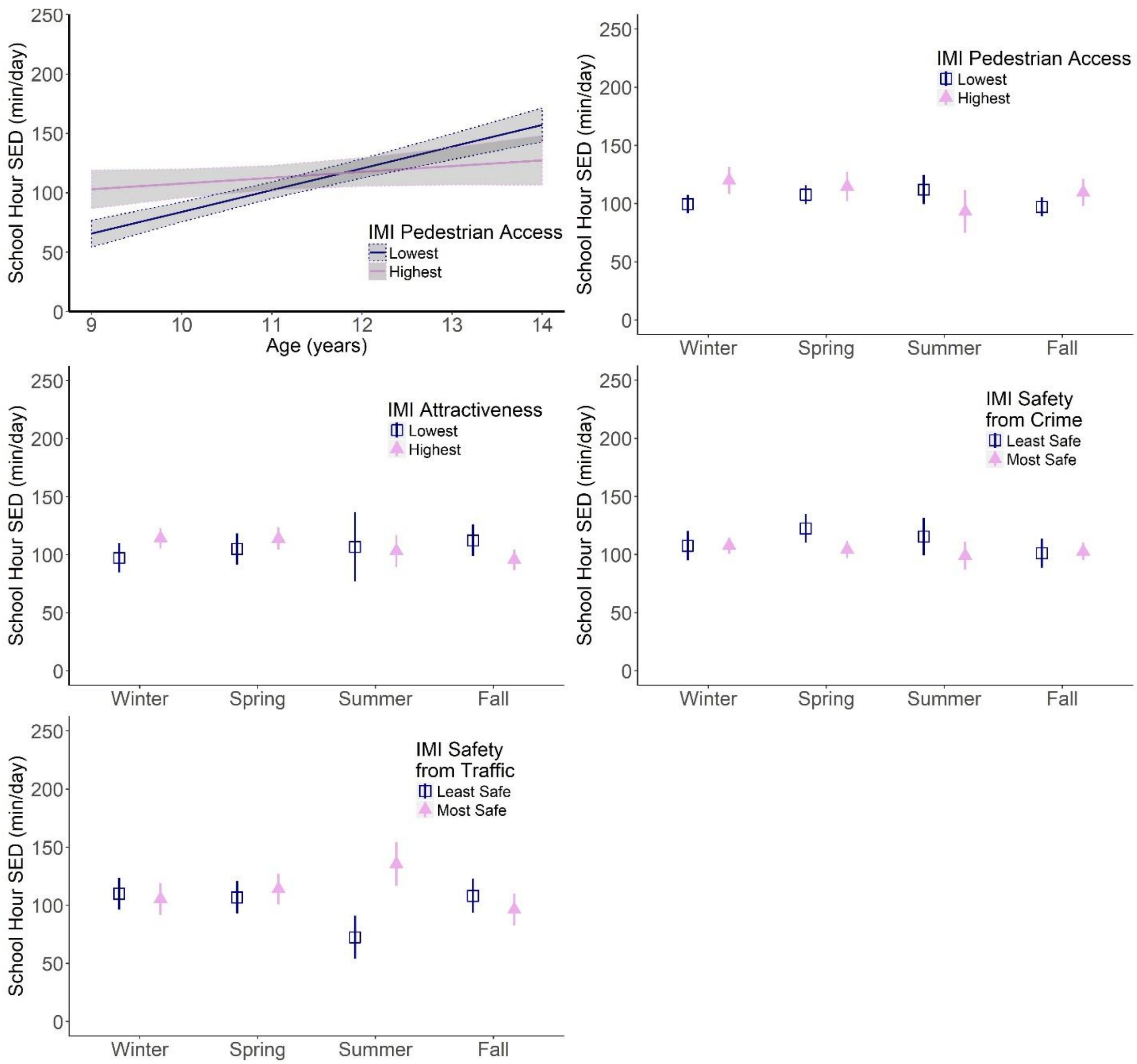


Figure B.4: Predicted moderating effects of built environment Irvine Minnesota Inventory dimension scores on school hour sedentary behaviour in children. *Predicted effects presented are derived from physical activity exclusionary multilevel model 4 presented in* ***Table B.5****. 95% CIs are shown as grey ribbons or vertical bars. Reference category: season - winter.*

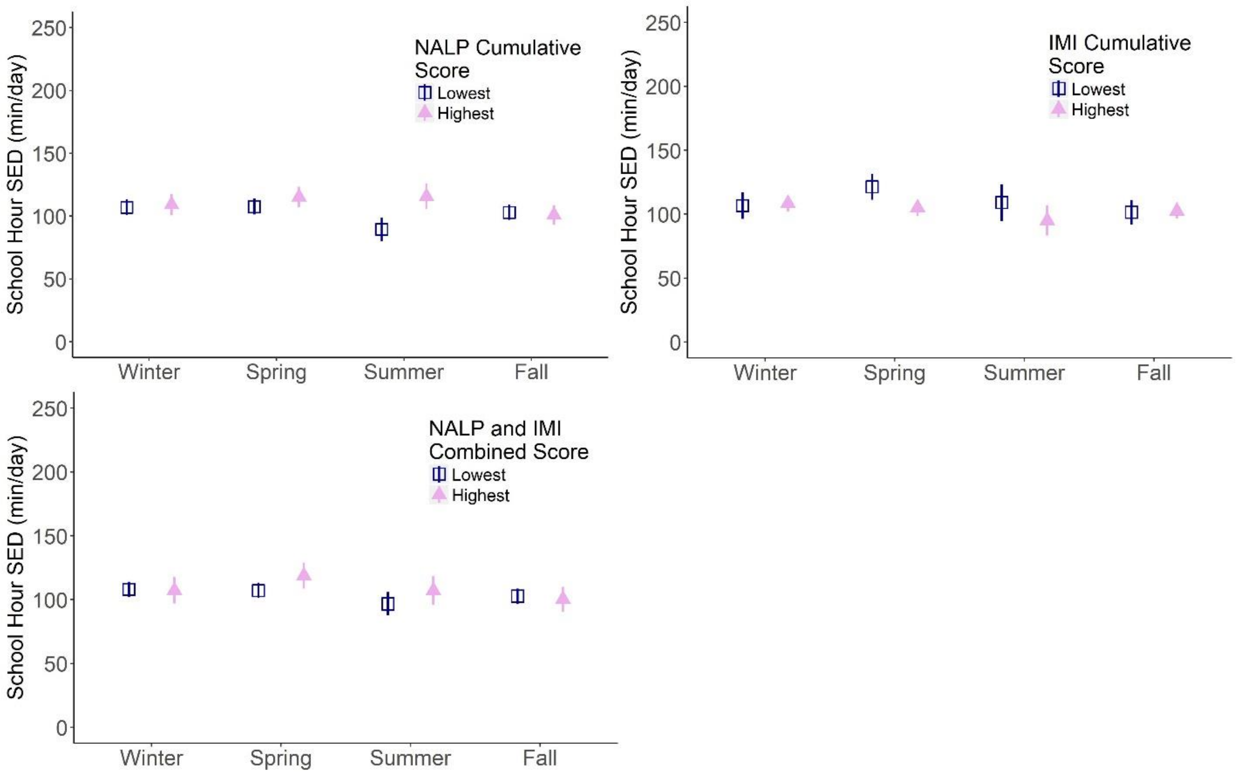


Figure B.5: Predicted moderating effects of built environment Irvine Minnesota Inventory dimension scores on school hour sedentary behaviour in children. *Predicted effects presented are derived from physical activity exclusionary multilevel models presented in **Table B.4** (Model 3: NALP and IMI Combined Score) and **Table B.5** (Model 5: Season*NALP Cumulative Score and Season*IMI Cumulative Score). 95% CIs are shown as vertical bars. Reference category: season - winter.*

Table B.6: Inidivudal demographic factors and neighbourhood era design predict home area sedentary behaviour in 9-14-year-old children: main effects and final multilevel models.

	Level 1-3 Main Effects		**Main Effects with Interactions**	
	β Estimate	**95% CI**	**β Estimate**	**95% CI**
Population Size (n)	431		431	
Constant	-47.5	(-100, 5.02)	-44.2	(-96.8, 8.38)
Level 1 Variables				
LPA	0.841	(0.803, 0.88)	0.844	(0.805, 0.882)
MVPA	-0.370	(-0.444, -0.297)	-0.373	(-0.447, -0.3)
Season (reference - Winter)				
Spring	6.34	(1.2, 11.5)	6.37	(1.24, 11.5)
Summer	1.99	(-5.61, 9.58)	1.89	(-5.69, 9.46)
Fall	-11.5	(-18.1, -4.86)	-11.5	(-18.1, -4.9)
Weekend Day (reference - Weekdays)	19.2	(15.1, 23.2)	9.32	(-2.44, 21.1)
Level 2 Variables				
Age	7.50	(4.32, 10.7)	7.44	(4.27, 10.6)
Gender (reference - Male)	-11.5	(-18.7, -4.34)	-11.6	(-18.7, -4.38)
BMI (reference - normal weight)§				
Underweight	-20.1	(-84.9, 44.8)	-19.6	(-84.4, 45.3)
Overweight	6.39	(-1.83, 14.6)	6.48	(-1.73, 14.7)
Obese	14.0	(2.84, 25.1)	13.9	(2.74, 25)
Income (reference - <$20,000)				
$20,000 to $60,000	-32.9	(-68.1, 2.22)	-33.1	(-68.2, 2.02)
$60,000 to $100,000	-29.1	(-64, 5.85)	-29.1	(-64, 5.8)
>$100,000	-21.2	(-55, 12.7)	-21.4	(-55.2, 12.4)
Unknown	-23.3	(-56.8, 10.2)	-23.5	(-56.9, 10)
Newcomer to Canada‡	17.2	(5.64, 28.8)	17.3	(5.69, 28.8)
Level 3 Variables				
Neighbourhood Era (reference - <1930 grid)				
1930-1960s fractured grid	17.2	(0.493, 33.9)	16.8	(-0.223, 33.9)
1960s-1998 curvilinear	21.0	(5.65, 36.4)	16.7	(0.974, 32.4)
1998-present modified grid	22.4	(4.73, 40.2)	20.5	(2.42, 38.7)
Interaction Terms				
Weekend Day*Era‡				
*Weekend*1930-1960s fractured grid*			0.0247	(-14.7, 14.8)
*Weekend*1960s-1998 curvilinear*			16.1	(3.29, 28.9)
*Weekend*1998-present modified grid*			7.07	(-7.77, 21.9)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).
‡ References Categories: weekend day - weekdays Newcomer to Canada (living in Canada for less than two years) - Living in Canada for more 2 or more years
Abbreviations: BMI – body mass index, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, Newcomer to Canada – living in Canada for less than two years.

Table B.7: Individual demographic factors and neighbourhood level factors predict home area sedentary behaviour in 9-14-year-old children: final multilevel models.

Main Effect Models with Interaction Terms

	Model 12		**Model 13**		**Model 14**		**Model 15**	
	β Estimate	**95% CI**	**β Estimate**	**95% CI**	**β Estimate**	**95% CI**	**β Estimate**	**95% CI**
Population Size (n)	420		420		420		420	
Constant	-30.5	(-88.0, 27.0)	563	(63.3, 1060)	-8.33	(-624, 45.7)	-30.2	(-81.7, 21.4)
Level 1 Variables								
LPA	1.03	(0.873, 1.18)	0.554	(0.282, 0.827)	0.829	(0.789, 0.87)	0.827	(0.785, 0.868)
MVPA	-0.384	(-0.459, -0.308)	-0.384	(-0.459, -0.308)	-0.384	(-0.459, -0.308)	-0.384	(-0.46, -0.309)
Season‡								
Spring	6.63	(1.40, 11.9)	6.56	(1.32, 11.8)	6.56	(1.32, 11.8)	6.64	(1.41, 11.9)
Summer	0.788	(-6.94, 8.52)	0.321	(-7.38, 8.02)	0.321	(-7.38, 8.02)	0.509	(-7.22, 8.24)
Fall	-11.7	(-18.5, -4.96)	-11.7	(-18.4, -4.91)	-11.7	(-18.4, -4.91)	-11.7	(-18.5, -4.99)
Weekend Day‡	44.8	(24.9, 64.7)	20.1	(16.0, 24.2)	20.1	(16.0, 24.2)	18.3	(14.0, 22.7)
Level 2 Variables								
Age	7.77	(4.57, 11.0)	7.54	(4.34, 10.7)	7.54	(4.34, 10.7)	7.70	(4.51, 10.9)
Gender‡	-10.9	(-18.2, -3.51)	-11.4	(-18.8, -4.13)	-11.4	(-18.8, -4.13)	-10.8	(-18.1, -3.48)
BMI‡§								
Underweight	-24.1	(-89.0, 40.8)	-26.3	(-90.7, 38)	-26.3	(-90.7, 38)	-24.1	(-88.9, 40.6)
Overweight	6.75	(-1.64, 15.1)	8.32	(-0.0848, 16.7)	8.32	(-0.085, 16.7)	6.94	(-1.44, 15.3)
Obese	14.8	(3.55, 26.1)	15.7	(4.47, 27)	15.7	(4.47, 27)	14.7	(3.45, 25.9)
Income‡								
$20,000 to $60,000	-34.4	(-69.5, 0.811)	-635	(-1140, -129)	-54.5	(-93.2, -15.9)	-34.1	(-69.2, 1.02)
$60,000 to $100,000	-30.4	(-65.5, 4.68)	-663	(-1170, -158)	-51.5	(-89.0, -13.0)	-30.9	(-65.9, 4.14)
>$100,000	-22.9	(-56.8, 11.1)	-657	(-1160, -154)	-44.8	(-82.3, -7.24)	-23.6	(-57.5, 10.2)
Unknown	-24.5	(-58, 9.11)	-646	(-1150, -145)	-45.2	(-82.4, -8.05)	-25.0	(-58.5, 8.54)
Newcomer to Canada‡	16.2	(4.35, 28.0)	16.1	(4.31, 27.9)	16.1	(4.31, 27.9)	16.2	(4.38, 28.0)

Level 3 Variables								
NALP Density of Destination	-0.196	(-6.98, 6.59)						
IMI Safety from Crime			-67.5	(-126, -9.43)				
IMI Cumulative Score					-73.5	(-137, -10.3)		
NALP-IMI Combined Score							-1.11	(-7.06, 4.85)
Interaction Terms								
LPA*NALP Density of Destinations	-0.0506	(-0.0914, -0.00966)						
Weekend Day*NALP‡ Density of Destination	-6.71	(-12.0, -1.44)						
LPA*IMI Safety from Crime			0.0326	(0.00216, 0.0629)				
Income*IMI Safety from Crime‡								
*$20-60,000*Safety from Crime*			68.7	(10.9, 126)				
*$60-100,000*Safety from Crime*			72.3	(14.7, 130)				
*>$100,000*Safety from Crime*			72.4	(15, 130)				
*Unknown*Safety from Crime*			71.0	(13.9, 128)				
LPA*IMI Cumulative Score					0.0354	(0.00237, 0.0685)		
Income*IMI Cumulative Score‡								
*$20-60,000*IMI Score*					74.8	(11.8, 138)		
*$60-100,000*IMI Score*					78.7	(16.0, 141)		
*>$100,000*IMI Score*					78.8	(16.3, 141)		
*Unknown*IMI Score*					77.4	(15.2, 140)		
LPA*NALP-IMI Combined Score							-0.0424	(-0.0775, -0.00728)
Weekend Day*NALP-IMI Combined Score‡							-5.51	(-10.2, -0.86)

§ Body Mass Index (BMI): Study population BMI was calculated using the World Health Organization (WHO) Age- and sex-specific growth reference BMI sample for 5-19-year-olds (2).

‡ References Categories: season – winter, weekend day – weekdays, gender – male, BMI – normal weight, Income – annual household income of <$20,000, Newcomer to Canada (living in Canada for less than two years) - Living in Canada for more 2 or more years.

Abbreviations: BMI – body mass index, IMI – Irvine Minnesota Inventory, Income – annual household income, LPA – light physical activity, MVPA – moderate-to-vigorous physical activity, NALP – Neighbourhood Active Living Potential, Newcomer to Canada – living in Canada for less than two years.

Table B.8: The level of agreement between parent-child dyad questionnaire item responses.

Item Temperature Grouping	Parent-Child Dyad Questionnaire Item	n	Cohen's κ	95% CI	Level of Agreement
-27°C or colder with the wind chill	Parental encouragement of outdoor play	106	0.48	(0.30, 0.62)	Moderate agreement
	Parental encouragement of indoor play	103	0.32	(0.055, 0.58)	Fair agreement
	Parental limit on screen time	104	0.50	(0.33, 0.67)	Moderate agreement
	Perception of outdoor play safety	106	0.39	(0.22, 0.57)	Fair agreement
-10 to -15°C	Parental encouragement of outdoor play	108	0.24	(-0.036, 0.51)	Fair agreement
	Parental encouragement of indoor play	102	0.35	(0.17, 0.53)	Fair agreement
	Parental limit on screen time	106	0.37	(0.20, 0.55)	Fair agreement
	Perception of outdoor play safety	106	0.56	(0.32, 0.80)	Moderate agreement
At least 10°C with little or no rain	Parental encouragement of outdoor play	107	0.39	(-0.16, 0.94)	Fair agreement
	Parental encouragement of indoor play	105	0.33	(0.11, 0.54)	Fair agreement
	Parental limit on screen time	106	0.40	(0.22, 0.59)	Moderate agreement
	Seasonal affordance	105	0.36	(0.11, 0.62)	Fair agreement